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The conference aims at bringing together scientists and engineers dealing with fundamental and applied research for reporting on the latest results and achievements in the ICT-related domains.

Address:
168, Stefan cel Mare av., MD-2004, Chisinau,
Republic of Moldova
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E-mail: info@ecco.utm.md
Web: http://www.ecco.utm.md

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- Mathematical Modelling and Applications;
- Algorithms and Computing Theory;
- Data Science/Data Engineering;
- Artificial Intelligence;
- Bioinformatics.

B. Computer Engineering:

- Automatic Control;
- Robotics;
- Computer Design.

C. Software Engineering and Cybersecurity:

- Methods and Tools of Software Engineering;
- Information Systems and Applications;
- Computer Security and Cryptography;
- Security and Privacy in Computing and Communications.

D. Electronics:

- Applied Electronics and Embedded Systems;
- Micro & Nano-electronics.

E. Biomedical Engineering:

- Biomaterials for medical applications;
- Molecular, cellular and tissue engineering;
- Biomimetics and sensors;
- Biomedical instrumentation;
- Medical physics and biophysics;
- Clinical engineering, health technology management and assessment;
    - New technologies for diagnosis, treatment and rehabilitation;
- Health informatics, e-health and telemedicine;
    - Biomedical imaging and image processing;
- Biomedical engineering education;
- Nuclear and radiation safety and security;

F. Networks and Communications:

- Telecommunications: Technology, Networks and Software;
- Electronics and Telecommunications: Operations, Administration and Maintenance;
- IoT Technologies: Software, Hardware and Connectivity;
- IT infrastructure and Cloud Computing;

H. Knowledge-based society:

- Research and Education for Knowledge-based Society;
- E-didactics & education methods based on ICT;

G. Management&Marketing and ICT:

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- Digital economy.

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Plenary and Invited Papers

Porous materials for electrical gas sensors and actuators without moveable part

Rainer Adelung[1]
[1] Chair for functional nanomaterials, Kiel University, ra@tf.uni-kiel.de,
www.tf.uni-kiel.de/matwis/fnano/de

Sensors and actuators that do not require additional converters must be able to be read out and set electrically. This enables optimal connection to the readout, adjustment and control electronics. Gas sensors sand actuators can be used directly in microfluidic chips as elementary building blocks. Microfluidics is concerned with the behavior of liquids and gases in very small spaces. This talk briefly summarizes the work of our group over the last decade, showing how highly porous materials can be used as both electrical sensors and electrical actuators without the need for moving parts. This is because both applications ultimately require flow through electrically conductive material, for which highly porous materials are ideally suited. Highly porous structures from the aeromaterial family proved to be ideally suited for both gas sensors and actuators. Aerographite was first described in 2012. The material is based on a template consisting of interpenetrating microscale tetrapoal ZnO crystals. The template, which can be shaped to the desired geometry at the macroscale, is fabricated by gently pressing the tetrapodal powder and then sintering it. The tetrapodal shape as basic blocks guarantees a high free volume between the blocks. In further steps, a desired nanomaterial, e.g. graphene, in the case of Aerographite graphite, but as well carbon nanotubes, layered materials like h-BN, etc., are first wrapped around the surface as a deposited thin film (wet chemical or CVD) and the underlying ZnO tetrapods are detached either by wet chemical or hydrogen gas etching. The resulting structure consists of an interconnected microscopic tubular network of macroscopic extent with wall thickness on the order of thin films, i.e., a few nanometers. These open structures are ideal for gas sensors. Surface effects dominate and enable high sensitivity and selectivity, both with and without the underlying zinc oxide template. Actuation can be accomplished by resistive heating of the aeromaterial. The usual resistive heating is associated with either slow heating or low volume effects. In this case, neither applies. The actuator responds in milliseconds, moves volumes up to four times its volumetric expansion, and is capable of carrying high loads, at least 10,000 times its own weight. This is due to the negligible mass of the aermaterial, which results in negligible heat capacity of the material. The 3d structure with the high open porosity provides homogeneous heating of the gas trapped in the material between the tubes and leads to rapid volume expansion or presure increase. In addition, the talk will provide application examples that go beyond microfluidics.

Hybrid Wireless Vehicular Communications and Information Technologies for Vehicle Safety and Driver Assistance

Mihai Dimian[1], **Alin Căilean**[1,2], **Eduard Zadobrischi**[1,3], **Lucian Cosovanu**[1], **Cătălin Beguni**[1], **Sevastian Avătămăniţei**[1]
[1]Ştefan cel Mare University of Suceava, Romania, dimian@usm.ro
[2]University of Paris-Saclay, France
[3]Technical University of Cluj Napoca, Romania

This presentation follows the main challenges and research directions in the area of hybrid wireless vehicular communications and the progress made in our research group in developing wireless communication systems for vehicle-to-vehicle and infrastructure-to-vehicle communications, as well as information technologies for vehicle safety and driver assistance. In the context of energy crises and the large number of car accidents, energy efficiency and traffic safety became the main research focus for automotive industry and public transportation administration. The use of wireless communications and information technologies for vehicular applications has a significant potential to address these global challenges. For example, a new safety standard proposal to mandate vehicle-to-vehicle communications for new cars was announced by USA Department of Transportation with the scope of stimulating automotive industry to develop communication and information technologies with applications in improving vehicle safety and energy efficiency.

Enabling connected mobility via reliable and low-latency communication

Ion Țurcanu[1]
[1] Luxembourg Institute of Science and Technology, ion.turcanu@list.lu

In an increasingly connected world, cooperation among and between people and devices is key to boost innovation, to improve quality of life, and to build a sustainable society. In this context, wireless technologies revolutionized the way in which people and devices interact, providing connectivity on the move and enabling novel cooperative services with stringent communication requirements. A prominent example of such service is Cooperative, Connected and Automated Mobility (CCAM), which has the potential to substantially increase the safety and the efficiency of future transportation systems. Recent advances in wireless networking, which are delivering increased speed and higher reliability, are opening opportunities for novel CCAM use cases based on real-time sensor information shared among connected and automated vehicles. Technologies and standards in the IEEE 802.11 and 5G ecosystems are being developed to address the stringent communication requirements of CCAM applications.

At the same time, modern vehicles integrate hundreds of embedded devices forming complex wired on-board networks. Many of these on-board networked systems are successfully fulfilling stringent system and communication requirements, such as deterministic and very low end-to-end latency and jitter, zero packet loss due to congestion, and tight synchronization between data producer and consumer. These requirements are addressed by ongoing standardization efforts, such as the ones developed by the IEEE Time-Sensitive Networking (TSN) task group.

In this talk we explore the main technologies enabling future CCAM services and applications. In particular, we describe the main standards, recent advances, and open challenges of wireless Vehicle-to-Everything (V2X) communications and wired intra-vehicle networked systems. We also discuss the main challenges that such isolated wired on-board networks face when opportunistically exposed to other similar networked systems via a wireless interface in a highly dynamic manner. Finally, we discuss the potentials of mixing TSN wired networks and best-effort wireless networks for V2X.

Nanosensors and Sensors Based on Heterostructured Materials for Safety and Biomedical Applications

Oleg Lupan[1,2,3,4]**, Thierry Pauporté**[3]**, Sandra Hansen**[2]**, Rainer Adelung**[2]
[1]Technical University of Moldova, National Center of Biomedical Engineering, oleg.lupan@mib.utm.md
[2] Functional Nanomaterials, Faculty of Engineering, Germany
[3]PSL Université, Chimie ParisTech, Institut de Recherche de Chimie Paris,France
[4]Department of Physics, University of Central Florida, USA

The development of multifunctional nanosensors based on advanced nanomaterials is in the focus of the scientific and engineering community today, as it is one of the largest and fastest growing market segments. Scientific research on heterostructured micro- and nano-materials contributes to the miniaturization and performance improvement of existing solid-state sensors and light/image detectors, which are key components of many electronic, optoelectronic, safety, and biomedical circuits. Multitasking nanosensors are in high demand for small-sized smart wearable devices (e.g., smartphones with environmental, safety, or biomedical sensors) and other applications (from high-capacity information storage to biochemical sensing, analysis chemical and biological, etc.) due to reduced power consumption and improved performance. The challenges of using the properties of semiconducting oxides for practical application will be discussed and strategies for the fabrication, characterization, and integration of nanodevices through new technologies will be outlined. The integration and applications of the single nanowire as sensing devices and, in particular, as multifunctional nanosensors are in demand too. In addition, the contribution of crystalline nanosensor and nanophotonic systems will be highlighted to act as an enabling technology for scientific achievements in other research areas. In this talk, nano-heterostructured semiconductor oxides as core nano-building blocks for nanodevices, namely our contribution to building a new route to nanodevices through top-down and bottom-up approaches to hybrid nanotechnologies will be discussed based on our research and comparison with current scientific literature.

Mixed Reality Technology in Support of Cultural Heritage

Dorin-Mircea Popovici[1]

[1]CERVA, Ovidius University of Constanta, Romania, mircea.popovici@univ-ovidius.ro

Facing the challenges that the Covid 19 pandemic imposed on all of us, i.e., maintaining a safe social distance or avoiding direct physical contact, we designed and implemented a VR-oriented solution that allows the users to experience free navigation and interaction with large and/or small replicas of cultural heritage artifacts, using simple hand gestures, with no touch. Chosing a point/artifact of interest, navigating to it and even exploring it, all these are possible in the open solution, for groups of tourists that visited the Archaeology Museum from Mangalia, Romania.

Nanoparticle beam deposition methods for functional electronics

Alexander Vahl[1,2]

[1] Institute for Materials Science – Chair for Multicomponent Materials, Faculty of Engineering, Kiel University, Germany

[2] Kiel Nano, Surface and Interface Science KiNSIS, Kiel University, Germany

Owing to their high surface-to-volume ratio, their small size and the high number of intrinsic defects, nanoobjects such as nanoparticles exhibit properties that go beyond typical bulk materials. In particular, nanogranular systems with nanoparticles as their fundamental building units exhibit electronic and optical properties that differ from their atom-assembled counterparts. As such, nanoparticles are promising building units for applications in catalysis, optics and functional electronics.

In the field of sensors, noble metal nanoparticles are readily used to cover surfaces of semiconducting metal oxide micro- and nano-structures, which consequently tailors sensor properties such as sensitivity, selectivity and response times. On the other hand, in the context of memristive devices and neuromorphic hardware, noble metal (alloy) nanoparticles can be applied to localize and enhance the electrical field and realize highly localized resistive switching processes. In addition, such nanoparticles can act as functional building units for self-arranged networks, which are poised at the threshold of electrical percolation and show criticality and avalanche dynamics.

Common to all of the abovementioned applications is the high demand on a precise control over nanoparticle composition and deposition process. In this contribution, nanoparticle beam deposition via a Haberland-type gas aggregation cluster source will be showcased as a versatile method that meets these demands. Nanoparticle beam deposition methods based on gas phase synthesis of nanoparticles offer the benefit of a high purity, surfactant free deposition that is compatible with a broad range of substrates. The fundamental processes of nanoparticle formation and trapping inside gas aggregation sources are highly dynamic and require a better understanding.

This contribution highlights the importance of in-operando diagnostic methods for the development of a deeper understanding of the nanoparticle formation processes inside a gas aggregation source. The applicability of in-operando UV-vis and OES to control the functional properties of nanocomposite thin films will be demonstrated at the example of AgAu alloy nanoparticles with tuneable alloy composition. Furthermore it will be demonstrated how laser light scattering techniques can be applied to comprehend the dynamic trapping processes of nanoparticles inside the nanoparticle source, in particular under consideration of different gas inlet geometries.

Initiated chemical vapor deposition of tailored polymer thin films for electronic applications

Stefan Schröder[1]
[1]Kiel University, Germany, ssch@tf.uni-kiel.de

Device miniaturization and the consequent need for new thin film materials on the nanoscale is a current trend in electronic devices in research as well as industrial production lines. The solvent-free, single-step initiated chemical vapor deposition (iCVD) process combines the advantages of CVD with organic chemistry and enables the fabrication of tailored polymer thin films on the nanoscale on complex geometries and large-area substrates. The talk presents results from fundamental studies on the process to advanced electronic devices. These range from sensors and generators to soft robotics. With the help of additional computational ab-initio approaches, the properties of the thin films can be tailored on the molecular scale. It turns out that the process provides new pathways for electronic applications requiring precise film thickness control and high film quality.

Synthesis and chemical gas sensing properties of WO3 nanomaterials

Vardan Galstyan[1]**, Matteo Borsi**[2]**, Annalisa D'Arco**[3]**, Stefano Lupi**[4]**, Elisabetta Comini**[5]
[1,2,5]Sensor Lab, Department of Information Engineering, University of Brescia, Italy, vardan.galstyan@unibs.it, matteo.borsi@unibs.it, elisabetta.comini@unibs.it
[3,4]Physics Department, University of Rome ‘La Sapienza’, Italy and INFN-LNF, annalisa.darco@uniroma1.it, salvatore.macis@uniroma1.it

Nowadays, sensing systems have become a necessary part of our daily lives including healthcare and environmental safety. Semiconductor nanostructures are very promising materials for the fabrication of high-performance gas sensing devices owing to their unique physical, chemical and electronic properties. However, the improvement of their functionalities to satisfy the requirements of sensing technologies is a challenging issue. Herein, we report a novel synthesis method for the fabrication of WO3 nanostructures. We performed the synthesis of nanomaterials by the thermal treatment of tungsten thin films using sodium chloride and distilled water. We examined the effect of water, sodium chloride and water vapor on the growth of WO3 nanostructures. The morphological, compositional and structural analysis of prepared samples demonstrates that it is possible to prepare porous structures composed of WO3 nanoparticles in an aqueous solution of sodium chloride and under exposure to water vapor. The studies of the gas sensing properties of materials indicate that they have a highly selective response to acetone. In the meantime, our investigations show that the monoclinic γ-WO3 structure is more reactive and selective to acetone compared to the orthorhombic β-WO_3. This feature can be attributed to the catalytic activity and large dipole moment of monoclinic γ-WO_3. Hence, we provide a new strategy for the preparation of WO_3 nanomaterials based on eco-friendly methods and their application in health and environmental monitoring.

Functional Metal Oxide Surfaces: Photocatalytic, Self-Cleaning, Sensing, and Micro-/Nanostructuring Applications

Salih Veziroglu,[1] Josiah Shondo,[1] Franz Faupel,[1] Oral Cenk Aktas,[1,2]
[1] Chair for Multicomponent Materials, Institute of Materials Science, Germany
[2] Additive Manufacturing Excellence Centre – URTEMM, Turkey

Titanium oxide (TiO_2) is one of the most used photocatalytic materials for various applications such as environmental remediation, (solar)water splitting, and self-cleaning due to its high activity, low cost, high chemical, and physical stability. However, the photocatalytic activity of TiO_2 is limited by the wide energy of the bandgap, low quantum efficiency, and rapid recombination of photogenerated charge carriers (electrons and holes). During the last decades, numerous approaches, such as tailoring the morphology (nanoparticles, thin film, etc.), combining with metal, noble metal, and metal oxide micro/nanostructures, have been demonstrated to enhance the photocatalytic activity of TiO_2. However, it is still a major challenge to find the best photocatalytic combination for specific applications. Recent studies have revealed that particle size plays a considerable role in the photocatalytic activity of TiO_2. Reducing the particle size (increasing active surface area) indicates a higher photocatalytic activity. Nevertheless, the use of photocatalytic nanoparticles in continuous flow systems (such as water remediation, water splitting, etc.) has some practical limitations such as reusing and splitting them up from the reaction media. Hence, the use of robust and stable thin film photocatalysts becomes more suitable rather than nanoparticle systems for practical applications. Nevertheless, thin films are restricted by low surface area in contrast to nanoparticles and they show extremely limited photocatalytic activity. Here we present some case studies on enhancing the photocatalytic performance of TiO_2 thin film by modification with metallic and oxide nanostructures for practical applications such as water purification, self-cleaning, selective oil absorption, and organic molecule sensing.

Recent trends in solar cell development and characterization - an overview

Jan-Martin Wagner[1]
[1]Institute for Materials Science, Faculty of Engineering, Germany, jwa@tf.uni-kiel.de

Sooner or later, the development of silicon solar cells with steadily increased efficiencies will encounter the “barrier” of the Shockley–Queisser limit; standard cells having efficiencies well beyond that can only be reached by tandem architectures. On the other hand, at the same time the cells continuously become cheaper, at least concerning the price per watt. Therefore, for solar cell companies to stay in the market, fundamentally new industrially feasible cell structures and manufacturing concepts are needed. In this talk I will review the relevant development efforts, considering the whole fabrication process from the ingot growth over the wafering to the cell-making. Also, extended requirements for quality checks are an issue, for which adapted characterization methods are needed; I will consider those as well.

CuO-plate decorated ZnO nanostructures and their sensing performances

Dinu Litra[1], Cristian Lupan[1], Tudor Zadorojneac[1], Maxim Chiriac[1], Nadine Depri[2], Oleg Lupan[1,2,3], Rainer Adelung[2], Leonard Siebert[2]

[1] Center for Nanotechnology and Nanosensors, Technical University of Moldova
[2] Chair for Advanced Materials, Department for Materials Science, Germany,
[3] Department of Physics, University of Central Florida, Orlando, United States
lesi@tf.uni-kiel.de, oleg.lupan@mib.utm.md, ra@tf.uni-kiel.de

In this paper, we report on the gas sensing properties of mixed oxide Zn-Cu nanostructures obtained by self-organized chemical deposition are presented. The nanosensors are made from individual ZnO whiskers and are coated with CuO/Cu2O. They exhibit selectivity towards H2 and NH3 over other tested gases. Measurements were made in the temperature range between 20 - 175 oC. In order to determine the crystalline phases of the studied nanostructures, XRD diffractogram was measured, and SEM images were obtained for the morphological analysis.

Multi-modal multi-view emotion detection using non-negative matrix factorisation

Nistor Grozavu[1], Yasser Khalafaoui[1], Nicoleta Rogovschi[1]

[1] CY Cergy Paris University, France,
nistor.grozavu@cyu.fr, mykhalafaoui@alteca.fr, nicoleta.rogovschi@parisdescarrtes.fr

Through this work we explore the unsupervised topological learning of multimodal data presenting a complex structure allowing to learn their representations. We are particularly interested in heterogeneous data whose representation may have been informed in different ways: expert representation which may be complex. Most classical machine learning and statistical inference systems dedicated to multimodal and/or complex data, whether they are based on random models, empirical measures or prototype-based models, rely on a strong hypothesis, consisting in supposing at least that the structure of the data generating process for the observed scene is fixed, though it can be supposed unknown. In an unsupervised context, some existed works on Ensemble and Collaborative machine learning approaches were proposed but are limited to the same data distribution, i.e. in a multi-view context.

Non-negative Matrix Factorization (NMF) is a data mining technique that splits data matrices by imposing restrictions on the elements' non-negativity into two matrices: one representing the data partitions and the other to represent the cluster prototypes of the data set. This method has attracted a lot of attention and is used in a wide range of applications, including text mining, clustering, language modeling, music transcription, and neuroscience (gene separation). The interpretation of the generated matrices is made simpler by the absence of negative values. In this work, we propose a study on multi-modal clustering algorithms and present a multi-modal multi-view non-negative matrix factorization, in which we analyze the collaboration of several local NMF models.

The validation of the proposed approach is done on fusion of several emotion detection models covering multiple modalities: visual, acoustic and textual based on a dual-layered attention architecture.

The obtained results will be also presented on a demonstration starting by downloading video from YouTube. From the video we extract the audio track and the transcription for processing using and finally, as far as the visual aspect is concerned, we use two approaches, the first being based on "MediaPipe" if the trained model requires input markers, otherwise we extract directly from the video the images containing a well-framed face and clear. After-that the proposed multi-modal Non-negative matrix factorisation method is used for emotional detection.

Privacy and mutual authentication under temporary state disclosure in RFID Systems

Ferucio Laurențiu Țiplea[1], Cristian Hristea[2], Bulai Rodica [3]
[1] "Alexandru Ioan Cuza" University of Iasi, Romania, ferucio.tiplea@uaic.ro
[2] Simion Stoilow Institute of Mathematics of the Romanian Academy,
Romania, cristi.hristea@gmail.com
[3] Technical University of Moldova, rodica.bulai@ati.utm.md

Privacy and mutual authentication are two significant requirements for real-life applications of RFID schemes. These two requirements have been studied for a long time only for adversaries that cannot corrupt the temporary internal state of the tags. Recently, however, it has been shown that corrupting the temporary internal state of the tag is practically possible. This raises the question: do the current RFID protocols that ensure mutual authentication and privacy keep these properties in the temporary state disclosure model? The answer is negative and thus it justifies the effort to propose new RFID protocols that are secure under temporary state disclosure.
In this paper, we amply discuss how temporary state disclosure affects mutual authentication and privacy of RFID protocols, and illustrate this on two well-known protocols. We argue then in favor of using the PUF technology in order to achieve mutual authentication and a reasonable enough level of privacy under temporary state disclosure. We close by presenting two RFID schemes that achieve destructive privacy, one of the most important levels of privacy in the context of the physical corruption of tags.

Designing Interactive Computer Systems within the Framework of Sensorimotor Realities

Radu-Daniel Vatavu[1]
[1]MintViz Lab, MANSiD Research Center, Ștefan cel Mare University of Suceava, Romania, radu.vatavu@usm.ro, http://www.eed.usv.ro/~vatavu

This keynote provides an overview of the new concept of Sensorimotor Realities (SRs) and exemplifies applications involving wearable and ambient devices.

Developing bioinformatics capacity in Moldova

Viorel Munteanu[1] , Dumitru Ciorba[2], Victoria Popic[3], Serghei Mangul[4]
[1,2]Technical University of Moldova, viorel.munteanu@bioninformatica.utm.md, dumitru.ciorba@fcim.utm.md
[3] Broad Institute of MIT and Harvard, USA, vpopic@broadinstitute.org
[4] University of Southern California, USA, serghei.mangul@gmail.com

The field of bioinformatics and computational biology is one of the hottest scientific fields that has emerged and grown recently from traditional disciplines such as biostatistics, medical informatics, mathematics, informatics, molecular biology, and genetics. Since the universities of Moldova have a historical strength and show enormous potential in these classic fields, until 2021, there were no research and higher education institutions in Moldova that incorporated the field of bioinformatics in their academic programs or hosted research groups or services in bioinformatics. Among the reasons for this we list the relative lack of research projects requiring computational biomedical data analysis, lack of local expertise, lack of necessary infrastructure, lack of adequate national financial support, and the resistance of many academic institutions to incorporating new areas of teaching and research. To

maintain and increase the quality and pace of existing research in the life sciences, biotechnology, molecular engineering and medicine, a rapid and significant investment in bioinformatics was needed. In 2021, the first bioinformatics laboratory was created at Technical University of Moldova, then in 2022 at State University of Medicine and Pharmacy of the Republic of Moldova, both laboratories being supported by the host universities and partner laboratories outside the country. Within a year, the integration of local laboratories into international projects and consortia in various current topics in bioinformatics was achieved, and young researchers were involved in research teams in various projects in the USA and Europe. At the same time, bioinformatics training and schools have played an important role in creating skills and early placement of researchers and students in research problems and projects. As a result, the Republic of Moldova has unlocked its bioinformatics capabilities thanks to the efforts of national universities and partners from abroad, managing to break out of academic isolation in the field of bioinformatics.

The choice of DVB-T2 signal transmission technology in the shadow areas of the Republic of Moldova

Mihail Iacob [1]
[1] State Enterprise «Radiocomunicatii», Rebublic of Moldova, mihail.iacob@radiocom.md

This article presents the results of research into the opportunity to use Gap Fillers in the shadow areas of the first national digital terrestrial television multiplex of the Republic of Moldova. A basic condition related to the expansion of the population's access to the DVB-T2 signal in the "shadow areas" was - the use of the existing terrestrial broadcasting infrastructure. It was demonstrated that, to achieve the proposed goal, the use of Gap Fillers is not appropriate, but for the signal emission in the "shadow areas" it is necessary to use low-power DVB-T2 transmitters. In this case, the transport of the T2-MI flow to the entrance of the mentioned transmitters will be ensured by means of the existing fiber optic networks.

Digitalization of Religion as a Reaction to the Pandemic Crisis

Andrei Coltea [1], Dina Barcari [2]
[1] Shanghai University, China
[2] Technical University of Moldova

In this article we reflect on the changes produced once the pandemic began. Changes have also taken place in the ability of religious communities to adapt to the new requirements of communication with parishioners, one of which is the digitization of religion.

Daniele Hervieu-Leger argued that religion rests on the authority of tradition and relies on an intergenerational transmission of the collective memory of that tradition. This does not mean that religion is static, nor that the fragmented nature of modernity is incompatible with religion. Modernity has not eliminated the individual's or society's need to believe. Indeed, it was observed that the uncertainty arising from the dynamics of change made the need stronger. The transmission of religious tradition is more difficult in the contemporary age, however, it would persist in different ways than before; religion retains a creative potential in modernity.

The response of religion and religious people to Covid-19 gives us an opportunity to examine the digitization of religion in response to the pandemic crisis. It has been observed that society, like our need for tradition, has continued to adapt. This is evident through an examination of religion during Covid-19, where it appears that a large number of regular church attendees have switched to online religious attendance, especially during the lockdown period.

Spintronic Functional Nanostructures for Artificial Neural Network

Maria Lupu[1], Nikolai Klenov[2], Igor Soloviev[2], Sergey Bakurskiy[2], Vladimir Boian[1], Cezar Casian Malcoci[1], Andrei Prepelita[1], Evgheni Antropov[1], Roman Morari[1], Anatolie Sidorenko[1,2*]

[1] D.GHITU Institute of Electronic Engineering and Nanotechnologies, Technical University of Moldova¸ Chisinau, 2028 Moldova

[2] M.V. Lomonosov Moscow State University, Skobeltsyn Institute of Nuclear Physics, Moscow, 119991 Russia

Energy consumption reduction becomes a crucial parameter constraining the advance of supercomputers. The non-von Neumann architectures, first of all – the Artificial Neural Networks (ANN) based on superconducting spintronic elements, seems to be the most promising solution. Superconducting ANN needs elaboration of two main elements – nonlinear one (neuron) [1] and linear connecting element (synapse) [2]. Results of our theoretical and experimental study of the proximity effect in a stack-like superconductor/ferromagnet (S/F) superlattice with Co-ferromagnetic layers of different thicknesses and coercive fields, and Nb-superconducting layers of constant thickness equal to coherence length of niobium are presented.

Superconducting spin-valves and superconducting synapse, based on layered hybrid S/F nanostructures was designed and investigated.

The layered nanostructures Nb/Co demonstrate change of the superconducting order parameter in thin s-films due to switching from the parallel to the antiparallel alignment of neighboring F-layers. We argue that such superlattices can be used as tunable kinetic inductors for ANN synapses design.

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EFFECTIVE MANAGEMENT OF MEDICAL TECHNOLOGIES FOR A FUNCTIONAL HEALTH SYSTEM

Gheorghe Gorceag [1], ORCID: 0000-0002-4470-8014
Victor Sontea [1], ORCID: 0000-0002-0372-8799
Artur Buzdugan [1], ORCID: 0000-0002-9226-004X
[1]Technical University of Moldova, Department of Microelectronics and Biomedical Engineering, National Center of Biomedical Engineering, Stefan cel Mare blv, 168, MD-2004, Chisinau, Republic of Moldova,
gorceag.gheorghe@gmail.com , victor.sontea@mib.utm.md, artur.buzdugan@mib.utm.md

***Abstract* – Medical devices are indispensable in performing the medical services, and their importance has become a priority at the institutional level as well as at the national level. In order to assure the proper functioning of the health system, it is necessary to provide medical devices, in accordance with the latest progress of medical technologies. However, qualified human resources and the implementation of effective management are vital for qualitative, safe, and efficient medical devices.**

Keywords* – *medical devices, management of medical technologies, endowment, technology assessment, maintenance, periodical verification, the user.

I. INTRODUCTION

Good international practices demonstrate the need for the operative and continuous implementation of research results, and new innovative technologies with the potential to improve medical services offered to the population. Effective technologies associated with relevant health improvements create an ongoing challenge for health systems, as their most effective application requires increasing identification of financial and human resources for the health system. Obviously, the increasing costs of new technologies require the optimization of the evaluation and management of medical devices, but also of the available resources, and the most effective technologies must be promoted taking into account organizational, ethical, and societal issues in particular. Adequate management is an indispensable condition [1, 2] for ensuring a high level of safety, in some cases also security, but also the performance of medical devices. Respectively, ensuring the uninterrupted functionality of the health system, increasing the quality of medical services, and the degree of satisfaction of the beneficiary, are dependent on the technical-material basis, the professional competence of the personnel involved, as well as the quality, efficiency, and safety of medical devices. To improve the availability of innovative healthcare technologies such as medicines and certain medical devices to patients in the EU, Regulation (EU) 2021/2282 on Health Technology Assessment (HTAR) [3] was approved, which aims to help ensure efficient use of resources, to strengthen the quality of HTA in the EU, to reduce duplication of effort for national authorities and industry, will facilitate business predictability and ensure the long-term sustainability of EU HTA cooperation, as well as the approval in May 2022 of an implementation plan by - in the year 2025 [4].

Health technology assessment provides evidence-based and up-to-date information for policy-making on the use of technology in health services. Periodic health technology assessment thus acts as a mediating mechanism between policy, research and implementation domains, providing a problem-oriented systematic overview of research needed by both producers and users. This allows the adoption of a high quality and current standard in the medical service system.

II. MEDICAL DEVICE ENDOWMENT AND TECHNOLOGICAL POTENTIAL

In order to implement the provisions of Law no. 92/2012 Regarding medical devices [5], the provisions of the Memorandum of Understanding between the Swiss Agency for Development and Cooperation and the Ministry of Health of the Republic of Moldova regarding the implementation of the project Development of the National Information System for Management of Medical

Devices (SIMDM) was approved, by order Ministry of Health no. 274 of 18.03.2013 [6], an Action Plan, according to which this SIMDM was implemented.

Responsible for the updating and management of SIMDM is currently the "Agency of Medicines and Medical Devices [7], which ensures the periodic verification of medical devices put into operation [8]. Currently, in the Medical Devices Management Information System of the Ministry of Health of the Republic of Moldova 41,273 medical devices of 3,893 models are registered. From the point of view of the quantitative endowment with medical devices, medical institutions are considered sufficiently equipped. But, from a technological point of view, the technological potential of endowment is physically and morally exceeded, taking into account the pace of development of medical technologies This obvious factor affects the quality and efficiency of medical services provided to the population.

The calculations show that the degree of endowment of public medical-sanitary institutions is 3.0 medical devices per bed, and the rate of medical devices older than 10 years, operated in public medical-sanitary institutions in the Republic of Moldova is below 40%.

The health system in the Republic of Moldova is provided with medical devices through purchases from the state budget, projects and donations. The basic mechanism being the public procurement carried out by the Center for Centralized Public Procurement in Health (CAPCS).

According to the accumulated data, more than 2000 names of medical devices are purchased annually through CAPCS, as a result of the organization and implementation of centralized public procurement procedures, according to table no. 1.

Table no. 1

Year	2020	2021	The first semester of 2022 / estimated for the 2022 year
No. procedures carried out	143	123	65/130

On the other hand, the provision of public medical and sanitary institutions with medical devices is also carried out through projects and donations. For example, through the projects: "Emergency Response to COVID-19", financed by the World Bank, and "Emergency Response to COVID-19", financed by the loan of the Development Bank of the Council of Europe (CEB), as well as through donations, the health system was equipped with medical devices such as:

- mobile digital radiology devices;
- ultrasonography;
- artificial respiration devices/ventilators;
- monitors for patients;
- oxygen concentrators;
- infusion/infusion pumps;
- electrocardiographs;
- pulse oximeters;
- laryngoscopes/video laryngoscopes;
- defibrillators;
- oxygen generators;
- Analyzers.

Thus, during the COVID-19 pandemic, in accordance with the medical device needs of the health system, public medical and sanitary institutions were equipped with approximately 10,000 units of medical devices, including over 1,000 medical beds. Some of the mentioned projects, as well as other projects in the form of grants, loans or technical projects, are currently underway, and respectively, the purchase and further equipping of medical devices (computed tomography, oxygen generators, analyzers, etc.) follow. Regardless of the way of equipping the health system with medical devices, the essential step that needs to be carried out initially is, of course, the assessment of needs and directly the assessment of medical technologies.

The needs of medical devices must be evaluated in accordance with the existing inventory of medical devices, the medical technologies used but also those applicable, the potential of human resources, as well as the best international practices in the field. In this sense, the primary role belongs to the Ministry of Health, which together with the public medical and sanitary institutions, carries out the continuous assessment of needs and launches the mobilization of financial resources. Human resources responsible for the use and maintenance of medical devices. The essential component in the effective use of medical devices are the users of medical devices, who in the sense of Law no. 102/2017 [5], represents - "medical and sanitary institution, regardless of the form of ownership and legal form of organization, as well as its staff involved in the use of medical devices, including clinical staff (doctors and nurses), paramedical staff (radiologists and physiotherapists) and support services staff" [5]. According to the Statistical Yearbook of the Republic of Moldova for 2020, 12,552 doctors and 23,584 medical personnel worked in the health system, of which 18,514 were nurses – all users of medical devices [5] International practices show us that people involved in the use of medical devices must possess the appropriate knowledge and skills. As a result of the research and study of the challenges of the health system at the national level, as well as international experiences, in art. 15, paragraph (7) of Law no. 102 regarding medical devices [5], for the first time (year 2017) for the Republic of Moldova, the obligation of users of medical devices to use medical devices only after being instructed on how to use them was provided. Also, in the management of medical devices, responsibilities and obligations are also outlined for other people, namely:

- Managers of medical institutions;
- Staff of the procurement and supply subdivision within the medical institution;
- Staff of the finance/economy subdivision;
- The staff of the human resources subdivision.

One of the most important roles in the management of medical devices belongs, of course, to the personnel responsible for the maintenance of medical devices (medical bioengineers, technical engineers, technicians, mechanics, etc.). Starting from 2016 until now, annual evaluations have been carried out regarding the endowment of the health system with human resources (medical bioengineers, engineers, and technicians). Recent evaluations have shown that their total number is about 150, of which 50 are medical bioengineers. At the same time, the real need of the health system is over 300 medical bioengineers. For this purpose, the Department of Microelectronics and Biomedical Engineering of the TUM [10], and the National Center of Biomedical Engineering within the Technical University of Moldova [11], which are authorized by statute with such functions, play a special role in the periodic training and improvement of staff.

CONCLUSIONS

In order to ensure the efficient functioning of the health system, only the endowments of medical devices and/or the allocation of financial resources are not sufficient. But, it is necessary to have qualified medical and technical personnel, as well as tools for managing resources and processes that ensure the efficient use of medical devices. In the same way, to increase the quality of medical services and patient satisfaction, it is necessary to ensure the process of periodic evaluation of the conformity of medical devices, which lesss to the use of qualitative, efficient, and safe medical devices.

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Dealing With Missing Continuous Biomedical Data: a Data Recovery Method for Machine Learning Purposes

Victor Iapascurta [1,2], ORCID: 0000-0002-4540-7045
[1] N. Testemitanu State University of Medicine and Pharmacy, 165, Stefan cel Mare si Sfant Blvd., Chisinau, MD – 2004, Republic of Moldova
[2] Technical University of Moldova, 168, Stefan cel Mare si Sfant Blvd., Chisinau, MD – 2004, Republic of Moldova, victor.iapascurta@doctorat.utm.md

Abstract—**There are different approaches to dealing with missing data. A common one is by deleting observations containing such data, but it is not applicable when the volume of the data is limited. In this case, a number of methods can be applied, such as Last Observation Carried Forward and the like. But these methods are not suitable when all data for a certain parameter are missing. This paper describes a possibility of addressing this issue in the case of time series of biomedical data. Behind the method is the idea of the human body as a complex system in which various parameters are correlated and missing data can be inferred from the available data using the estimated correlation. For this, machine learning-based linear regression models are built and used to recover data describing the sepsis state. Finally, recovered data are used to create a sepsis prediction system.**

Keywords—biomedical data; missing data; data recovery; sepsis; machine learning

I. Introduction

Missing data are often unavoidable in research, but their potential to influence the research results is rarely discussed. In this respect it is considered of importance the nature of "missingness": at random versus not at random.

Unfortunately, quite often it is not possible to distinguish between missing at random and missing not at random using observed data. Since the data set used in this study is not accompanied by an explanation concerning the nature of missingness, it is assumed that they are missing at random (e.g. during the time the patient is undergoing a medical procedure that requires the sensors used for data collection to be removed, equipment malfunction, etc).

Although data recovery may be possible independent of the nature of missingness, the bias introduced by the recovery procedure is considered to be lower in the case of data missing at random [1].

There are many methods for dealing with missing values in data. Most of these methods are appropriate for static data and the set of tools suitable for continuous data, or time series is of a smaller size. The simplest approach is to delete observations with missing values, known as complete case analysis (CCA) [2], but in many cases, this can be hardly applicable, especially when the volume of available data is limited. This issue is of particular interest when using the data for machine learning purposes, especially when dealing with unbalanced sets, where every observation in the minority class is important.

Methods for data recovery can be conventionally divided in:

a. Single imputation methods - replace a missing data point with a single value, which is usually coming from the observed values from the same subject (Last Observation Carried Forward (LOCF), Baseline Observation Carried Forward (BOCF), and Next Observation Carried Backward (NOCB) or from other sources (e.g., mean value imputation, regression imputation, etc);
b. Multiple imputation methods - by creating several different plausible imputed data sets and appropriately combining results obtained from each of them. There are a number of statistical packages for this purpose (e.g., MICE, Amelia, HMISC in R, etc.)

According to the Guideline on Missing Data in Confirmatory Clinical Trials [3], “if missing values are handled by simply excluding any patients with missing values from the analysis, this will result in a reduction in the number of cases available for analysis and therefore normally result in a reduction of the statistical power. Clearly, the greater the number of missing values, the greater the likely reduction in power. Hence every effort should be made to minimize the amount of missing data [and select an appropriate imputation method].

Unfortunately, there is no methodological approach for handling missing values that is universally accepted in all situations".

As such, how to minimize the amount of missing data and how missing data are going to be handled in the analysis are critical issues that must be considered when planning a trial.

The current work presents a method of data recovery that consists of several steps, including regression imputation, which imputes the predictions from a regression of the missing variables on the observed variables.

One of the behind-the-scene concepts for the current method is the idea of approaching the human body as a complex system in which the various parameters that describe its functioning (in health or disease) are correlated and missing data can be derived from available data using estimated correlation.

Recovered data are finally being used to build a machine learning system, which is part of a larger research with the goal of creating a machine learning-based software application for sepsis prediction.

II. Research Data and Processing Methods

A. Data

The data used in this research are from a public database made available by "Early Prediction of Sepsis from Clinical Data: the PhysioNet/Computing in Cardiology Challenge 2019" [4]. The public part of the data comes from two distinct hospitals in the US: Beth Israel Deaconess Medical Center (set A) and Emory University Hospital (set B). These data were collected over the past decade with approval from the appropriate Institutional Review Boards, de-identified, and labeled using Sepsis-3 clinical criteria [5]. They consist o a combination of hourly vital sign summaries, lab values, and static patient descriptions for 40,336 patients, including 8 vital sign variables, 26 laboratory variables, and 6 demographic variables. All patient features were condensed into hourly bins (e.g., multiple heart rate measurements in an hourly time window were summarized as the median heart rate measurement).

The data contain more than 80% of missing values (e.g., set B). Since set A contains fewer missing values (i.e., 79,4%) and the prevalence of sepsis is higher (i.e., 8,80% vs 5,71% in set B) this set is used for further research.

There are 20336 patients/subsets in the set, including 1790 septic subsets, of which 502 subsets contain all missing values for at least one parameter (out of 6 parameters of interest). After applying initial selection criteria (e.g., the presence of at least 7 hourly observations before sepsis is diagnosed, absence of artifacts, etc.) the number of subsets that contain missing values but can potentially be recovered is 211. These subsets are the focus of the current research.

Table 1 shows the appearance of an original sepsis file with all-missing values (NA) for one parameter (i.e. Temperature). It describes observations on seven parameters of interest selected for further research (i.e. heart rate (HR), arterial blood oxygen saturation (O_2Sat), temperature (Temp), systolic blood pressure (SBP), diastolic blood pressure (DBP), respiratory rate (Resp), the age and labeling (0 – for non-sepsis cases and 1 – for sepsis).

TABLE I. Original appearance of a sepsis file

HR	SaO_2	Temp	SBP	DBP	Resp	Age	Sepsis label
83	100	**NA**	129	50	17	77.3	0
80	99	**NA**	89	41	18	77.3	0
79.5	100	**NA**	143	52.5	19	77.3	0
85	100	**NA**	161	56	18	77.3	0
69	95	**NA**	91	43	15	77.3	0
66	98	**NA**	116	40	20	77.3	0
68	99	**NA**	148	50	17	77.3	0
73	97	**NA**	117	44	14	77.3	1

B. Methods

The algorithm used here for data recovery purposes is a Generalized Linear Model (GLM) [6] provided by the H2O platform (www.h2o.ai) and is described below.

Gaussian approach (behind GLM) models the dependency between a response y and a covariates vector x as a linear function:

$$y = x^T\beta + \beta_0 + \epsilon, \tag{1}$$

where, β is the parameter vector, β_0 represents the intercept term and $\epsilon \sim \mathcal{N}(0, \sigma^2)$ is a gaussian random variable which is the noise in the model.

The estimation of the model is obtained by maximizing the log-likelihood over the parameter vector β for the observed data. The GLM [6] used in this research fits the model by solving the following likelihood optimization with parameter regularization:

$$\max_{\beta,\beta_0}(GLM\ Log \cdot likelihood - \ Regularization\ Penalty). \tag{2}$$

The regularization penalty is the weighted sum of the ℓ_1 (least absolute shrinkage parameter) and ℓ_2 (ridge regression) norms of the coefficients vector and is defined as:

$$\lambda P_\alpha(\beta) = \lambda\left(\alpha\|\beta\|_1 + \frac{1}{2}(1-\alpha)\|\beta\|_2^2\right) \tag{3}$$

with no penalty for the intercept term, where α is the elastic net parameter, $\alpha \in [0, 1]$ and λ is a tuning parameter.

The optimization over N observations is performed as follows:

$$\max_{\beta\beta_0} \sum_{i=1}^{N} log\, f\,(y_i;\, \beta,\beta_0) - \lambda\left(\alpha\|\beta\|_1 + \frac{1}{2}(1-\alpha)\|\beta\|_2^2\right). (4)$$

At the final machine learning (ML) stage, the Gradient Boosting Machine (GBM) provided by the same H2O platform [7] proved to be the best-performing algorithm.

The programming language used for current research is R [8], including a number of packages coming from the same environment and used for various tasks throughout the research. The same language/environment is used for interacting with the H2O ML platform and plotting.

III. Data Processing and Results

Data processing flow in this research consists of a number of steps, including missing value recovery and aims to generate datasets suitable for machine learning purposes. The following is a description of the main processing steps.

A. Preprocessing stage

Initially, there are 502 sepsis files with all-missing values for at least one parameter of interest (i.e. heart rate, arterial blood oxygen saturation, temperature, systolic and diastolic blood pressure respiratory rate) and 211 files where hourly missing values can be reconstructed. In order to create a more or less balanced dataset to be subsequently used for ML there was randomly sampled a commensurate number of non-sepsis subsets (i.e. 349 files/cases, or to be not larger than 40% compared to the sepsis subset).

B. Sepsis Data Reconstruction

The first step for sepsis data reconstruction includes applying LOCF (Last Observation Carried Forward, by "DescTools" package, R). This will recover missing values in columns in which some of the values are missing, but will not work for columns with all missing values.

In order to address the all-missing values cases there was examined the correlation between the 6 parameters of interest for the sepsis cases with no missing values described previously (Fig. 1). The plot includes an additional parameter – the age, which shows a moderate correlation with some parameters of interest and also has no missing values.

Based on the correlation coefficients there were selected 3 most correlated parameters for each of the 6 parameters (e.g., for temperature the most correlated parameters are HR, SBP, and Age; for respiration the most correlated are HR, O_2Sat, and temperature, etc.).

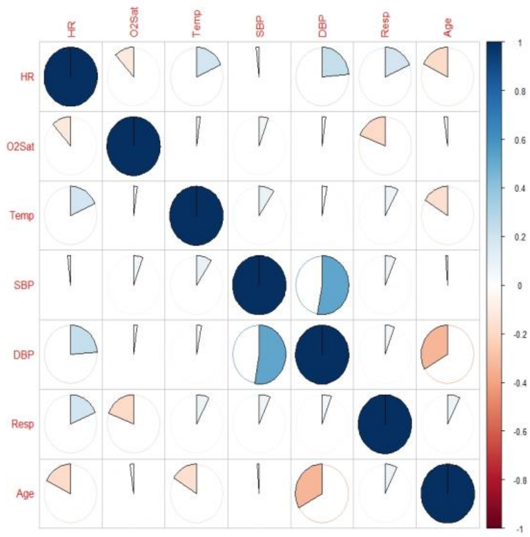

Figure 1. Correlation plot

Table 2 presents the correlation matrix for 7 parameters. Bold font denotes the highest correlation coefficients.

TABLE II. Correlation Matrix

	HR	O_2Sat	Temp	SBP	DBP	Resp	Age
HR	1.00	-.12	.18	-.02	**.24**	**.18**	**-.18**
O_2Sat	**-.12**	1.00	.02	**.06**	.02	**-.19**	-.02
Temp	**.18**	.02	1.00	**.09**	.03	.08	**-.16**
SBP	-.02	.06	**.09**	1.00	**.53**	**.07**	-.01
DBP	**.24**	.02	.03	**.53**	1.00	.06	**-.33**
Resp	**.18**	**-.19**	**.08**	.07	.06	1.00	.07
Age	-.18	-.02	-.16	-.01	-.33	.07	1.00

Using this correlation information a number of Generalized Linear Models (GLM) were trained and the best-performing models were selected for further search. Table 3 shows the main characteristics of these models.

These models are integrated into the data recovery pipeline and used to reconstruct the sepsis files with missing values.

TABLE III. LOGISTIC REGRESSION PARAMETERS (NORMALIZED)

	Intercept	Parameter/Coefficient		
HR	89.4392	*DBP* 3.2658	*Resp* 3.2980	*Age* -2.3973
O_2Sat	97.4894	*HR* -0.2305	*SBP* 0.1840	*Resp* - 0.4954
Temp	37.2479	*HR* 0.1233	*SBP* 0.0720	*Age* -0.1001
SBP	123.6418	*Temp* 1.6593	*DBP* 11.7255	*Resp* 0.6840
DBP	61.4999	*HR* 2.5176	*SBP* 6.8117	*Age* -3.7355
Resp	20.3789	*HR* 0.9001	*O_2Sat* -1.0138	*Temp* 0.3220

Table 4 shows the appearance of a recovered file. Recovered values are in bold. This is the same file as in Table 1 above.

TABLE IV. APPEARANCE OF A SEPSIS FILE AFTER RECOVERY

HR	SaO_2	Temp	SBP	DBP	Resp	Age	Sepsis label
83	100	**37.13**	129	50	17	77.3	0
80	99	**36.98**	89	41	18	77.3	0
79.5	100	**37.15**	143	52.5	19	77.3	0
85	100	**37.25**	161	56	18	77.3	0
69	95	**36.91**	91	43	15	77.3	0
66	98	**36.97**	116	40	20	77.3	0
68	99	**37.09**	148	50	17	77.3	0
73	97	**37.02**	117	44	14	77.3	1

C. *Preparing Data Sets for Machine Learning*

Once reconstructed, the data are split into training (393 files/subsets) and test (167 files/subsets) sets. On each file/subset there is applied a sliding window approach that groups observations in chunks of length three. Finally, the difference between the parameter's values in three consecutive hourly samples is estimated as well as the algorithmic complexity (by the Block Decomposition Method) on each of the two 3x3 matrices [9]. The resulting 14L vector generated for each sample represents the format of data to be passed to the ML algorithm. Since each file contains at least 7 hourly observations of the 6 parameters of interest on which the sliding window approach is applied, the size of the final data sets is larger than the number of initially selected files/subsets.

D. *Machine Learning Stage*

The training set for ML consists of 3126 samples (1330 sepsis and 1796 non-sepsis). This set is used to train a number of ML models using the H2O platform with 10-fold cross-validation.

The algorithms used include Gradient Boosting Machine (GBM), Generalized Linear Model (GLM), Distributed Random Forest (DRF), Stacked Ensemble (SE), and Deep Learning (DL). Although GBM and SE showed the best performance, because of explainability reasons the GBM model was chosen for further research.

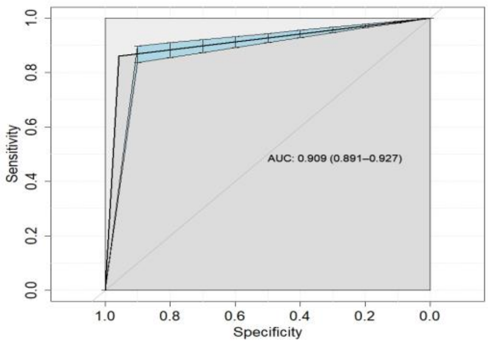

Figure 2. GBM model performance on the test set (by AUC).

The classification efficiency (sepsis vs non-sepsis) of this model (as measured by AUC) on the test set consisting of 167 cases/1065 samples that did not participate in model training is 0.91 (95% CI: 0.89 – 0.93) as shown in Fig. 2.

More detailed statistics concerning the best-performing GBM are summarized in Table 5.

TABLE V. CONFUZION MATRIX AND STATISTICS

		Reference	
		0	1
Prediction	0	598	62
	1	26	379
Accuracy		0.9174	
95% CI		0.8992 - 0.9332	
P-Value		< 2.2e-16	
Cohen's Kappa		0.8277	
Mcnemar's Test P-Value		0.0001907	

IV. DISCUSSION AND CONCLUSIONS

With careful planning, it is possible to reduce the amount of data that are missing to a certain extent. This is important because missing data are a potential source of bias when analyzing data. Handling missing data during model building is a challenge that this study addresses using a known perspective. But as far as we know it is the first time the method is used for such or similar datasets. The core of the method consists of a number of GLMs (one for each missing parameter of interest to be imputed/recovered) combined with LOCF [10] at an earlier stage in the data processing.

The proposed method has certain limitations. First, the method is not tested on different datasets, such as datasets containing categorical features, datasets generated by another disease (non-septic), etc. It also does not consider data in which there is no correlation between features and does not take into account the type of the variable distribution (normal, logarithmic, etc.).

Thus, our approach could be considered for similar datasets with continuous features and outcomes, and with similar correlations between features. Possible future studies will have the scope to determine the robustness of the method in different datasets.

One of the future research directions would be using the approach described in this paper on a larger data set (e.g. the full set A, which includes a total of 20366 patients and 1760 septic cases). Under these conditions, measures of the method adequacy and reliability can serve the performance of classification ML models in discriminating septic and non-septic cases together with sensitivity analysis results, especially when evaluating a number of methods used for missing data imputation (e.g. comparing the results of the full set analysis to those of the complete case analysis).

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Features of Application of the Experimental Stand for Reception of the New Measuring Information Concerning Morphological Signs of An Erythrocyte

Yevgen Sokol [1], ORCID: 0000-0003-1370-1482
Roman Tomashevskyi [1], ORCID: 0000-0002-5278-9272
Kostyantyn Kolisnyk [2], ORCID:0000-0003-1417-6608
Tatyana Bernadskaya [2], ORCID: 0000-0002-9371-6248
[1] National Technical University “KhPI”, Kharkov, Ukraine, sokol@kpi.kharkov.ua, romiocat.khpi@gmail.com
[2] Department of Industrial and Biomedical Electronics, National Technical University “KhPI”, Kharkov, Ukraine, kolesniknet@ukr.net, tatyana.bernadskaya@gmail.com

Abstract— **During the research work to increase the resolution of three-dimensional image of erythrocytes to determine morphological parameters, the Laboratory of Biomedical Electronics of NTU KhPI developed and manufactured an experimental stand with better characteristics. The peculiarities of using an experimental stand for obtaining new measuring information on morphological features of erythrocytes, its design and methods of use, which allows obtaining new measuring information on geometric and morphological features of erythrocytes, with its further use to obtain new laboratory clinical features and improve diagnosing the relevant pathological processes of the patient's body.**

Keywords— medical laboratory diagnostics, erythrocyte, morphological parameters, three-dimensional image.

I. INTRODUCTION

The idea of using morphological features of erythrocytes has recently received universal recognition, and research in this direction has been conducted by a number of research organizations. The task was reduced to obtaining a mathematical model of real erythrocytes, allowing to calculate its geometric parameters.

Currently, mathematical modeling of the shape and deformation of the erythrocyte is carried out on the basis of continuous and discrete approaches [1]. Within the framework of the first approach, the membrane is considered as a two-dimensional continuum. In this case, the equilibrium configuration of the considered medium under isotropic loading is maintained due to internal tension, bending moments, and transverse forces.

In this case, it is calculated on the basis of various variants of the nonlinear theory of thin-walled shells [2].The second approach uses the representation of the membrane as a system of elastically bound mesoscopic particles, the movement of which is calculated on the basis of classical (Newtonian) mechanics, taking into account the forces of elastic deformations of stretching, bending, the dissipative force of viscous friction, and the conditions limiting the area of the membrane and the volume of the cell, simulating the weak extensibility of the membrane and incompressibility of cell contents [3].

In work [4], a posteriori features of the multiple implementation of a two-dimensional model of the shape of an erythrocyte by the particle method are considered. The two-dimensional model only illustrates the possibilities of a discrete approach to erythrocyte simulation by the particle method. For an adequate description, it is necessary to use a three-dimensional model.

In works [5 - 7], an optical system is proposed that allows obtaining a three-dimensional model of an erythrocyte. The principle of operation of the digital holographic interference microscope, considered in this work, is as follows. Interferograms of the investigated microscopic phase interference objects are formed by superimposing two coherent laser beams, one of which passes through the object, and the other goes parallel. After superimposing the rays, an interference picture is formed. The shift of the interference bands corresponds to the height of the microobject at the point with the corresponding coordinate.

By recognizing the bands on the interferogram, filtering, skeletonizing and calculating the shift of the band at individual points of the image, the original three-dimensional shape of the studied object is restored. The disadvantage of the proposed method is the large size of the optical device, as well as the instability of the interference image to various types of vibrations and, as a result, the complexity of its practical application.

The authors of this work conducted research on increasing the resolution of the three-dimensional image of blood erythrocytes to determine morphological parameters [8 - 11].

At the same time, an experimental stand with improved characteristics was developed and manufactured as part of the CTW carried out in the Laboratory of Biomedical Electronics of NTU KhPI.

The stand was designed to obtain new measurement information regarding geometric and morphological features of erythrocytes, with subsequent use of it to obtain new clinical features and improve the diagnosis of the corresponding pathological processes of the patient's body.

Taking into account the main goal of this work - improving the method of determining the morphological features of erythrocytes by visualizing a three-dimensional image, research was carried out on optical methods of monitoring the morphological features of erythrocytes of blood, and the directions of the search for optimal methods capable of obtaining geometric parameters of erythrocytes with the desired density for qualitative analysis were determined.

During the work, the authors considered various ways to improve the quality of the image obtained by optical devices, namely:

- improvement of the method of obtaining three-dimensional images from two-dimensional images for the synthesis of panoramic images of single erythrocytes;
- improvement of a method of the spectral analysis on illumination by coherent waves for definition of parameter of dynamics of absorption of light by phase objects;
- improvement of the method of spectral analysis to determine the informative parameters of the geometric structure of erythrocytes.

When developing an experimental stand to obtain new measurement information on the morphological features of erythrocytes, it should be noted:

- the ability to dynamically change the elements of the optical scheme,
- reduced weight;
- the possibility of determining the effective ratios of the structural parameters of optical elements and other elements of the stand;
- improved technological parameters of the stand;
- universality of research algorithms.

II. GENERAL FEATURES OF CONSTRUCTION OF EXPERIMENTAL STAND WITH IMPROVED CHARACTERISTICS

Based on the research, a number of technical solutions were proposed, which were the basis for the creation of an experimental stand to obtain new measuring information on the morphological features of blood erythrocytes.

The final version of the basic optical scheme of the device is shown in Fig. 1.

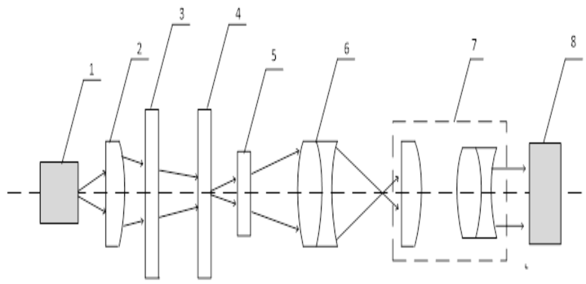


Fig. 1 - Schematic optical scheme of the experimental stand with improved characteristics: 1-coherent light source, 2 - condenser, 3 - polarizer, 4 - Goryaev camera with a sample, 5 - analyzer, 6 - microscope lens, 7 - digital camera eyepiece, 8 - photosensitive matrix.

In the basic optical scheme of the experimental stand with improved characteristics of Fig. 1, it is proposed to use two Galileo telescopic systems with different magnification, which will provide four options for the image size of the sample. The fifth option is achieved by completely removing the Galileo telescopic systems from the beam and inserting a tube with two diaphragms.

A semiconductor laser 1 with a radiation wavelength λ= 638 nm was used as the light source. The choice of this source was determined by its properties, the essence of which is to emit light in a narrow spectral range in the form of a directed, focused, highly coherent monochromatic beam of electromagnetic waves. Interference of light is obtained exclusively from the addition of coherent waves, ie waves that have the same frequency and time-constant phase difference.

The interference of light waves is obtained from a coherent source, in the proposed case of a laser, by dividing a monochromatic beam of light in two by means of a surface that partially reflects and partially refracts light. followed by superimposing them on each other. In order to determine the anisotropic areas in the sample, two polarization plates with mutually perpendicular direction of the optical axes were introduced into the beam. The first magnified image of the sample builds the microscope lens, and the final magnified image builds the eyepiece of the digital camera and builds it on a photosensitive matrix, which converts the optical signal into an electric one with the image output to a computer monitor. The experiment used a digital camera SIGETA M3CMOS 16000 16Mp USB3.0, which is an ocular digital camera with a high resolution of 16.0 Mpix.

The digital camera of this model can be used for stereoscopic, biological, metallographic microscopes. It is installed in an eyepiece tube or a separate optical port. The diameter of the chamber tube is designed for a standard tube width of 23.2 cm. For large tube diameters, two 30 and 30.5 mm adapters are included.

a)

b)

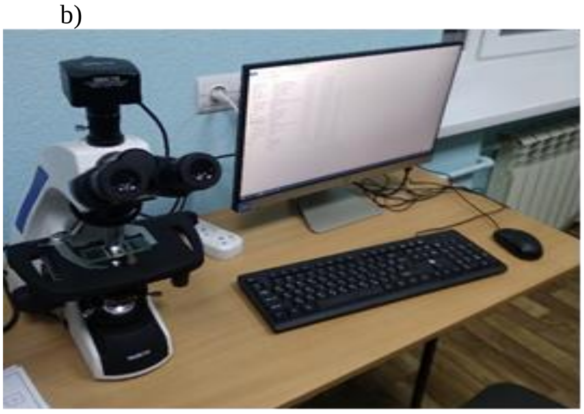


Fig. 2 - Appearance of the experimental stand with improved characteristics: a) front b) surface

The SIGETA M3CMOS 16000 eyepiece is powered via a USB cable that connects to the microscope via a USB3.0 interface.

ScopePhoto software (included on the CD), similar capture programs (ACD See, Amcap) and even photo editors such as PhotoShop are used to obtain images from the microscope. DShow & TWAIN driver, which is on the disk and is used to support third-party software.

Recommended software ScopePhoto is designed for translation and storage of images, functions for measuring linear and angular dimensions, editing, calculating the area of selected areas.

When capturing a video stream in maximum quality and setting a lower resolution, it is possible to watch video in real time at a specified speed. The appearance of the experimental stand with improved characteristics is shown in Fig. 2.

III. Assembly And Adjustment Of The Experimental Stand With Improved Characteristics.

The assembly of the experimental stand with improved characteristics was carried out in the Laboratory of Biomedical Electronics of the Department of Industrial and Biomedical Electronics of NTU KhPI. the object under study.

The basic basis for the sequential arrangement of optical and mechanical parts and components in general is the optical bench. Optical parts fixed in mechanical units were installed on the optical bench in accordance with the developed schematic diagram in a given order. It should be noted that the design of mechanical components must ensure compliance with all technical requirements for mounting optical parts in mechanical [12, 13].

Before attaching the optical parts to the mechanical, additional operations were performed to clean the surfaces of the optical elements. Mechanical parts that are in direct contact with the optical, such as: lens frames, glasses, intermediate and clamping rings of lenses, clamping bars of prisms, in the manufacturing process on machines are contaminated with cooling emulsions.

Therefore, for high-quality manufacturing of mechanisms and ensuring their operability during operation of the device, as well as in order to prevent contamination of optical parts in the process of assembling optical-mechanical components, washing of mechanical parts is provided. The process of washing mechanical parts is to remove various contaminants, degreasing all surfaces of the part. using aviation gasoline or petroleum ether, followed by drying with a stream of clean compressed air [14-16].

In accordance with the technical conditions for the manufacture and reception of optical-mechanical devices to the cleanliness of the surfaces of the optical parts of the device are high requirements. To meet these requirements in the assembly process it is necessary to clean the optical parts.

Optical details of the experimental stand should correspond to the I - III class of purity [17, 18]. Assembly is performed by ensuring the necessary mutual arrangement and interaction of circuit, especially optical, elements, among themselves or in relation to the design bases of assembly units and body parts.

Then the alignment is carried out, the essence of which is to bring the optical system of the device into working condition and to the compliance of the device with all the requirements of the technical conditions.

In the process of assembling optical-mechanical devices control their optical characteristics. The optical systems of all instruments must give high quality images, have specified characteristics (magnification, angular field), ensure high measurement accuracy and be reliable during operation.

The main condition that ensures high image quality is strict centering of optical elements. The essence of this operation is to combine the centers of curvature of all optical elements of the circuit with the optical axis of the device. And the optical axis must coincide with the geometric axis of the microscope tube.

To fulfill this condition, the design of mechanical parts provided for the possibility of longitudinal and transverse movements of optical and optical-mechanical components relative to each other. The designed mechanical units have three adjusting screws located at an angle of 120° relative to each other. The surface of mechanical parts was covered with black paint to eliminate light reflections.

After assembly and adjustment, control operations were performed to determine the quality of the image built by the optical system. The most common method of checking the quality of the image created by the optical system of the microscope is a visual assessment of the type of diffraction image of a glowing point.

The method is based on the study of light distribution in the diffraction image of an infinitely distant glowing point. lenses in frames, deviations in the centering of the lenses relative to the frames [21].

A diaphragm with a diameter of 0.02 mm is used to determine the image quality of a microobject constructed by an optical system. The microscope constructs an image of a point aperture, which creates a controlled lens (Fig. 3).

The following pictures of the field of view of the microscope are possible:

a) the image of the point is a bright unpainted spot surrounded by one or two concentric circles - the lens is assembled correctly (Fig. 3 a).

b) asymmetric image of the diffraction point means that there is a deviation in the centering of the lenses relative to the frames. The centering of the lens is considered satisfactory if the bright core of the diffraction image of the point when rotating the lens by 180 ° around the axis is slightly increased and the whole diffraction pattern does not change (Fig. 3b).

c) increased number of rings around the central spot - the presence of spherical aberration as a result of error in the length of air gaps or a large error in the manufacture of radii (Fig. 3 c).

d) the image of a point in the form of a cross, which passes when refocusing the microscope in a horizontal or vertical strip means the presence of astigmatism. The cause of astigmatism is the distortion of the lens surface in one direction, which is caused by deformation of the lens during its assembly or manufacture (Fig. 3 d).

e) the image of the point has a one-sided gap and when refocusing the microscope at the point of rupture of the enlarged halo of the point visible dark or light band crossing the halo means the heterogeneity of the refractive index in the glass (Fig.3e).

k) rupture of the first diffraction ring in the form of a tail means that one of the lenses on the edge there is a flooded surface - chamfer (Fig. 3k).

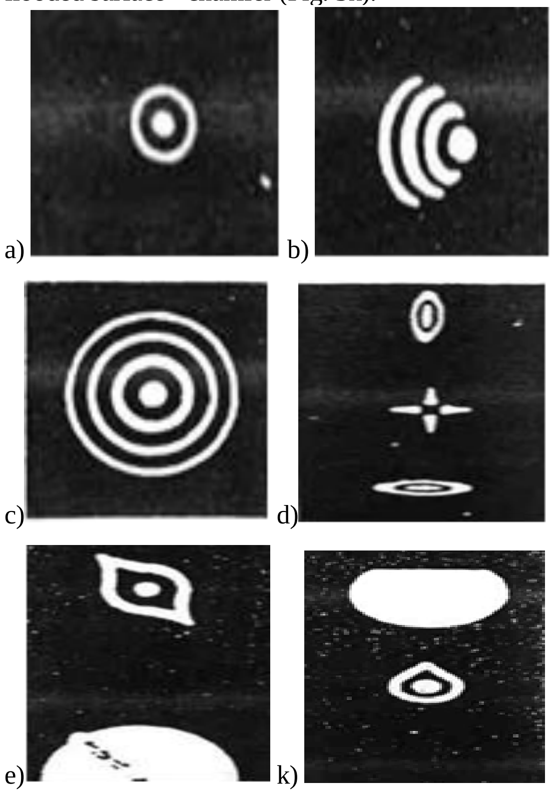


Figure 3 - Examples of diffraction point images: a) image of a point with a lens assembled correctly b) image of a point by a lens in which no centering is performed, c) image of a point by a lens with spherical aberration. d) image of a point by a lens having a non-constant radius of the surface in different meridians, e) image of a point by a lens having areas with different refractive indices, e) image of a point by a lens having a chamfer at the edge of the surface

The essence of control operations is that as a result of measurements and research to identify deviations of the actual characteristics of the optical system from the nominal values specified by the technical conditions. Errors and defects detected in the system are eliminated by adjusting, adjusting, replacing individual parts and components of the device [22].

IV. CALIBRATION OF THE EXPERIMENTAL STAND WITH IMPROVED CHARACTERICTICS

To test the magnification of the microscope, the Goryaev chamber grid was used, which is designed to count the formed elements of blood and cellular elements of cerebrospinal fluid (Fig. 4).

Technical data of Goryaev's camera:

- depth - 0.1 mm;
- area - 9 mm²;
- volume - 0.9 mm³ .

The chamber consists of a thick slide with transverse slots on it, forming three transversely located flat areas. The middle area is divided by a longitudinal slot into two sections, each of which has an engraved grid on it. On both sides of the middle platform in Goryaev's cell there are two others 0.1 mm above the average. The planes of these sites are used to grind the cover glass to the appearance of so-called Newtonian rings. After grinding the cover glass, a chamber is created, closed on two sides, and on the other two sides there are gaps (capillary space), through which the chamber is filled.

Fig. 4 - Microscope with Goryaev's camera located on the subject table

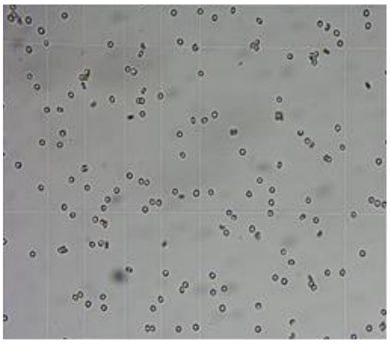
The microscopic grid of Goryaev's camera is drawn into large and small squares, grouped in different ways. Goryaev's grid contains 225 large squares (15 rows of 15 large squares in each), delineated vertically, horizontally, crosswise and undistributed. The sizes of small divisions of cells of a grid make 0.05 mm, and big - 0.2 mm. It is important that a small square with a side of 0.05 mm in all grids is a constant value. The area of the small square is 0.0025 mm2, and the area of the large square is 0.04 mm2. Then we obtain that the volume of liquid above the square formed by the large distributions of the Goryaev grid is 0.004 microliters.

In addition to the intended use of Goryaev's camera to calculate the formed elements of the blood, this glass can be regarded as a kind of standard for determining the magnification of the microscope according to formula 1:

$$X = \frac{p_1 - p_2}{a \times N} \tag{1}$$

where: X - is the magnification of the microscope, lattice;
p_1 - is position of the left border of the Goryaev chamber cell;
p_2 - is the position of the right border of a cell or group of cells;
N - is the number of cells between the boundaries;
a - is the cell size of the Goryaev chamber (equal to 0.05 mm).

To calibrate the microscope magnification, a small square of the Goryaev camera grid was taken (Fig. 5).

a) 

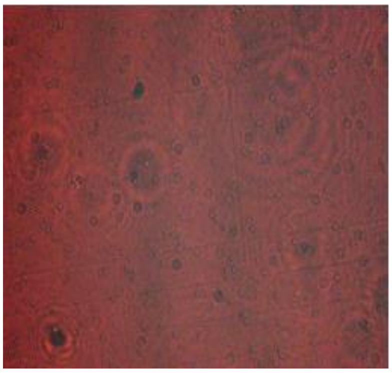
b) 

Fig. 5- Snapshot of the small square of the Goryaev camera grid: *a) in ordinary light, b) in coherent light*

The magnification of the microscope can be calculated by formula 2:

$$\Gamma_{мік} = \frac{l'}{l}. \tag{2}$$

where: l'– the value of the image of the Goryaev camera cell taken with the help of digital camera scales;
l – the size of the Goryaev chamber cell.

Fig. 6 - Snapshot of the plate inserted into the interference image

To test the program. allowing to construct a three-dimensional image of erythrocytes with superimposed vertical and horizontal scales, a picture of the interference pattern of the introduced plane-parallel plate of a given thickness was taken. 0.35 mm thick glass was used as a plate (Fig. 6).

V. Methods of Using the Experimental Stand With Improved Characteristics to Obtain a Difraction Image of Erythrcytes

Using the new qualities of laboratory equipment proposed in the experimental stand with improved characteristics, the authors have improved the method for obtaining images of erythrocytes.

For the study, the following algorithm was proposed for determining the morphological features of erythrocytes by visualizing a three-dimensional image:

1. Prepare a blood sample. Add 20 µl of blood to 4 ml of 0.9% NaCl solution and mix thoroughly.

2. Thoroughly wipe Goryaev's chamber and cover glass with a clean bandage slightly moistened with alcohol, then a gauze ball without alcohol. Grind the cover glass to the appearance of iridescent rings on both sides.

For better grinding, you can exhale a little air on the chamber and cover glass so that a small amount of moisture condenses on the glass surfaces to ensure better contact.

After grinding the cover glass, a chamber is created, closed on two sides, and on the other two there is a capillary space, through which the chamber is filled.

3. Place the prepared drug on the subject table.

4. Insert the digital camera connected to the computer via the USB cable into the eyepiece tube. ScopePhoto software (included on the CD) is used to obtain images from the microscope and must be pre-installed.

5. Connect the microscope illuminator to the mains by inserting a red laser into the light beam. The program for controlling the node responsible for the intensity of the laser radiation is given in Appendix D.

6. Gently move the microscope slide until a sharp image of erythrocytes appears on the computer monitor, using first coarse and then fine focusing screws.

7. Make panoramic views of the microscope.

8. Fine focusing screw to achieve diffraction image of erythrocytes formed by interfering

9. Take panoramic images of the field of view of the microscope.

10. To process the image by means of the offered algorithm of reception of a three-dimensional picture of an erythrocyte.

11. To detect anisotropic areas, enter the polarizer and analyzer in the course of the beam according to the location of the elements in the optical circuit. Rotating the analyzer around the optical axis of the device to achieve the most contrasting image of erythrocytes and take a screenshot.

13. When changing the magnification of the microscope, enter the lens smoothly into the course of the beam and focus with a fine guidance screw.

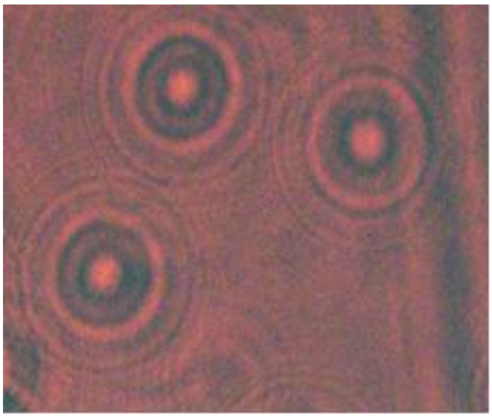
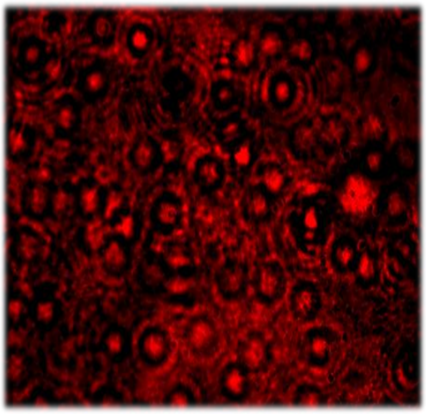


Fig. 7 - Diffraction image of erythrocytes formed by interfering rays

a)



b)

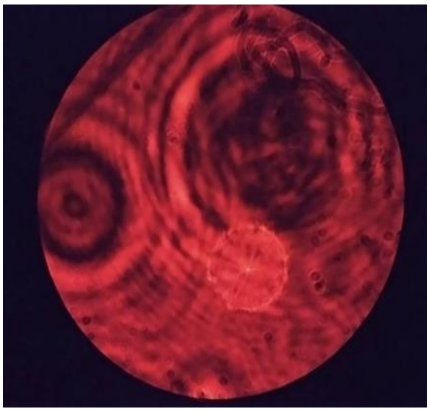


Fig. 8 - Interference pattern of erythrocytes in hypotonic solution with increasing: a) 400x and b) 900x.

For example, in Fig. 7 - 8 shows the photos obtained using the above method on the developed experimental stand with improved performance.

The obtained images are of sufficient quality for conducting research on the morphological features of human erythrocytes and further analysis.

VI. CONCLUSION

The peculiarities of application of the experimental stand for obtaining new measuring information on morphological features of erythrocytes of blood are given in the work.To improve the image quality of erythrocytes, the authors carried out targeted optimization of the optical elements of the device, which significantly reduced light loss with decreasing mass and dimensions of the device and allowed to obtain a clear image of microobjects with a standard size of 7.5-8.3 microns [23-24].

The optimal values of the numerical aperture of the lens were also selected, which provide sufficient resolution for this micro-object, namely in the range of 1-2 μm. The use of a multi-lens lens has reduced the aberrations of the optical system and improved the discreteness of the lens settings.

The introduction of polarizing light filters into the optical branch improves the quality and contrast of the interferogram, as well as the possibility of detecting anisotropic areas in the studied microobject. This significantly improves the optical and technical characteristics of the device (increasing the accuracy of the image relative to the object due to the optical magnification of x400 -x900 times) and simplifies the research process, thereby increasing the manufacturability of the process.

The experimental stand of the interference microscope developed as a result of work can be further used as a prototype of the medical device, for carrying out additional researches concerning morphology of erythrocytes and definition of superfluous diagnostic signs.

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New Biophysical Approach in Analysis of Heart Rate Variability for Increasing its Predictive Value

Ludmila Sidorenko [1], ORCID: 0000-0003-0382-4542
Larisa Spinei [1], ORCID: 0000-0002-5370-9801
Gert Baumann [2],
[1] State University of Medicine and Pharmacy “Nicolae Testemitanu”, Stefan cel Mare str. 165, Chisinau, RM
ludmila.sidorenco@usmf.md
[2] Charite University Clinic, Chariteplatz 1 10117 Berlin, Germany

***Abstract*—Background. Regarding the high incidence of cardiovascular diseases, it is critical to find predictors. The aim of this study is to appreciate the predivtive value of of recently-found parameters of cardiorhythmogram analysis applying the new biophysical approach for predicting the recurrence of atrial fibrillation. Material and methods. This is a case-series study, where 350 cardiorhythmograms were assessed. For assessment both methods were applied, the standard heart rate variability analysis and new approach by the parameters HF counterregulation and LF drops. Results. The both newly-found parameters predict reliably atrial fibrillation recurrence. The significance of the parameter HF counterregulation is $p < 0.0001$, in case of the parameter LF drops it is $p < 0.001$. Conclusions. In case if prediction is needed, the standard heart rate variability should be completed by the new biophysical approach, applying the parameters HF counterregulation and LF drops. Steady-state cardiorhythmograms with events of unstationarity can be realiably analysed just by these parameters. Events of unstationarity are informative sources for prediction.**

Keywords—cardiorhythmogram; atrial fibrillation; prediction; biophysics; unstationarity.

I. Introduction

Cardiovascular disease are in the top ten globally spread pathologies which affect the health and quality of life of millions of people worldwide [1]. This is the reason why relevant prediction methods in cardiology are of high importance. Reliable predicton can be elaborated just interdisciplinary, using therefore different physiological, electrophysiological, cardiological investigation tools, biophysical parameters, statistical analysis and mathematical models. The new biophysical approach described in this paper is applied with the aim to increase the predictive potential of heart rate variability (HRV) analysis. The HRV analysis is a well-known method. It is applied in different medical branches [2]. However, it still has its known limitations [2,3]. One of the limitations in the use of HRV in the cardiology is the problem of steady-state cardiorhythmograms [3]. The literature review shows that majority of the articles does not regard a very important biophysical parameter during their analysis of HRV – the appearance of non-stationar events in a steady-state cardiorhythmogram. In case of respecting all the recording condotions and excluding arrousels from body movement, the unstationarity is respresented by additional waves in the cardiorhythmogram. The problem is that these are cut out to make the classical analysis possible [4]. The reason is that a classical HRV analysis with automatically programmed analysis cannot be done with waves of unstationarity [4]. However, cutting out, the biosignal loses some of its quality and reliability [4, 5]. That is the main reason, why such cardiorhythmograms are mostly taken out of analysis or minimal information is extracted from such an HRV analysis. Furthermore, exactly the fragmetns of cardiorhythmograms before and following after the unstationar event reveal maximum of information regarding prediction during HRV analysis [5]. So just cutting them out in order to ensure a classical HRV analysis is a big mistake from biophysical and pathophysiological point of view [5]. That is why in this study the aim was to stydy cardiorhythmograms with unstationar events in steady-state cardiorhythmograms in order to extract maximum of information regarding the predictive value of HRV due to the application of a new approach to the analysis. The predictive value was applied to a concrete pathology – the prediction of atrial fibrillation. The prediction of atrial fibrillation is of very high importance because it is the most common sustained arrhythmia in cardiology which affects remarkably the health state, is followed by a lot of consequences like stroke or arterial hypertension and effects the quality of life [6]. So the prevention of paroxysms of atrial fibrillation via finding relevant predictors is an important medical and social challenge.

II. Material and Methods

A. *Analysis of cardiorhythmograms*

The following study is a case-series study. It was written according to te STARD criteria. The new biophysic approach was assessed on 350 cardiorhythmograms. Inclusion criteria of the cardiorhythmograms was diagnosed paroxysmal atrial fibrillation, but at the moment of the biosignal recording has to be sinus rhythm. Exvlusion criteria was atrial fibrillation at the moment of biosignal recording. The biosignal was obtained by a 5-minute ECG recording using a specialized hardware (Polyspectrum-HRV-device, Neurosoft). The data obtained from the biosignal recording were further analysed with the software „Neuro-Soft“. It is important to mention, that the biosignal for further HRV analysis was obtained not from a Holter ECG. In order to obtain a reliable biosignal and to ensure the reproducibility of the data, all standard conditions during measurement were regarded [4]. All the 350 cardiorhythmograms which were included in the study were included in the analysis. At the moment of biosignal recording the patients were paroxysm-free, so they had sinus rhythm. After the baseline recording every three months the biosignal was during follow up recorded. The follow-up lasted 18 moths. Every recording was analysed regarding the predictive value of non-stationr events in the steady-state cardiorhythmograms. The fragments of the cardiorhythmograms where the non-stationarity events occurred waere analysed separately. The non-stationar event was regarded as an “LF drop” and the fragment of cardiorhythmogram followed after the “LF drop” was regarded as “HF counerregulation”, descriebed in detailed elsewhere [5].

B. *Standard Operating Procedure for obtaining a steady-state cardiorhythmogram*

In order to obtain a steady-state cardiorhythmogram, a resting state probe is required. Therefore a 5-minute ECG in supine position is recorded. In the room all conditions for ensuring a calm state of the person shoul be respected. The person is alert, sleeping during biosignal recording is prohibited, important is the free spontaneous breathing. Recording just in sinus rhythm is possible. Before the beginning of the biosignal’s recording, a steady-state hast to be achieved. For that reason after having connected the electrodes, the investigator monitors the biosignal on the monitor until the moment when a steadystate signal is reached. Only after having achieved the corresponding indicators for that state, the biosignal recording which will be used further for analysis, starts. The time required for achieving the steady-state signal varies, it lasts individually. Usually it takes from 5 to 20 minutes [4]. It is important in order to exclude false positive reactions of an increased sympathetic or parasympathetic reaction of the vegetative nervous system. This is critical because the intension of this rest state biosignal recording, is a further assessment of the sympathetic, parasympathetic and the central modulations of the vegetative nervous system on the heart rhythm. Thus, a qualitative biosignal can be obtained only if all additional influences, which do not belong to rest state probe, are excluded [3, 4]. This is the only way to deliver a forther reliable assessment of the biosignal.

I. Results and Discussion

Among the 350 cardiorhythmograms, in 280 paroxysms of atrial fibrillation during the 18 months of follow-up were observed. 70 cardiorhythmograms remained paroxysm-free. For that reason was the possibility to analyse both types of cardiorhythmograms, with and without paroxysm. It means, both pathophysiologic and biophysic conditions were reflected, those which indicate the prognosis of sinus rhythm and conditions, which indicate the appeareance of paroxysm of atrial fibrillation. Standard HRV analysis methods are not described in this paper as these are well known [2, 3, 4]. The new biophysic approach to cardiorhythmogram analysis is described. Several cardiophysiological biomarkers and biophysical parameters were taken for cardiorhythmogram analysis, but in this paper are described only the most informative, most important and most convenient ones for the data analysis: Low frequency (LF) drops, high frequency (HF) cunterregulation and increased central activity in rest state. These parameters describe in an appropriate way the biophysical aspect of unstationarity in steady-state cardiorhythmograms [5]. The pathophysiological background of these parameters is in detail described elsewhere [7]. In case that no unstationarity in a steady-state cardiorhythmogram occurs, it can be analysed according to the standard HRV analysis. In this case the classical prediction describes the high HRV as a predictive factor for keeping the sinus rhythm and the low HRV predicts the risk for appearance of atrial fibrillation paroxysm [2, 4]. The problem is that in patients with atrial fibrillation the functionl state of the regulatory systems of the heart is pathological [7, 8], so that seldom cardiorhythmograms without unstationarity were analysed. In these cases standard HRV analyses are not possible [4]. From 350 cardiorhythmograms just 27 were without any stationarity In 323 cases unstationar events were present. In these cases the biophysical approach was useful. Therefore the LF drops and HF counterregulation were analysed. From 280 cardiorhythmograms with paroxysms of atrial fibrillation 263 were with LF drops in combination with a low HF counterregulation. In the 70 cases of paroxysm-free cardiorhythmograms 43 had LF drpos in combination with a high counterregulation, 27 had no LF drops, so were classiefied by the standard HRV as paroxysm-free. So from these data is clear that LF drops and HF counterregulation are reliable predictors for paroxysms of atrial fibrillation and for remaining in sinus rhythm, correspondingly. The combination LF drops with a low HF counterregulation predicts significantly paroxysm of atrial fibrillation ($p<0.0001$). The combination LF drops with a high HF counterregulation predicts significantly the maintanace of sinus rhythm ($p<0.001$).

A. Assessment of cardiorhythmogram

In this paper the following approach to the analysis of cardiorhythmograms, taking in account important biophysical and pathophysiological parameters, is proposed: first of all to recognize whether LF drops in the cardiorhythmogram are detected. In case that no LF drops are identified, the cardiorhythmogram can be analysed by the standard approach to HRV analysis [4]. Under this circumstances the cardiorhythmogram is regarded as a steady-state one, without unstationar events (fig. 1 and fig. 2). Correspondingly, in such cases the risk stratification says that the difference of wave structrure in the figure 1 and 2 is a standard important parameter to be taken in account [9]. In such a case like presented in cardiorhythmogram on figure 1 there is a low risk for paroxysm of atrial fibrillation. This cardiorhythmogram (fig. 1) is mainly modulated by HF waves. Physiologically it means that the parasympathetic nervous system works efficiently enough, so that the heart is regulated in calm state mainly by the medullar level [7, 8, 9]. As consequence, the prognosis for sinus rhythm was confirmed.

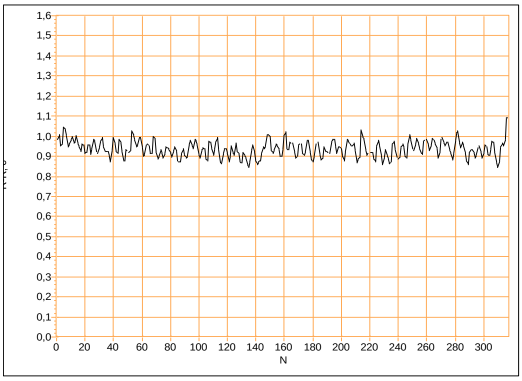
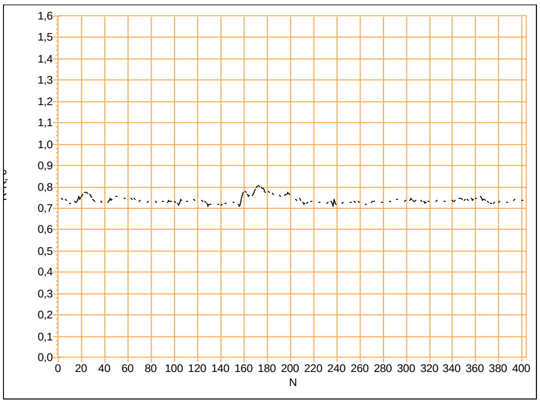


Figure 1. Cardiorhythmogram. In this cardiorhythmogram the HFwaves dominate. There are no LF drops.



Figue 2. Cardiorhythmogram. HRV is modulated predominantly by VLF and LF waves. There are no LF drops.

On the next figure (fig. 2) there is another extreme.
There are still no LF drops present, but the modulation of HRV is ensured mainly by VLF waves and LF waves. Pathophysiologically it means that the heart is modulated even at rest predominantly by the central level insead of the medullar level [5, 7]. In this case atrial fibrillation prognostically was expected. However, usually there are cardiorhythmograms when a prognosis cannot be made so obviously, just comparing LF or HF waves. This is the reason why respecting the biophysical parameter of ustationarity, analysing the cardiophysiological biomarkers in the cardiorhythmograms, like LF drops and HF counterregulation was proposed. The next example (fig. 3) represents a cardiorhythmogram with LF drops.

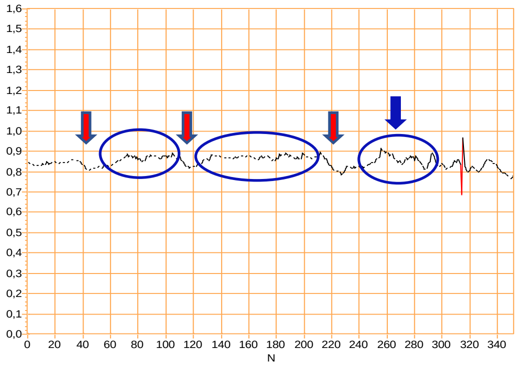


Figure 3. Cardiorhythmogram. By red arrows are marked the LF drops. The waves of counterbalancing are encircled blue. The latter are modulated mainly by LF waves instead of HF waves. A parasympathetic break-down is marked by the blue arrow, it occurs during the counterbalance of the LF drop.

The LF drop ia a nonsteady-state event evoked by unstationarity. As far as these are recognized, the standard HRV assessment is not possible [4]. LF drops represent waves on a cardiorhythmogram, which occur suddenly at the end part or in the middle part of VLF waves (fig. 3). Physiological low frequency (LF) waves on a cardiorhythmogram are driven usually by sympathetic inputs [4, 8]. The difference between LF physiological waves and LF drops is in the moment of appearance and in the morphology. LF dropps appear suddenly because of the sympathetic overflow of the heart, represented by LF waves of a high-amplitude drop-down on a rest-state cardiorhythmogram. The hight of the amplitude is taken relatively to the hight of the waves of every certain cardiorhythmogram. The sympathetically driven overflow of the heart rhythm modulation during rest state occurs when the medullar modulation of the heart rhythm is functionally insufficient and the central modulation of the heart is increased [7, 8, 10]. This pathophysiological state destabilizes the rhythm of the heart [8, 10]. As consequence, the LF drops in a cardiorhythmogram during rest state recording increase the risk for paroxysm of atrial fibrillation. The next parameter which should be analysed in cardiorhythmograms with LF drops, is the HF counterregulation. This is the fragment of the cardiorhythmogram following the LF drops (fig. 3 encircled blue). The HF counterregulation occurs with the aim to counterbalance the LF drops [5, 7]. It is important to analyse which waves' structure the fragmant of cardiorhythmogram which corresponds to the HF counterregulation has. Physiologically the counterbalancing has to be ensured by parasympathetic compensation [7, 10]. Under such conditions on cardiorhythmograms the HF waves should be detected [7]. During a pathological counterregulation the LF waves are detected. In this case a high risk for the recurrence of atrial fibrillation was observed. A pathological counterregulation you can see on figure 3. [7, 8]. Here the parasymphatetic counterreaction is not effectively enough in order to compensate the sympathetic overflow of the heart rhythm and the central overactivity in calm state. This state is a parasympathetic break-down (fig. 3 blue arrow). As consequence it resulted in atrial fibrillation recurrence until the next follow-up check. In case that a pathological counterregulation after the LF drops appeared, occurred recurrence of atrial fibrillation during the follow-up. LF drops can occur not only on cardiorhythmograms with a low HRV (fig. 3) but they also occur often on cardiorhythmograms with a high HRV (fig. 4).

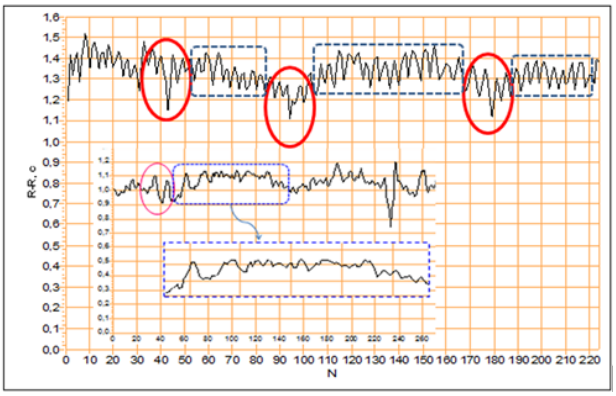


Figure 4. Comparison between two cardiorhythmograms with LF drops (encircled red). On the first (at the bottom of the figure) cardiorhythmogram the LF drops are followed by a sufficient physiological counterregulation (blue frame) by HF waves, whereas on the second one they are followed by a pathological counterregulation (blue frame): predominantly modulated by LF waves and with a dropdown of waves during counterreacting.

On figure 4 you can see two cardiorhythmograms with with a high HRV and in both cases LF drops (encircled red) are present. The difference is in the quality of the counterreaction. On the upper cardiorhythmogram it is ensured by physiological HF waves, meaning sinus rhythm in prognosis whereas the lower, the inseted cardiorhythmogram represents a pathological counterregulation (blue frame), so recurrence of atrial fibrillation occurs. The inseted one is ensured mainly by LF waves. It means, that the parasymphatetic counteractivity is functionally not sufficient to compensate for sympathetic central overactivity in calm state [8, 10]. This is connected with a high risk for atrial fibrillation recurrence. On the upper cardiorhythmogram on figure 4 there is an example when the LF drops are present, meaning an increased central modulation, but the counterregulation is modulated by HF waves (fig. 4, the upper cardiorhythmogram). That means, the parasymphatetic counterbalancing activity is still sufficient to compensate for an increased central modulation of the heart in calm state [8, 9]. In case of such cardiorhythmograms a sinus rhythm during follow-up was observed.

B. *Conclusions*

1. The parameters LF drops and HF counterregulation predict significantly the recurrence of atrial fibrillation.
2. The standard heart rate variability should be completed by the new biophysical approach, applying the parameters HF counterregulation and LF drops.
3. Steady-state cardiorhythmograms with events of unstationarity can be realiably analysed just by the biophysical approach, apllying the parameters HF counterregulation and LF drops. parameters.

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New Biotechnological Opportunities to Assess the Influence of Lifestyle Factors in Obesity

Attia Guy [1], ORCID: 0000-0003-2383-5505
Levinberg Roee [1], ORCID: 0000-0001-9854-410X
Arad Erez [1], ORCID: 0000-0003-0126-9880
Davidov Ilan [1], ORCID: 0000-0002-5725-5827
Ludmila Sidorenko [1], ORCID:0000-0003-0382-4542
[1]Nicolae Testemitsanu State University of Medicine and Pharmacy, Stefan cel Mare str. 165, Chisinau, the Republic of Moldova, gyaa52@gmail.com

***Abstract*— Background. Obesity results from a malfunction of the body's weight-control mechanisms, which may be influenced by environmental changes. Essentially, the obesity risk relies on two significant interdependent factors: genetic variations (single-nucleotide polymorphisms, haplotypes) and environmental risk exposure. Due to new biotechnologies over 127 potential genes for obesity have been identified, and evidence supports the function of 22 genes in at least five distinct groups. Gene and environment interactions mean that the synergy between genotype and environment is neither additive or multiplicative. The application of innovative methods for both genotype and lifestyle variables should be emphasized.**

Aim of study: Investigate variable data of lifestyle factors in obese people with genetic predisposition and without in order to figure out the trigger risks which transform the predisposition into obesity.

Material and methods: This is a descriptive study. A questionnaire was elaborated. It was developed based on the data of new biotechnological analysis of metabolic changes in obese humans. 142 individuals were included. 82 obese individuals, 42 with genetic predisposition and 40 without, and 60 healthy probands were interviewed. Further followed a comparative statistical analysis. Results: Obese probands were found with higher levels of disability compare those without, cardiovascular events higher compared with healthy probnads, disability level and smoking habits had significantly correlation in obese with genetic predisposition. On the other hand, health probands were found in higher level of anxiety compared obese people with genetic predisposition. Conclusions: All the lifestyle aspects which lead to an increased central nervous overactivity disturb significantly the metabolism and are critical risk factors for people with genetic predisposition relate to the pathogenesis of obesity. that might lead to high disability level associated comorbid states and high risk of cardiovascular events.

Keywords*— *obesity, genetic predispositions, genetic variants, lifestyle, metabolism, risk factors, biotechnology.

I. INTRODUCTION

Obesity results from a combination of environmental and genetic factors. Twin and adoption studies provide the most compelling evidence of a genetic component to obesity [1]. In studies that measured body fat content (either as body mass index [BMI] or skinfold thickness), the comparison of obesity in monozygotic twins with obesity in dizygotic twins revealed heritability quotients ranging from 0.40 to 0.98 (where 0 = no inheritance and 1.0 = complete inheritance of the trait). Although the environments shared by monozygotic twins are more comparable than those shared by dizygotic twins, there is no difference in the heritability of BMI between identical twins raised together and those raised apart. Adoption studies have also shown that obesity has a hereditary component. These findings imply that the genetic transmission of obesity is about equivalent to the nongenetic transmission [2]. Genetic segregation investigations in extended families indicate that 30% to 50% of the obesity phenotype is inherited, and there is evidence for a significant recessive gene or genes with an allele frequency of 0.30. A number of candidate genes for obesity have been found, and the significance of some of these genes has been verified in mice created with human DNA[3]. In the last 20 years, several methodologies have been used to identify genetic determinants of obesity, including severe obesity studies, genome-wide linkage studies, candidate gene analysis, and genome-wide association studies (GWAS). Since 2005, GWAS has helped us understand the genetic causes of obesity. The National Human Genome Research Institute GWAS collection lists 50 locus. The FTO gene has the highest influence on obesity risk to date; each extra risk allele in FTO is linked with a 1- to 1.5-kg rise in body weight and a 20% to 30% increase in obesity risk [4]. The hereditary causes of obesity may be categorized into three categories. First, genes encoding proteins that regulate food intake at the level of the hypothalamus, such as centrally produced molecules, such as proopiomelanocortin [POMC]-derived alpha-melanocyte-stimulating hormone, which signals via the melanocortin-4 receptor [MC4R], or peripheral molecules, such as leptin, ghrelin and peptide YY [PYY]3–36, appear to influence obesity [5]. In obesity phenotypes linked with relative hyperphagia, defects at this level are likely to prevail. These people may have rapid weight loss in response to calorie restriction and may benefit most from appetite-suppressing drugs. Genetic variation in several genes that regulate preadipocyte differentiation (e.g., peroxisome proliferator-activated receptor-gamma [PPAR]), triglyceride synthesis (e.g., diacylglycerol acyltransferase [DGAT]-1) and lipolytic potential (e.g., beta-adrenergic receptors and perilipin) have been associated with a predisposition to obesity [6]. genes that affect mitochondrial biogenesis and/or adaptive thermogenesis may influence the tendency to acquire or lose weight and may serve as therapeutic targets in obese individuals who are resistant to weight reduction [7].

II. MATERIAL AND METHODS

In order to collect data regarding the studied topics, questioners were collected from subjects by me and my colleagues in a convenient form of sampling. The questioners contained 25 items. Item number one asked about age. Number two asked about gender. Number three asked about smoking habits in terms of pack years. Item number 4 asked about height and weight from which BMI score calculation could be obtained. Item number 5 asked about level of disability from a scale of 1 to 10 in which 1 stands for no disability and 10 for severe disability. Item number 6 asked weather suffering from diagnosed chronic illness. Item 7 asked whether there is a medication which is prescribed under regular base. Item number 8 asked about balanced diet or weather some of the main group such as proteins, carbohydrates, lipids or vitamins are missing. Item number 9 asked about the possibility to eat a decent warm meal during work or not. Item number 10 asked about hours of physical exercise each week. Item number 11 asked about two or more relative who is suffering from the condition, when 2 or more relative suffering from the condition, were assumed to be genetically predisposed. Item 12 asked about level of satisfaction from health from a scale of 1 to 5 where 1 stand for low level satisfaction, and 5 for high level of satisfaction. Item number 13 asked whether a subject is going for a walk after dinner. Item 14 asked whether subject is watching tv after dinner or not. Item 15 asked whether there is a stressful event that led to weight gain. Item number 16 asked about number of cardiovascular events that subjects has been through. Item number 17 asked whether your work is causing you stress or not. Item number 18 was an open question and asked about ways and practices taken by the subject in order to relief stress. Item number 19 asked about alcohol consumption in doses per week. Item number 20 asked weather there is an endocranial disorder, and if so, which hormone does it involve. Item number 21 asked about number of meals

Group Statistics

	obesity	N	Mean	Std. Deviation	Std. Error Mean
number_of_cardiovascular_events	healthy_probands	60	.3833	1.12131	.14476
	obese	82	1.9756	2.90158	.32043

eaten each day. Item number 22 asked about quantity of water per glass that the subject drink every day. Item number 23 asked about number of sweet drinks that subject drink each day. Item 24 asked for number or glasses of coffee and with or without sugar. Item number 25 asked about number of steps that the subject is walking each day.

III. RESULTS AND DISCUSSION

On independed t test, obese people were found with a higher number of cardiovascular events than healthy probands ($p<0.01$). the mean of cardiovascular events in healthy probands was 0.3 and was 1.9 on obese subjects (Fig.1)

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means							
						Significance				95% Confidence Interval of the Difference	
		F	Sig.	t	df	One-Sided p	Two-Sided p	Mean Difference	Std. Error Difference	Lower	Upper
number_of_cardiovascular_events	Equal variances assumed	11.048	<.001	-4.033	140	<.001	<.001	-1.59228	.39482	-2.37285	-.81170
	Equal variances not assumed			-4.529	111.086	<.001	<.001	-1.59228	.35161	-2.28901	-.89555

Figure 1. Obese people compared to healthy probands in cardiovascular events count.

Obese individual was also found with higher level of disability ($p<0.01$) than healthy probands (Fig.2).

Group Statistics

	obesity	N	Mean	Std. Deviation	Std. Error Mean
Disability_Level	healthy_probands	60	2.0500	1.58836	.20506
	obese	82	8.0000	2.84583	.31427

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means							
						Significance				95% Confidence Interval of the Difference	
		F	Sig.	t	df	One-Sided p	Two-Sided p	Mean Difference	Std. Error Difference	Lower	Upper
Disability_Level	Equal variances assumed	13.982	<.001	-14.607	140	<.001	<.001	-5.95000	.40734	-6.75533	-5.14467
	Equal variances not assumed			-15.856	131.843	<.001	<.001	-5.95000	.37525	-6.69229	-5.20771

Figure 2. Obese individuals compared to healthy probands in level of disability

Among obese individials that were with genetic predespostion a negative correlation($r=-0.3$) was found between level of physical activity and level of disablilty. That corrolation was not found in obese subjects without genetic predisposition (Fig.3)

Correlations

genetic_predesposition			Disability_Level	PHYSICAL_ACTIVITY
without	Disability_Level	Pearson Correlation	1	-.152
		Sig. (2-tailed)		.574
		N	16	16
	PHYSICAL_ACTIVITY	Pearson Correlation	-.152	1
		Sig. (2-tailed)	.574	
		N	16	16
with	Disability_Level	Pearson Correlation	1	-.357**
		Sig. (2-tailed)		.003
		N	66	66
	PHYSICAL_ACTIVITY	Pearson Correlation	-.357**	1
		Sig. (2-tailed)	.003	
		N	66	66

**. Correlation is significant at the 0.01 level (2-tailed).

Fig.3 correlation between physical activity and level of disability in obese subjects with genetic predisposition and without.

In obese subjects with genetic predisposition a significance correlation ($p<0.01$) with a positive coefficient($r=0.4$). this correlation was not found among obese subjects without genetic predisposition (Fig.4)

Correlations

genetic_predesposition			number_of_cardiovascular_events	ALCOHOL_CONSUMPTION
without	number_of_cardiovascular_events	Pearson Correlation	1	-.473
		Sig. (2-tailed)		.064
		N	16	16
	ALCOHOL_CONSUMPTION	Pearson Correlation	-.473	1
		Sig. (2-tailed)	.064	
		N	16	16
with	number_of_cardiovascular_events	Pearson Correlation	1	.400**
		Sig. (2-tailed)		<.001
		N	66	66
	ALCOHOL_CONSUMPTION	Pearson Correlation	.400**	1
		Sig. (2-tailed)	<.001	
		N	66	66

**. Correlation is significant at the 0.01 level (2-tailed).

Fig.4 The correlation between alcohol consumption and number of cardiovascular events. In obese subjects without genetic predisposition, and individual with genetic predisposition.

Pack year number was also found significantly($p<0.01$) correlated with Disability level among obese subject with genetic predisposition($r=0.4$). this correlation was not found in obese subjects without genetic predisposition (Fig.5)

Correlations

genetic_predesposition			Pack_years	Disability_level
without	Pack_years	Pearson Correlation	1	-.271
		Sig. (2-tailed)		.311
		N	16	16
	Disability_level	Pearson Correlation	-.271	1
		Sig. (2-tailed)	.311	
		N	16	16
with	Pack_years	Pearson Correlation	1	.316**
		Sig. (2-tailed)		.010
		N	66	66
	Disability_level	Pearson Correlation	.316**	1
		Sig. (2-tailed)	.010	
		N	66	66

**. Correlation is significant at the 0.01 level (2-tailed).

Fig.5 the correlation between pack year number and level of disability among obese individual with genetic predisposition and those without.

The results consistent with the based knowledge, and shows that obese individuals are found with higher level of disability and higher number of cardiovascular events. In obese people with genetic predisposition, a correlation was found between smoking habits and level of disability, suggesting these factors have even worse outcomes on this group. Physical activity level however, was found correlated with level of disability with a negative coefficient of correlation, which indicates that physical activity is even more beneficial in this group. It is important to mention that this is a correlation study and according to which we cannot conclude causality. In order to study the causality of the observed variable, a cohort study can be made in order to study the nature of the risk factors and beneficial factors in the studied population.

IV. Conclusions

1. All lifestyle aspects which had central nervous overactivity as pathophysiological background are triggers of realizing genetic predisposition into obesity.
2. New biotechnologies make possible a better understanding of genetic causality of metabolic changes.
3. Hypodynamia is a critical trigger in obesity with genetical predisposition, comparing with non-genetic obesity.
4. Physical disability and cardiovascular events were consequences met more often in those obese with genetic predisposition.

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Arousal from sleep, alertness induced by bimodal signals during "environment-person" communication

Anatolie Jacob Baciu [1,3], ORCID:
Ion Mereuta [1], ORCID:
Vasile Fedash [1], ORCID:
Lyudmila Listopadova [2,3], ORCID:
[1] Institute of Physiology and Sanocreatology, MD-2028, Academy str. 1, Chisinau, Republic of Moldova, anatolikbacio@gmail.com, https://ifs.md/
[2] Moldova State University, MD-2009, Alexei Mateevici str. 60, Chisinau, Rebublic of Moldova, https://usm.md/
[3] Transnistria State University, MD-3300, 25th Octomber str. 128, Tiraspol, Rebublic of Moldova, http://spsu.ru/

***Abstract*—An attempt to carry out a conceptual synthesis based on reviewed data and conduct experimental testing of the effects of bimodal signaling in the "environment-person" communication. It is emphasized that The environment has a very important role in the process of evolution of living beings, which, in turn, are a factor in the transformation of the environment. Bi- or multimodal signaling in the course of "environment-person" communication may be the most suitable neuromodulator and trigger of adaptive plastic remodeling in the control nerve centers. (Abstract)**

***Keywords*—environment-person; communication; arousal; alertness**

I. INTRODUCTION (HEADING 1)

The survival of the living organism to a large extent depends on the ability of the animal or human to maintain an adequate level of alertness, as well as on its ability to dynamically adjust emotional status in accordance with physiological requirements and changing environmental conditions. Wakefulness is characterized by adequate awareness of behavior, voluntary motor activity, and adequate sensitivity to environmental sensory stimuli. From the point of view of electrophysiology, the waking state is characterized by the integral activation of the cerebral cortex and the increased excitability of neurons. Despite the fact that wakefulness is often called a single state, it includes several interrelated neuropsychic components, including arousal, alertness, attention, memory, motivation, and emotions. Vigilance is determined by the general level of sensitivity of the neural centers. Often this can be measured by the degree of stimulation required to elicit a specific response. Maintaining an adequate level of arousal essential for triggering or maintaining appropriate behavioral reactions to environmental conditions that are ultimately oriented towards the regulation of homeostatic parameters.

It is extremely important that neurons of the orexinergic activating lateral hypothalamus system have central chemosensitivity. A well-known stimulator of the activity of orexinergic neurons is: the hunger hormone ghrelin, and inhibitors: leptin and glucose, which signal satiety. The focal specific sensitivity to changes in CO_2 and H^+ concentrations is also important for a sensitive response to hypoxic signals (lack of oxygen supply) from the external and internal environment [1, 2]. It is also important that the orexinergic activating system does not act alone, but as an integral part of a single complex system of regulatory chemosensitive centers: RTN (retrotrapezoid nucleus); the raphe nucleus, the caudal NTS (nucleus of the solitary tract), the locus coeruleus (LC), the caudal ventral medulla, the pre-Bötzinger complex (the pre-Bötzinger complex in the ventral respiratory center of the brainstem medulla), and the perifornical region of the lateral hypothalamus [3-9]. Along with the suprachiasmatic nucleus of the hypothalamus, the orexinergic activating center is modulated by signals of various physical modalities about the circadian cycle from the external environment. Themselves, being the drivers of the circadian rhythm, coordinate the strict internal circadian biorhythm of homeostatic processes and behavior [10-14]. Thus, the increase in hyperventilation reactions to focal acidification in the perifornical region of the lateral hypothalamus during respiratory activity during the day is more pronounced in the waking state [15, 16]. It has long been suggested that electrical impulses from the lateral region of the hypothalamus stimulate respiration. Recent evidence suggests that orexinergic neurons project directly to the respiratory centers in the brainstem. It is important that the relationship between the orexinergic center and gas exchange is bidirectional. Therefore, the activating system is important for the daily regulation of respiration and may potentially play a role in the pathophysiology and pharmacological treatment of respiratory diseases. The indirect effect on respiration is carried out through the serotonergic (5-HT-ergic) dorsal raphe nuclei and the parasympathetic autonomic nervous system. This is how vagal neimodulation and immunomodulation are performed, which is important for the prevention of dysfunction of the pulmonary branch of the vagus nerve and the pathogenesis of some chronic respiratory diseases, such as bronchial asthma and obstructive sleep apnea syndrome. Whereas, on the contrary, dysfunction of the central orexinergic system increases the severity of respiratory diseases [17-19]. Currently, the technological possibility of neuromodulation, accompanied by the immunomodulatory action of the parasympathetic autonomic nervous system, is of particular importance. Vagal neuromodulation is a promising alternative immunomodulatory prophylaxis for respiratory syndromes due to its potent systemic anti-inflammatory effects.

Various physical natural environmental factors can negatively affect cognitive function. Factors that can be considered extreme, namely heat, hypoxia, and cold, can alter a person's cognitive function due to a variety of psychological and/or biological processes. It is noteworthy that acclimatization, adaptation to acceptable environmental conditions is based on a neuromodulatory effect, which can lead to impaired cognitive functions during communication. The states of activation of the cerebral cortex allow you to increase the ability to process information during communication. Whereas the activation itself may not contain specific information. Such activation states are tonic or phasic, and also relatively global or more localized. Among these states are arousal, alertness, vigilance, and attention. Sometimes these terms are not ideal to describe these states of cortical activation, as most of the terms are widely used with various associations. In general, ideal physiological markers do not exist [20].

The goal is a conceptual synthesis based on reviewed data and experimental testing of the effects of bimodal signaling during the "environment-person" communication.

II. MATERIAL AND METHOD

The Experimental models for studying the influence of the environment on neuronal and neuromuscular plasticity are urgently needed under both physiological conditions and developing pathology. At the same time, initial standardization in laboratory animal models is accompanied by parallel interpolation of data on the human body. The use of experimental models on laboratory animals allows us to fundamentally argue the revealed mechanisms of the relationship between the organism and the environment and to expand our understanding of the neuromodulatory effects of its factors, characterized by adaptive plastic remodeling of nerve centers and neuromuscular junctions. However, the "positive" effects on brain plasticity in response to an enriched and stimulating environment have only recently been investigated. An enriched environment (EE) can be simulated in rodents by placing mice in larger cages equipped with toys and nesting material to encourage sensory stimulation and wheel running to promote voluntary physical activity.

An experimental animal model was used with the inclusion in the experiment of 3 groups of laboratory animals (mature male rats): control (n=5); hypoxic/hypercapnic environmental signal during the rest period (08:00-16:00) (n=5); auditory environmental signal during the rest period (08:00-12:00 h) (n=5).

In our experimental model, we used sexually mature laboratory animals (rats) raised in a vivarium on a standard diet with free access to water and natural light. Prior to the start of the experiment, all animals underwent surgery using a stereotaxic technique under general anaesthesia by inspiration of oxygen and isoflurane (1-3%) mixture. Animals were implanted with electrodes for electrophysiological recordings. After the postoperative recovery period, an experiment on modeling hypoxic/hypercapnic environmental signal (n=5) began, in which, using a rostral mask equipped with a corrugated hose and a tap, breathing from the atmosphere through the mask and rebreather breathing (without exhalation into the atmosphere) with a closed tap were simulated. The combined effect of hypoxia/hypercapnia was dosed by varying the exposure of breathing with a closed tap (from 1 to 5 s). Polysomnographic 24-hour recording was carried out in experimental animals (n=5) by using of 6 electroencephalogram (EEG) channels, 1 electrooculogram (EOG) and 1 electromyogram (EMG) channel and was accompanied by video behavior monitoring. Arousals from slow-wave (delta) sleep and REM-sleep were evoked by auditory environmental signal application (natural threat vocalization of rat) of different intensities (50-60 dB). For arousal estimation the ratio of total power of delta-rhythm before and after stimulus application was calculated. Total power was determined for period of ten 3-second epochs (30 seconds). In addition, the latency of arousal, duration of slow wave recovery, and magnitude of arousal induced EEG desynchronization were manually scored "Fig. 1" and "Fig. 2".

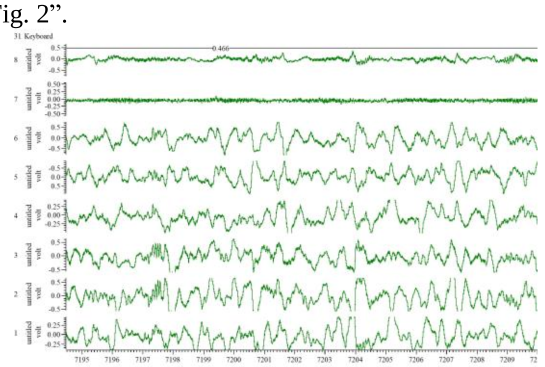

Figure 1. Appearance of electrophysiological recordings of EEG, EOG and EMG for identification of stages of sleep, awakening and alertness

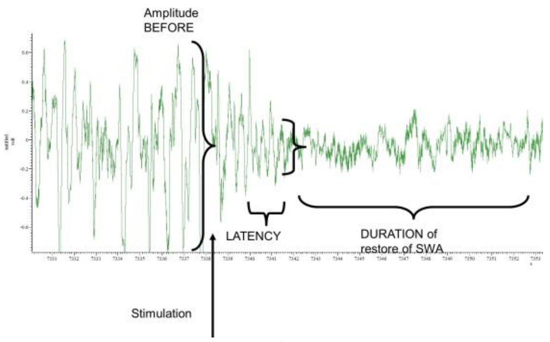

Figure 2. Maximized recording of EEG activity to measure the latent period, amplitude and duration of response to environmental bimodal signaling

Statistical analysis was realized by use of ANOVA method with Student's t-criterion utilization.

III. Result and Discussion

Conceptually, strategically, we postulate some basic provisions for favoring the environment-person communication and the modulating action of natural environmental factors of various modalities induced by it. For the formation and estimation of the common indicators of healthy/unhealthy communication regarding 1) – the presence/absence of communicability that creates a state of mutual satisfaction and 2) – the presence/absence of communicative aggressiveness that creates social discomfort, it is particularly important to understand that communication is determined not only of communication between people (interpersonal), but also of communication between people and the external environment (surrounding space). In most acts of communication, an individual (person) communicates, namely, with the external environment. For the target directed study and mental health promotion we take into account the fact that communication between the person and the environment is carried out permanently and is conditioned by evolution. Living organismal machines favorably differ from man-made machines in their abilities for self-organization, self-assembly, self-diagnosis, self-repair, structural and functional improvement. These unique advantages are determined by communication with the environment, daily activity in this environment and the success of adaptive remodeling of structures. This environment-person communication is fulfilled through the communicative channels which according to their physical nature are: visual; auditory; tactile or haptic; olfactory; biomagnetic; biochemical. It is obvious that channel identification depends on the sensory modality that ensures the perception of signals from the environment. There is already a branch of science that investigates the functioning of communication and the meaning of communicative signals, i.e. the relationships between code and message, between sign and discourse, and which is called "Semiotics". Currently, semiotics is a research technique that explains exactly how communication and meaning work. Biosemiotics represents communication, namely, between living organisms, in general. During the millions of years of evolution in the genome of living beings, all the nuances of the organism's communication with the environment were determined. We remind you that the environment, specified when necessary as the surrounding environment, the ambient environment or the natural environment, is a notion that refers to the totality of the natural conditions on Earth or in a region of it, in which beings or things evolve. These conditions include atmosphere, light, water, soil, relief, temperature, etc., as well as other living beings and things. The environment has a very important role in the process of evolution of living beings, which, in turn, are a factor in the transformation of the environment.

Anthropogenically, there was a danger of losing the close ties between the organism and the natural environment by means the creation of the artificial environment. According to the statistical analysis carried out, for example, in Canada, most people around 90% of the time during the circadian activity stay indoors at work, at home or even in the hospital. From this consideration, in particular, the interior must be arranged in a sanogenic way, i.e. naturally. In general, Canada has a social justice orientation and is a global leader in promoting the health of every citizen. The replacement of the natural environment, to which the organism's adaptation is genotypically determined, with an artificial environment causes disharmony expressed, first of all, in the changes in the higher nervous activity. Communication with the environment is carried out thanks to the reception capacities, that is, the functioning of the sensory apparatus. That's why every change in the set of communicative signals from the surrounding environment is exactly directed towards certain neural information processing centers.

The whole ensemble of communicative sensory signals is received through the prism of Security, Reproduction and Nutrition. Because of this, any threat signal leads to anxiety, fear or aggression. Conversely, the lack of threat, pacifying conditions initiates a relaxed and comforting disposition. The presence of foods with a hedonic character that brings pleasure or to the sexual partner triggers a series of sensory, affective, cognitive and somato-vegetative reactions closely related to the activity of the central activation and reward systems.

We are already developing communication laboratory experimental models that accurately model healthy and unhealthy environmental conditions.

The First Step that is strictly necessary for mental health promotion is the direct or indirect (virtual) contact of the individual with Living Nature, the more this contact is limited, the further the mental health is far from the ideal. Unbridled urbanization and rural design characterized by an aggressive environment, the isolation and fragmentation of the natural landscape face this strict condition “Fig. 3”.

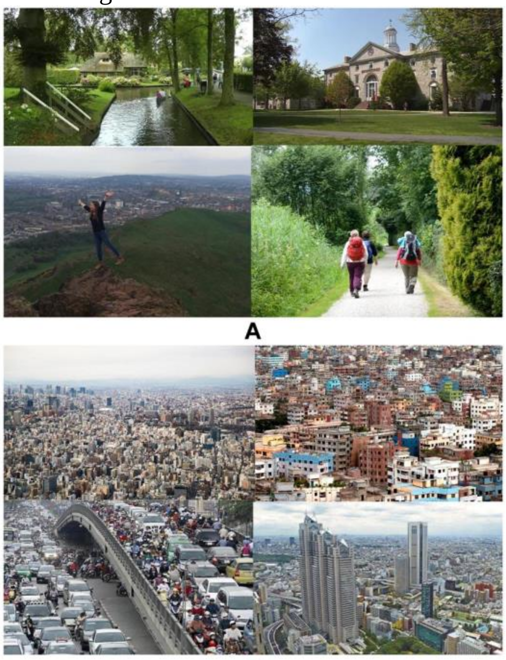

Figure 3. Comparison of the communication of individuals with the natural (A) and artificial (B) environments: A – example of a sanogenic environment (promotion of mental health and harmony); B – example of dissanogenic environment (causing mental disorders).

The Second Step consists in the absence of threats to destroy the body or the environment. Otherwise, anxiety, depression or a host of disorders related to exaggerated aggression develop. An individual who has been brought up and constantly communicates with the psychologically dissonant environment can represent a danger to civil society. We do not have the bioethical and social right to carry out a social experiment as a result of which a psychopath develops.

For application in practical The Health Creation Program we propose tests based on natural or virtual immersion of the individuals in the modeled environment and synchronous recording of the psycho-somatic and/or psycho-vegetative reactivity that expresses through the language of the face (facial muscles activity) and body language (gesture), as well as through fluctuations in the activity of the breathing systems and blood circulation. Such experiments were carried out by the imitation of the sanogenic and dissanogenic environment accompanied by the psychosomatic reactions recordings. We applied a method of estimation through video monitoring of individual psychomotor reactions to the experimental simulation of threatening, gratifying and neutral environmental conditions. Imitation of the flow of communicative signaling with a negative, positive and neutral content was achieved by applying the video presentation.

Obtained data of experimental testing manifest that arousal during deep slow wave (delta) sleep, and REM-sleep is symmetrical and more pronounced, but arousal is regionally different, i.e. asymmetrical, during superficial slow wave (delta) sleep “Fig. 4”.

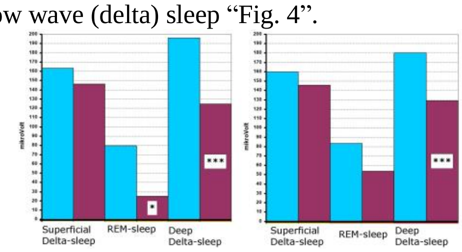

Figure 4. Average amplitude of the delta range of EEG-activity at different stages of sleep during arousal hyperventilation due to hypoxic/hypercapnic environmental signaling

The expression of EEG-arousal is characterized by the decrease in frontal-parietal-occipital direction. It is for interest that arousal threshold is higher during REM-sleep in comparison with superficial and even deep slow wave (delta) sleep in the same hemisphere. Latency shows lengthening, but the duration of alertness, on the contrary, is reduced during deep slow wave sleep “Fig. 5”.

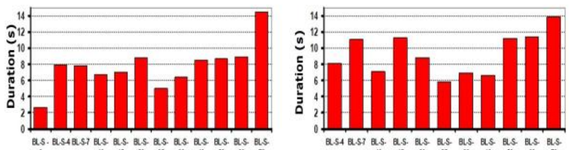

Figure 5. The duration of arousal and the state of alertness after the application of environmental auditory signaling until the restoration of delta waves in the EEG (in dependence on signal intensity).

These findings suggest that sensory inhibition is more pronounced during REM-sleep and deep slow wave sleep.

IV. CONCLUSION

Bi- or multimodal signaling in the course of "environment-person" communication may be the most suitable neuromodulator and trigger of adaptive plastic remodeling in the control nerve centers.

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Recent Biotechnological Approach to Genetically Determined Atrial Fibrillation

Erez Arad [1], ORCID: 0000-0003-0126-9880
Lital Haim [1], ORCID: 0000-0002-2864-5455
Guy Attia [1], ORCID: 0000-0003-2383-5505
Ilan Davidov [1], ORCID: 0000-0002-5725-5827
Ludmila Sidorenko [1], ORCID: 0000-0003-0382-4542
[1] Nicolae Testemitsanu State University of Medicine and Pharmacy Chisinau, the Republic of Moldova
*Corresponding author: erezarad4@gmail.com

***Abstract*—Background. The most prevalent persistent arrhythmia in cardiology is atrial fibrillation. Former atrial fibrillation which appears without any underlying reason was called „lone atrial fibrillation“. Due to new biotechnological methods in electrophysiology, like mapping, unusual conducting mechanisms were stabilized. Due to new biotechnological methods of DNA analysis recently the reason is detected. This is a genetically determined atrial fibrillation. The aim of this study is to analyse what are the most common mutations which lead to atrial fibrillation. Material and methods. This is a systematic review study. The sources of information which were analysed are mostly from google scholar and web of science. From 2000 sources, several sources were filtered out by the keywords and remained 14 sources on which is based this review study. Results. More than 70 genes are recently detected which lead to atrial fibrillations. Majority of them are mutations of the genes which encode the transport proteins of the heart's conductive system. The most common mutations that lead to genetically determined atrial fibrillation occure in KCNQ1, KCNA5 and 6q14–16. Conclusions. Before starting treatment of lone atrial fibrillation, a genetical test should be done in order to stabilize the type of the underlying mutation. This is a tactical step in taking the decision on treatment strategy by antiarrhythmic drugs or ablation. So ablatogenoics is the best solution for patients with genetically determined atrial fibrillation.**

Keywords: Atrial Fibrillation, genetic predisposition, gene mutation, ablatogenomics, biotechnological tools.

I. INTRODUCTION

The most prevalent persistent arrhythmia in cardiology is atrial fibrillation affects approximately six million individuals within European Union [1]. According to the "Worldwide Epidemiology of Atrial Fibrillation: Global Burden of Disease" research from 2013, 33.5 million individuals worldwide, or around 0.5 percent of the world's population have atrial fibrillation. 25% of persons over the age of 40 will have the illness at some point in their lives, and it is linked to significant morbidity and a roughly doubled death rate [2]. Although the impact of structural heart determinants on the arrhythmogenesis of atrial fibrillation is well defined [3], it's important to know the circumstances that lead to atrial fibrillation in individuals who don't have any obvious structural heart abnormalities, this is the so-called was called „lone atrial fibrillation [4]. Wolff reported a family of three brothers with atrial fibrillation in one of the first studies of an inherited type of atrial fibrillation published in 1936. The first gene mutation related with familial atrial fibrillation was identified in the KCNQ1 gene, which codes for the Kv7.1 potassium channel that mediates the slow rectifying potassium current [5]. Other ion channel genes involved in atrial fibrillation include the sodium channel encoding gene SCN5A. In a Japanese family with autosomal dominant familial atrial fibrillation, for example, an unique gain-of-function mutation in SCN5A (M1875T) was found [5]. 5% of the unselected atrial fibrillation population has SCN5A mutations, with a greater incidence in younger cohorts. Also related with atrial fibrillation are single-nucleotide polymorphisms encoding sodium channels (SCN family) [5, 6]. Intriguingly, a loss-of-function mutation in the potassium voltage-gated channel, shaker-related subfamily member 5 (KCNA5) affected tyrosine kinase regulation, indicating that malfunctioning ion channels are not the only cause of cardiac electrophysiological disturbances [5]. Later investigations found additional genetic loci linked to atrial fibrillation at 6q14–16, 5p13, 10p11–q21, 20q12–13, and 5p15 [6]. The first gain of function mutation (KCNQ1) in the potassium voltage-gated channel in the afflicted Chinese family was described by Chen et al. in 2003. The candidate gene study, however, was expensive, time-consuming, and limited to a few selected scanning genes. Additionally, since potassium channel genes contain more than 30 distinct variations, the causation impact hypothesis of these variants remained unclear [6]. It is important to determine what type of gene mutation causes the atrial fibrillation. The reason is that individuals with genetically determined atrial fibrillation do not react in an expected way to antiarrhytmic drugs, even vice versa, by proarhhythmic effect [7]. This is dangerously as the consequences are hard to predict if no information about the type of mutation. The aim of this study is to analyse what are the most common mutations which lead to atrial fibrillation.

II. ATRIAL FIBRILLATION CAUSED BY GENE MUTATION

A. Potassium Channel Mutations

Several mutations in potassium channel subunits have been linked to uncommon types of atrial fibrillation [7]. Several mutations in potassium channel subunits have been linked to uncommon types of atrial fibrillation [8]. In addition to having a role in the various stages of repolarization, the various potassium channel subtypes expressed on cardiac cells are crucial for maintaining resting membrane potential [9]. Potassium channels are made of subunits that constitute the pore as well as several additional partner proteins, including accessory subunits. Two to six transmembrane domains arranged as dimers and tetramers comprise the entire channel's subunits [8]. IKs, the delayedrectifier potassium current, is one of the earliest ion channel mutations that have been investigated [5]. Gainoffunction mutations in both subunits boost potassium repolarizing currents mechanistically. This shortens the action potential duration and effective refractory period in cardiomyocytes, producing a substrate for profibrillation in the atria [9].

B. Mutations Involving the Rapidly Repolarizing Potassium Current

The potassium voltagegated channel subfamily H member 2 (KCNH2) gene encoding the subunit of the voltagegated potassium channel Kv11.1, which causes the quickly repolarizing potassium current [9, 10]. KCNH2 gene mutations are associated with a greater risk of atrial fibrillation. In a family with short QT syndrome and atrial fibrillation, a mutation in the KCNH2 gene causing in a gain of function of the rapidly repolarizing potassium channel was also identified [7]. This gainoffunction mutation causes a reduction in APD length [9]. Atrial fibrillation has also been related to a mutation in the KCNH2 gene that results in a lack of function [11].

III. BASIS OF THE HEART'S ELECTRICAL CONDUCTION SYSTEM

At the point where the superior vena cava enters the right atrium, pacemaker cells of the SA node depolarize spontaneously to provide electrical impulses that begin regular cardiac rhythm [3]. Then, the signals are sent to the AV node in the posteroinferior area of the interatrial septum. The AV node retards the transmission of the electrical signal to the ventricles, allowing for the optimum fill of the ventricles. The signal then propagates via the left and right bundles of His, followed by the left and right ventricular Purkinje fibers [12]. These signals are subsequently carried through the membranes of cardiac myocytes. The movement of sodium, calcium, and potassium ions significantly affects the cardiac action potential[3, 8]. Every phase of the action potential is caused by a significant ionic current. Through adherens junctions and desmosomes, intercalated disks among myocytes provide celltocell adhesion and bind the cytoskeletal structures to the cell membrane [13]. M oreover, they coordinate the movement of ions and tiny molecules across cells through other proteins. 5 Ion transfer is crucial to the propagation of the action potential [13].

IV. TREATMENT STRATEGY

A. Rate Control

A In general, a resting heart rate of up to 80 beats per minute and an exercise heart rate of up to 115 beats per minute are appropriate targets for ventricular rate management in atrial fibrillation [3]. Mobile telemetry is advised for objectively assessing atrial fibrillation - heart failure patients [2, 3]. Traditionally, beta-blockers have been used to moderate heart rate, especially in patients with heart failure, unless they are rapidly decompensated, and they are effective either alone or in conjunction with other medications in the majority of patients [2]. Particularly with exercise, rate control may be a tough objective to attain in actual clinical practice. No pharmacological class is universally successful, and combination therapy or other treatments are necessary to ease symptoms [4]. Current recommendations prescribe beta-blockers strongly for people with HFrEF (class I, level of evidence A) [10]. Rate control is the use of negatively chronotropic medicines or electrophysiological/surgical techniques to lower the often fast ventricular rate in atrial fibrillation patients [11].

B. Rhythm Control

A strategy of rate control alone may not be enough to treat atrial fibrillation-mediated cardiomyopathy or chronic symptoms [11]. Rhythm regulation, whether done pharmacologically, with electrical cardioversion, or catheter ablation, has been demonstrated to improve LV dysfunction and have a positive influence on survival and quality of life [12]. The goal of the rate control technique is to solely lower ventricular rates brought on by atrial fibrillation [11]. The CAFÉ-II trial found evidence that rhythm control is associated with better quality of life (p=0.020) and LV function (p=0.014) in heart failure patients, despite the restricted number of participants [12]. The biggest effect was noticed in patients who maintained sinus rhythm for one year. Compared to amiodarone alone, adjunctive treatment with cardioversion and amiodarone restored and maintained sinus rhythm at 1 year with a higher success rate (80% v/s 66%) [12, 13].

V. Biotechnological advances in Electrophysiology for identifying the conductive abnormality in atrial fibrillation

In order to comprehend this complicated arrhythmia, the electrophysiology of atrial fibrillation has remained a profound enigma [6]. Despite substantial investigation, the pathophysiological causes of atrial fibrillation are complicated and frequently remain unexplained [2, 10]. Therefore, the application of fundamental scientific information to clinical practice is difficult [2]. After more than two decades, pulmonary vein isolation remains the primary ablation technique for preserving sinus rhythm [12, 13]. There is little question, however, that in many instances, particularly in chronic and long-standing persistent atrial fibrillation, ablation by pulmonary vein isolation is insufficient, and the final restoration of SR requires further intervention in the remainder of the atrial myocardium [4, 12]. Substrate mapping is a contemporary problem because it might uncover focused sources of rotational activity that may be responsible for the maintenance of atrial fibrillation. It is uncertain if these regions are the true source of the atrial fibrillation maintenance. If this is the case, then focused ablation may be the best option [10]; alternatively, more invasive procedures, such as atrial compartmentalization, may be more helpful. Catheter ablation for atrial fibrillation is an invasive technique that is successful at restoring normal rhythm, but it fails in up to 40% of patients receiving their first surgery and bears the risk of major side outcomes [3, 10]. Recent research indicates that a common genetic mutation on chromosome 4q25 may be a robust predictor of procedural success, underlining the promise of a "ablatogenomic" method [8, 13].

Conclusions

1. New biotechnological methods of DNA analysis made possible to detect that gene mutations are the reason of „lone atrial fibrillation“.
2. The most common mutations that lead to genetically determined atrial fibrillation occure in KCNQ1, KCNA5 and 6q14–16.
3. Before starting treatment of lone atrial fibrillation, a genetical test should be done in order to stabilize the type of the underlying mutation.
4. Gene analysis to determine the type of mutation is a tactical step in taking the decision on treatment strategy by antiarrhytmic drugs or ablation.
5. Ablatogenomics is the best solution for patients with genetically determined atrial fibrillation.

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Biotechnological Tools in Genetics for Primary Prophylaxis of Essential Arterial Hypertension

Ilan Davidov [1], ORCID: 0000-0002-5725-5827
Roee Levinberg [1], ORCID: 0000-0001-9854-410X
Guy Attia [1], ORCID: 0000-0003-2383-5505
Erez Arad [1], ORCID: 0000-0003-0126-9880
Ludmila Sidorenko [1], ORCID: 0000-0003-0382-4542
[1]Nicolae Testemitsanu State University of Medicine and Pharmacy Chisinau, the Republic of Moldova,
ilandavidov11@gmail.com

***Abstract*— hypertension is one of the most spread cardiological diseases, due to recent biotechnological tools it is discovered that arterial hypertension is a polygenic disease. Another possible explanation might be the variety of the studied populations. The current results of genetic analyses of essential hypertension highlight the need for a more differentiated approach to the understanding of complex, polygenetic traits that implements gene-gene- and gene-environment interactions or differentiated functional testing of thoroughly phenotyped cohorts under standardised environmental conditions. The advancement of molecular genetics now permits the establishment of a connection between high blood pressure and certain traits. The aim of this work is to analyse how genetic testing for primary prophylaxis of arterial hypertension can be applied.**

Keywords—hypertension; gene mutation; polygenic; epigenetics; biotechnology

I. Introduction

Hypertension, or high blood pressure, is a dangerous medical condition that raises the risk of heart, brain, kidney, and other ailments dramatically. [1] In Western nations, arterial hypertension is one of the primary cardiovascular risk factors [2]. Globally, an estimated 1.28 billion persons aged 30-79 have hypertension, with the majority [two-thirds] residing in low- and middle-income nations [3]. Genetic testing for example pcr screening, dna sequencing methods, Southern blot is already an option to identify of appearance of arterial hypertension and treat this before it appears [4]. In this illness, essential hypertension is the most prevalent diagnosis, indicating that a single cause has not been found. Nonetheless, other risk factors for EH have been discovered, including age, gender, demographic, environmental, genetic, and vascular variables [5] Arterial hypertension is genetically complicated, which explains why the discovery of the underlying genes for hypertension has been less effective than for other disorders [6]. Significant advances have been made in the area as a result of genetic analysis of well-defined endocrine types of hypertension in which classification of individuals into homogenous cohorts is achievable [7]. The aim is to analyse how genetic testing for primary prophylaxis of arterial hypertension can be applied.

II. Material and Methods

This is a systematic review study. It represents the results of anlysis of 200 surces wich were selected according to the key words in web of science and google scholar. After filtering out remained 10 sources.

Atrial hypertension

Systemic Hypertension is elevated blood pressure in the systemic arteries, which deliver blood from the heart to the tissues of the body. Usually, the constriction of the tiny arteries causes high systemic blood pressure[2]. This increases peripheral blood flow resistance, which in turn increases the heart's workload and arterial pressure.It is measured at its peak and lowest points. Normal systolic blood pressure varies with age, but a maximum normal adult reading is around 140 mm Hg. Around 90 mm Hg is the top range for normal diastolic blood pressure. [3] Pulse Pressure refers to the difference between systolic and diastolic blood pressure. In 95% of instances, the etiology of primary systemic hypertension is unknown. Secondary hypertension is systemic hypertension that is caused by another aliment or disease. The advancement of molecular genetics has made it possible to now demonstrate a connection between high blood pressure and certain traits. [2]

Gene mutation that lead to hypertension

The identification of susceptibility genes involved in multifactorial hypertension is based on linkage and gene association studies, which aim to establish a significant association between a specific chromosomal region or allelic variant and the disease and are based on the hypothesis of "common disease–common variant"[4]. This hypothesis begins with the premise that the major susceptibility alleles can be identified in all patients with the same condition. Families of patients underwent chain tests on the idea that patients would carry a particular allele [of a candidate gene] more frequently than healthy family members [5]. Association studies are conducted in a population to compare the incidence of a particular gene polymorphism with its incidence in a control group;[6] if a specific allele of the polymorphic locus is significantly more prevalent in diseased individuals than in unaffected individuals, then the allele is assumed to be involved in the pathogenesis of the disease. Several gene variations that confer vulnerability to hypertension were found during the "pregenomic" period, including genes. [5]encoding different components of the renin–angiotensin system, ion channels, and enzymes involved in the manufacture of aldosterone. Following items were identified: the ADD1 gene [-bringing, hydrostatic pressure change sensor, located on chromosome 4p16]; the AGT gene [for angiotensinogen, located on chromosome 1q42-q43]; the REN gene (for renin, located on chromosome 1q32]; the ACE gene [for the angiotensin converting enzyme, located on chromosome 17q23[; the AT1R gene (for the angiotensin receptor. [3]

Primary prophylaxis

It is possible to prevent hypertension by using measures that target both the general public and individuals and groups at a greater risk for developing high blood pressure [2]. Lifestyle treatments are more likely to be effective, and absolute reductions in the risk of hypertension are likely to be larger, when focused at older individuals and those with a higher risk of developing hypertension, compared to younger individuals or those with a lower risk. However, early life preventive methods have the greatest long term promise for preventing the precursors that lead to hypertension and increased blood pressure levels and for minimizing the total burden of blood pressure-related diseases on the population.[8]

Genetic approach

- Arterial hypertension is presently the leading cause of worldwide mortality and illness burden, with a substantial link between high blood pressure and cardiovascular disease. Therefore, a greater knowledge of the genetic basis of a polygenic illness, such as hypertension, might bring antihypertensive treatment one step closer to achieving the suggested therapeutic targets[7]. Individual risk and prognosis stratifications based on the identification of particular genetic variations may also benefit from the use of a genetic profile. A targeted genetic analysis for hypertensive patients would enable the identification of disease-causing genes and the precise characterization of genomic regions associated with arterial hypertension. The study of genetic variations has progressed in the direction of pharmacogenomics, the study of genomic variation that affects individual reactions to medication [5, 8]. This idea is important for clarifying antihypertensive pharmacological therapeutic activities and for comprehending why some patients react to regular therapy while others do not. [9]Different metabolic profiles and genetic variations of metabolizing enzymes, the genetic variability of sodium sensitivity, and proteins from renal tubules [responsible for the regulation of ion transport or variability of response to diuretics] appear to be associated with the genetic individual variability of antihypertensive treatment response[7]. The Genome Wide Association Study (GWAS) has been an important tool for uncovering the genetic implications of essential arterial hypertension from this perspective. A GWAS allows for the broad-scale typing of a significant number of Single Nucleotide Polymorphisms (SNP), and in the context of major consortia, several research were published that led to the discovery of more than 100 SNPs associated with high blood pressure. [4] the mutotion in the foloowinh genes wich are importat for the develompent of arterial hypertension were discovered- systolic BP ATP2B1, CYP17A1, PLEKHA7, SH2B3 (Levy et al., 2009), Diastolic BP ATP2B1, CACNB2, CSK-ULK3, SH2B3, TBX3-TBX5, ULK4 (Levy et al., 2009), Systolic or diastolic BP CYP17A1, CYP1A2, FGF5, SH2B3, MTHFR, c10orf107, PLCD3 (Newton-Cheh et al., 2009), Pulse pressure CHIC2/PDGFRA, PIK3CG, NOV, ADAMTS8 (Wain et al., 2011), Mean arterial pressure CHIC2/PDGFRA, PIK3CG, NOV, ADAMTS8 (Wain et al., 2011)

Biotechnological tools for genetic screening of arterial hypertension

Therefore, a greater knowledge of the genetic basis of a polygenic illness, such as hypertension, might bring antihypertensive treatment one step closer to achieving the suggested therapeutic targets. Individual risk and prognosis stratifications based on the identification of particular genetic variations may also benefit from the use of a genetic profile. [9] A targeted genetic analysis for hypertensive patients would enable the identification of disease-causing genes and the precise characterization of genomic regions associated with arterial hypertension. The study of genetic variations has progressed in the direction of pharmacogenomics, the study of genomic variation that affects individual reactions to medication. This idea is important for clarifying antihypertensive pharmacological therapeutic activities and for comprehending why some patients react to regular therapy while others do not.[8] Different metabolic profiles and genetic variations of metabolizing enzymes, the genetic variability of sodium sensitivity, and proteins from renal tubules seem to be associated with the genetic individual variability in response to antihypertensive therapy (responsible for the regulation of ion transport or variability of response to diuretics) [5,6]

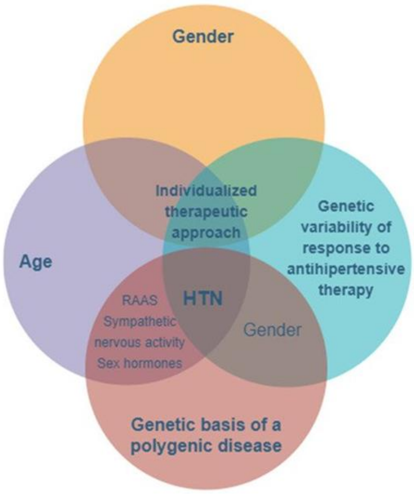

Figure 1. The main features and key factors for personalizing treatment in hypertension., https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8229802/#B6-pharmaceutics-13-00856

III. *Conclusions*

1. A complicated interaction of genetic, epigenetic, and environmental variables causes essential arterial hypertension.
2. New biotechnologies permit genetic screening of genetic variants leading to essential arterial hypertension to ensure its primary prophylaxis in relatives predisposed to this disease.
3. Application of genetic testing is important for personalized medicine and may enhance the design of randomized controlled trials.

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Information support of the processes of diagnosis and surgical treatment of chronic subdural hematoma of the brain

Anatolii Balabanov [1], ORCID: 0000-0001-7618-5708
Anatolie Gumeniuc [2], ORCID: 0000-0003-3321-9191
Rostislav Călin [1], ORCID: 0000-0002-2672-1717
[1]Technical University of Moldova, anatolii.balabanov@ati.utm.md, rostislav.calin@isa.utm.md, https://fcim.utm.md/en/home/
[2] Institute of Neurology and Neurosurgery of the RM, gumeniuc.anatolie6@gmail.com

***Abstract* - The study relates to the field of automation and information support of the processes of diagnostics and surgical treatment in neurosurgery. On the basis of complex software (BCS), computing and information systems of local corporate information networks of neurosurgical clinics are used, the initial data of standardized diagnostic protocols for clinical and instrumental studies of the brain of neurosurgical patients are formed. The data necessary for modeling are obtained after performing computed tomography (CT) and / or Magnetic Resonance Imaging (MRI), converting an image of the DICOM-PACS (Digital Imaging and Communications in Medicine) format on the network or from standard media (CD-R, CD-RW , USB flash drives, etc.) to build a real-time 3D model of the current state of the operated chronic subdural hematoma of the brain(CSDH), directly during its surgical treatment, based on the current 3D model of the real object of treatment**

Keywords— information technologies in medicine, 3D models, animation, control algorithms, real-time 3D hematoma model, subdural brain hematoma

I. Introduction

OBJECTIVE: The 3D model of the CSDH of the human brain is a three-dimensional digital image of the target object in the surgical field, both real and for virtual analysis. Typically, the creation of 3D models takes place in the environments of special software for 3D modeling, the functionality of which may differ slightly and specifically.

There are already programs focused on the design of 3D engineering models, there is software designed for modeling internal organic objects, as well as popular software applications for 3D visualization and animation. There is no strict classification of software for 3D modeling in this medical field, but most practical applications contain certain special functions aimed at performing specific local tasks in Neurosurgery

3D modeling is the process of creating a three-dimensional digital image of the required research object. Depending on the specific goals, the requirements for 3D modeling may also vary. So, for example, in the development of computer games, the well-known, which have already become standard, laws for constructing 3D models are used, which, however, may not be useful when creating 3D models for subsequent 3D printing.

MATERIAL AND METODS :We note here that from the point of view of mathematics, the surface of a 3D model is a set of geometric shapes - triangles or rectangles, the combination of which forms the necessary object.To build a model, a separate subroutine is created that will process already marked images selected from a CT scan of the patient's brain. Its task is to generate a 3D model of an object in vtk (Visualization Toolkit) format so that you can work with it later.

II. Reading data to create a 3D brain hematoma model based on CT and/or MRI images

It is necessary to create an algorithm and a program to determine, based on the initial data, Fig.1, the labeled part of the CT image, Fig.2. For this operation, the Python library cv2 is used. OpenCV is an open source library of computer vision, image processing and general purpose numerical algorithms.

This library allows you to define the contours of the marked part and represent them as a polygon. The logic is that all unlabeled parts are removed and the **Python algorithm** contour finding is applied.

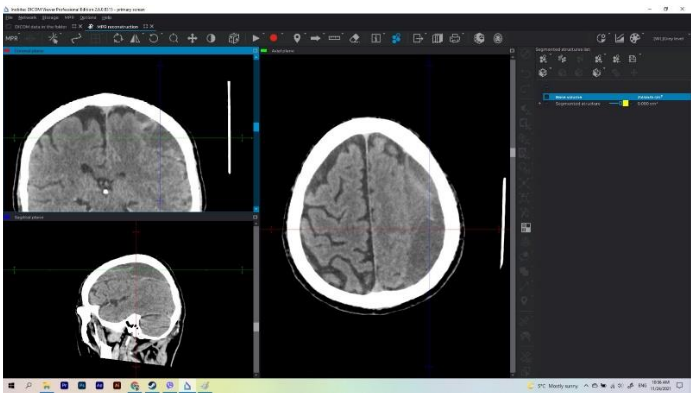

Fig.1. Primary image of a CSDH of the human brain obtained using standard medical technology based on a 256-slice CT

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Figure 2b shows the CT image after removing the unlabeled part of the original CT image. The image is programmatically desaturated, which is required by the algorithm for finding contours. Figure 2c shows a graph drawn using the matplotlib library. The graph is an open contour of the hematoma (in the form of points, not a solid line!). Initially, it appears upside down - this is a side effect of the algorithm, which is eliminated later

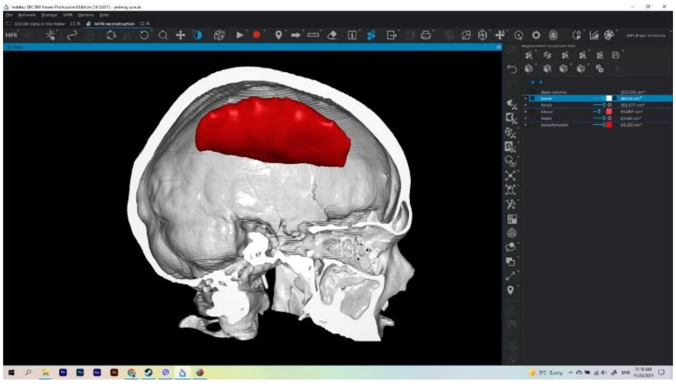


Fig.2.a. Representation of a labeled CSDH of the human brain in sagittal section (lateral view)

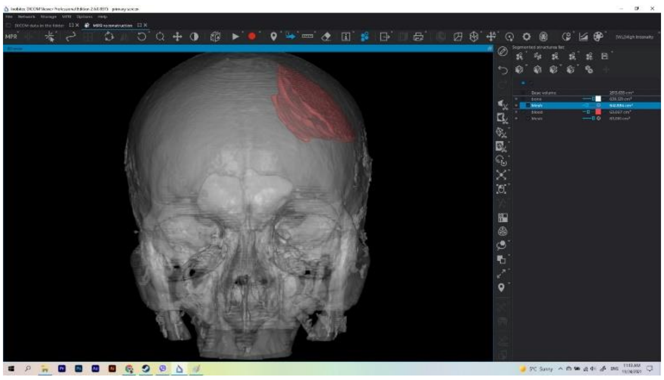
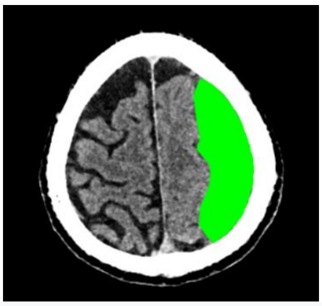
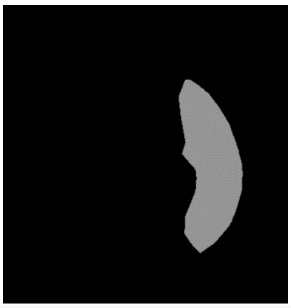


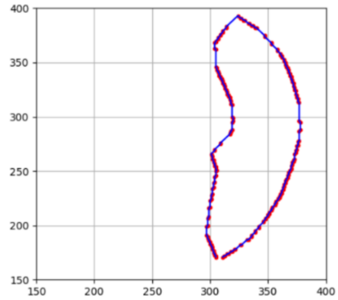
Fig.2.b. Representation of a labeled CSDH of the human brain in the frontal plane (front view)



(a)Original image
CSDH of the human brain
(coronal section)



(b)PC image,
obtained after cleaning



(c) polygon plot

Fig.3.a.b.c. Stages of obtaining contours of a hematoma (marked part)

Figure 3.b shows the CT image after removing the unlabeled part of the original CT image. The image is programmatically desaturated, which is required by the algorithm for finding contours. Figure 3.c shows a graph drawn using the matplotlib library. The graph is an open contour of the hematoma (in the form of points, not a solid line!). Initially, it appears upside down - this is a side effect of the algorithm, which is eliminated later. The vertices of the polygon are shown in red, and the sides in blue.

The polygon is stored as an array of vertex coordinates, and in the same form is used in the next stage of data transformation. These operations are carried out with all CT images marked at the previous stage.

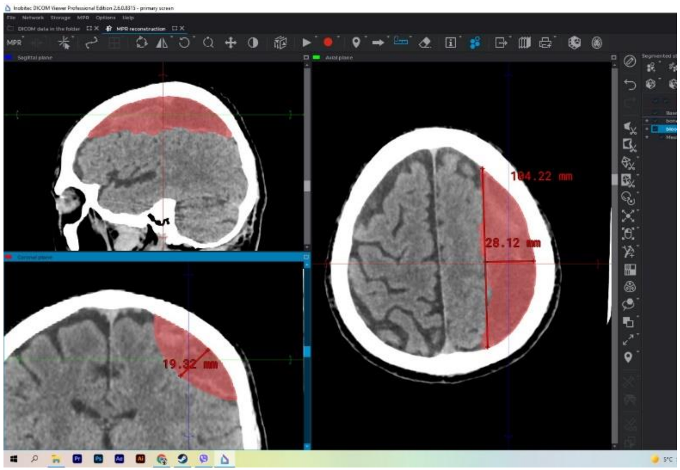


Fig.4. Image of chronic subdural hematoma in 3 planes (highlighted with a computer program)

II.Construction of a preliminary (rough) 3D model of a CSDH

Having a set of vertices that describe the shape of a hematoma, you can start creating its 3D model. To do this, it is necessary to connect the vertices of the contours located on adjacent layers of CT images. This can be done in a simple way, fig.5.a.b.c.d.

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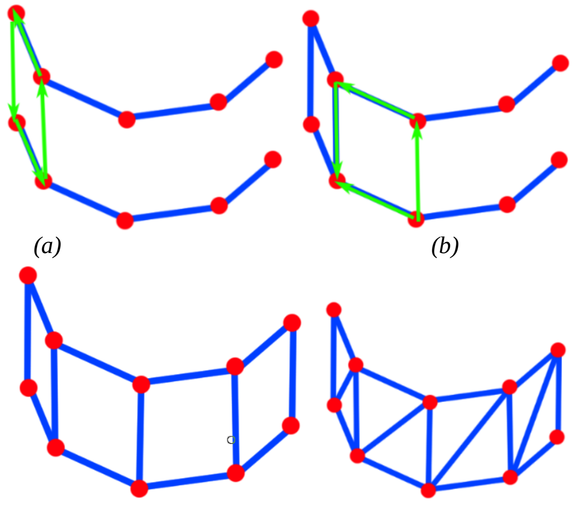


Figure 5. Steps for joining the vertices of neighboring image layers in a 3D model: (a) a demonstration of how two polygons of adjacent layers will be connected; (b) a stage in which two vertices are already connected; (c) stage with completed connectionvertices of polygons; (d) triangulated view of the resulting two-layer model.

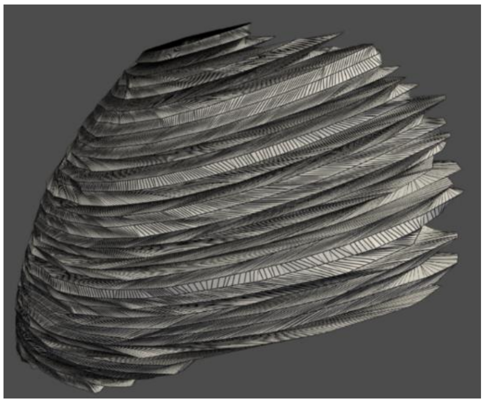
Fig. 5 graphically shows the algorithm of how a 3D hematoma model is assembled from the contours of individual images (layers). In this case, each step is achieved by connecting 4 vertices that define one quadrangular polygon. When connecting, it is necessary to take into account the sequence, as shown in Fig. 3,(a and b) with green vertical arrows. After carrying out a series of such steps, we obtain figure 3, c, which we can already work with. But to work with programming tools, it is necessary to bring the model to a triangulated form, that is, to divide each quadrangular polygon into two triangular polygons, Fig. 3 c.

However, already at step (a) a problem arises: it is possible that it will not be possible to connect all the vertices of the polygons, since each polygon has a different number of vertices. To solve this problem, you can add to each polygon such a number of vertices that all polygons have an equal number of them. This can be done using the following algorithm:

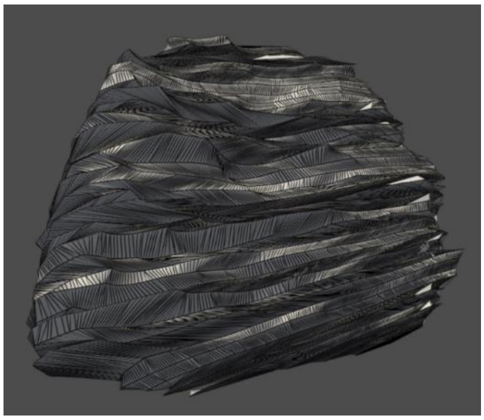
1. The polygon with the largest number of vertices is determined.

2. For each polygon, a vertex is added to the area between the outermost vertices until their number equals the number of vertices in the largest polygon.

Now, having polygons with equal vertex counts, you can connect their respective vertices.



a) front view;



(b) rear view;

(c) approximate (enlarged) section of the model

Fig. 6. a.b.c. Received 3D model

On Fig. 6 shows the resulting hematoma model. It can be seen that the surface of the model has a rather chaotic relief, which is far from ideal. The main reason lies in the lack of the algorithm itself, which has just been described. Although the polygons of each layer of the 3D model received the missing vertices, the pointer to the "first" vertex of the polygon has shifted. Because of this, you can observe the texture of the object shown in Fig. 3, (c). It seems that the vertices of the polygons are not connected

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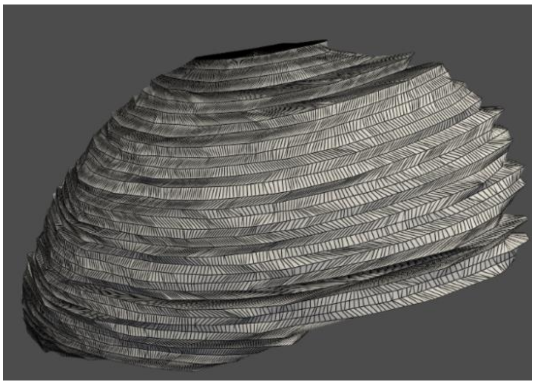
in the most successful way. Additional smoothing algorithms are needed to improve the quality of the model.

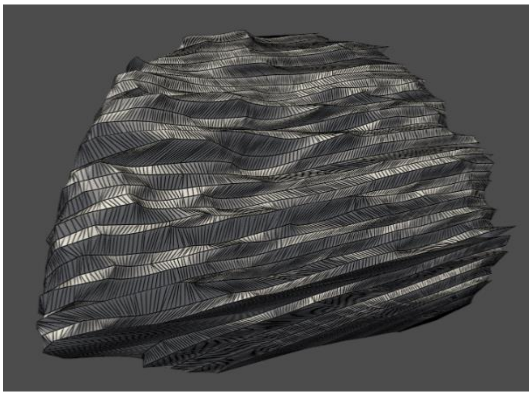
III. SMOOTHING THE 3D HEMATOMA MODEL

Above, a hematoma model was obtained, but its quality does not allow any useful actions to be carried out with it. The model needs to be smoothed. Looking at the image shown in Figure 3, (b) you can see that if you move the pointers to the vertices of one polygon, it will be more successful to connect it to another polygon. Then the shift algorithm will look like this:

1. Calculate the arithmetic mean of the slopes of each line formed by connecting the corresponding two vertices from the next and previous layers of the polygon arrangement.
2. Move the pointers left and right up to a certain amount until the arithmetic mean of the slopes of the lines between the current and next polygon is as close as possible to the slope calculated in step 1.
3. Again apply the algorithm from the previous paragraph and build a model.



(a) front view

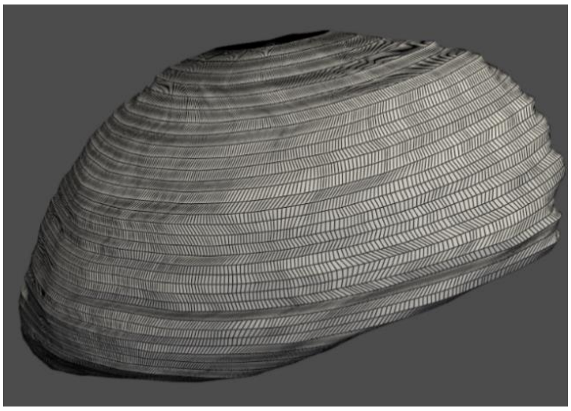


(b) back view

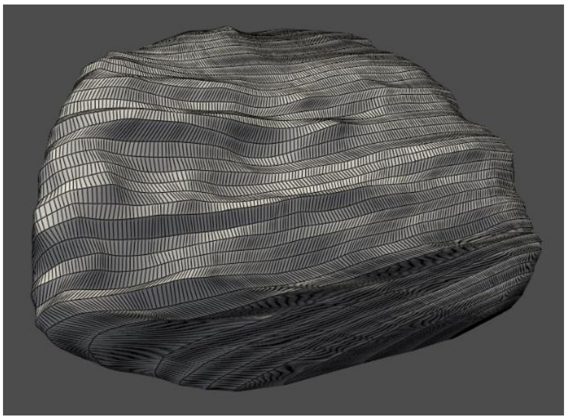
Fig. 7. The resulting 3D model after vertex shifts

Fig. 7 shows a model of a hematoma after shifts of the vertices. It can be seen that it is already better suited for analysis, but some problem areas still remain. It is quite difficult to solve such a problem by means of ordinary mathematics, so it is necessary to use a combination of algorithms to smooth these Fig. 7 shows a model of a hematoma after shifts of the vertices. It can be seen that it is already better suited for analysis, but some problem areas still remain. It is quite difficult to solve such a problem by means of ordinary mathematics, so it is necessary to use a combination of algorithms to smooth these areas.

At this stage, you can use the pyvista library. PyVista (formerly vtki) is a Visualization Toolkit (VTK) helper module that uses a method other than the VTK interface via NumPy and direct array access. This package provides a well-documented Pythonic interface that can render a powerful VTK render server to facilitate rapid prototyping, analysis, and visualization integration of spatial reference datasets.



(a) front view



(b) back view

Fig. 8. The resulting 3D model, after shifts and application Laplace smoothing algorithm

ou can use the pyvista library function - smooth. This function implements the Laplace smoothing algorithm. This iterative algorithm can help solve the current problem, but with a large number of iterations, the model will be smoothed with unacceptable distortion, tending to become spherical and losing useful information about the model. For our problem, it was decided to perform 150 iterations by the trial method.

After applying the smoothing algorithm, we obtain the model shown in Fig. 5. As you can see, the model turned out with a smoother relief. Theoretically, this model is already suitable for analysis, but two problems arise. First, such a model may still contain problem areas, the presence of which does not guarantee

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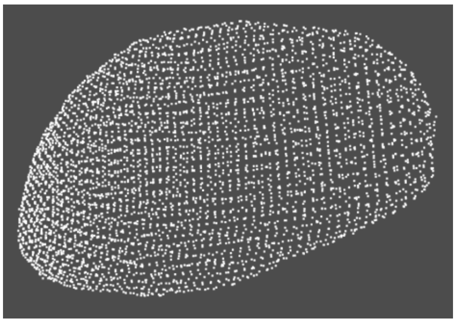
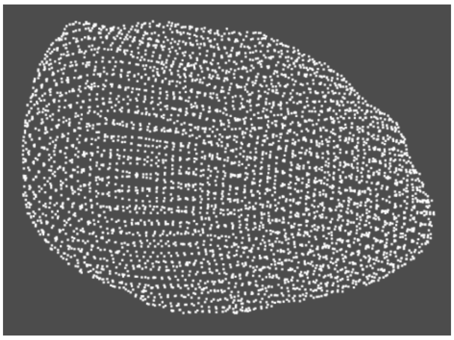
the correct analysis of the object. The second problem is the huge number of vertices, which makes the analysis process long, measured in hours. In some areas, such as the upper and lower poles of the model, the vertex density can be thinned out, thereby reducing the analysis time.



(a) front view

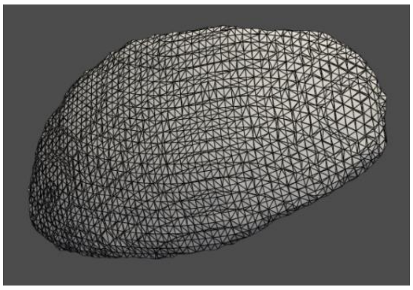


(b) back view

Fig.9. Model represented as a point cloud

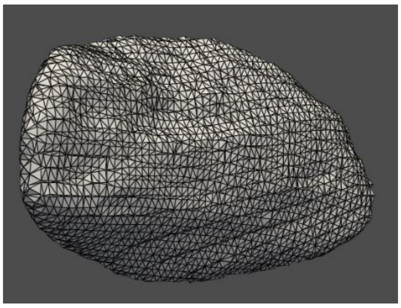
Another method for processing image data of a hematoma model is surface reconstruction of the model. In computer graphics and computer vision, 3D reconstruction is the process of obtaining the shape and appearance of real objects. The process can be performed by passive or active methods. If the shape of the model can change over time, one speaks of a non-rigid or spatio-temporal reconstruction.

The algorithm that is used here is called the "ball rotation" or alpha spheres algorithm. This algorithm is implemented using the create_from_point_ cloud_alpha_shape function of the open3d library. To use the function, you first need to generate a point cloud, which can be obtained using the sample_points_poisson_disk function, passing data about the model shown in Fig. 10. To simplify the analysis, a tenth of the points of the primary model was taken. The points are taken uniformly according to their density in space.



(a) front view

Fig. 10a. Reconstructed model using the "ball rotation" algorithm



(b) back view

Fig. 10b. Reconstructed model using the "ball rotation" algorithm

As a result, we get the HSDG model shown in Fig. 11. As expected, the polygons are evenly distributed over the surface of the model.

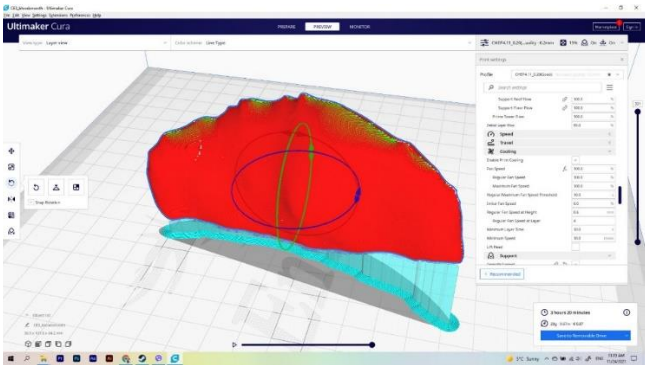


Fig.11. The final view of the rotating 3D model of the HSDG

However, like any anti-aliasing algorithm, the algorithm used neglects some of the useful information that described the more detailed topography of the model. This is not very critical, as the analysis will use the spherical part of the hematoma model surface, which is adjacent to the dura mater. This side effect can be reduced by choosing better parameters for the above functions, but this may require more effort. The resulting model is most likely suitable for analysis, which has shown its practical use in the practice of neurosurgery, which the authors will talk about in their next articles and communications.

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RESULTS: The originality of the method proposed by the authors lies in the systemic, multi-stage programmed visual information that is promptly received by the surgeon at a convenient time and at the right time, according to his desire, to support and ensure the reliability and safety of processes in the surgical treatment of CSDH, Fig. 10 and Fig. 11.

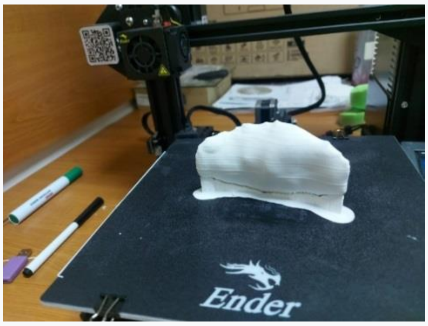

Fig. 10

Conclusions: The results of the practical use of the developed 3D model during brain surgery are very positive. An analysis of the current practice in neurosurgery and the results of scientific research indicate the need for differentiated approaches to the choice of management tactics for patients with chronic subdural hematomas, taking into account the clinical phase of the disease.

Information support in the development of pathogenetically substantiated methods of surgical and conservative treatment of hematomas, taking into account the data of a comprehensive study, will make it possible to substantiate the timing, volume and nature of the surgical intervention - the number, nature and location of inlets in emergency conditions in neurotraumatology using 3D models in real time.

Information support of Fig.10 and Fig.11 based on the original software for the formation of a 3D model facilitates a comprehensive diagnostic system, improves the safety of surgical treatment and improves the prevention of intracranial complications in patients with traumatic subtentorial chronic subdural hematomas using therapeutic and diagnostic neuroendocscopy and effective methods of rational drainage and sanitation of the postoperative cavity.

Visualization, up to 3D printing of the SHSG model, provides reliable spatial information in the form of virtual and/or spatial models. The possibilities of diagnosing chronic subdural hematomas have significantly expanded with the introduction into neurosurgical practice of such highly informative and non-invasive examination methods as computed tomography and magnetic resonance imaging, transcranial Doppler ultrasound.

Their use opens up new possibilities and perspectives in the study of chronic subdural hematomas.

(Корниенко В.Н., Васин Н.Я., Кузьменко В.А., 1987; Туркин А.М., Эль-Кади ХА., Корниенко В.Н., Becker D.P., Miller J.D., Young H.F., 1982;) and, as a continuation of this path, the technology of neurosurgical operations on the brain described in this article.

The mini invasive neurosurgical interventioncombined with information support and 3D reconstruction and printing offers a better medico-financial balance.

The use of the algorithm of measures for information support developed by the authors in the diagnosis and surgical treatment, prevention and treatment of intracranial complications in patients with traumatic CSH, depending on the nature and location of the compressive factor, favorably and expediently affects the nature of operations and the psychological climate in the medical environment.

Fig.11

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Electronics

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The Reliability to Gamma Radiation of Gas Sensors Based on Nanostructured ZnO:Eu

Cristian Lupan [1], ORCID: 0000-0003-2268-6181
Adrian Bîrnaz [1], ORCID: 0000-0002-2906-7255
Artur Buzdugan [1], ORCID: 0000-0002-9226-004X
Lukas Zimoch [2], ORCID: 0000-0002-4860-065X
Rainer Adelung [2], ORCID: 0000-0002-2617-678X
Oleg Lupan [1,2], ORCID: 0000-0002-7913-9712
[1] Center for Nanotechnology and Nanosensors, Department of Microelectronics and Biomedical Engineering, Technical University of Moldova, 168 Stefan cel Mare str., MD-2004, Chisinau, Republic of Moldova
[2] Chair for Functional Nanomaterials, Faculty of Engineering, Institute for Materials Science, Kiel University, Kaiserstr. 2, D-24143, Kiel, Germany
e-mail: cristian.lupan@mib.utm.md

***Abstract*—In this work it was investigated the reliability to ionizing radiation of Eu-doped ZnO nanostructured films functionalized with Pd. Morphological, sensorial and electrical properties of sensors were studied initially, after irradiation and after 6 months to observe the influence of irradiation.**

Keywords: gas sensors, ZnO, Eu doping, gamma irradiation, reliability.

I. INTRODUCTION

In present time, electronic devices, sensors and other devices that are used in spatial missions have requirements regarding weight, energy consumption, reliability to different types of radiation, such as ionizing radiation. To obtain reliable devices that are immune to radiations in cosmic space, new nanoscale materials have been studied in this domain. Nanomaterials are a promising source of crystalline structures for the use and research of nanoelectronics.

ZnO is one of the most important binary semiconductors in group II-VI, with a large band gap of 3.37 eV at room temperature, with *n*-type conductivity. This material has high chemical, thermal and mechanical stability, which makes it one of the most promising materials for use in different applications (fig. 1) such as solar cells, photodetectors, LED, laser systems, medicine, sensors, etc. [1-3].

There are a lot of methods to obtain ZnO, with the possibility to change its electro-optical properties by doping, which makes it an attractive and cost-efficient material for use in different domains [4,5].

Gas sensors based on ZnO are useful in the detection of dangerous gases and monitoring of air quality, which can be used in cabin crews of spaceships or for fast and reliable detection of leaks of gases on board, to avoid explosions. Sensors can also be used in the detection and analysis of existing gases in space. Technological possibilities allow the achievement of sensor systems that are selective, light and small. This allows testing instantly, monitoring of space habitats and other space objects from distance, without the need of sending probes to laboratories on Earth. Another advantage of nanosensors is their high sensitivity which allows detection of the presence of individual gas molecules or single photon. The potential self-powering of sensor systems from sources of cosmic radiation allows autonomy in use that is limited by the reliability of the used material.

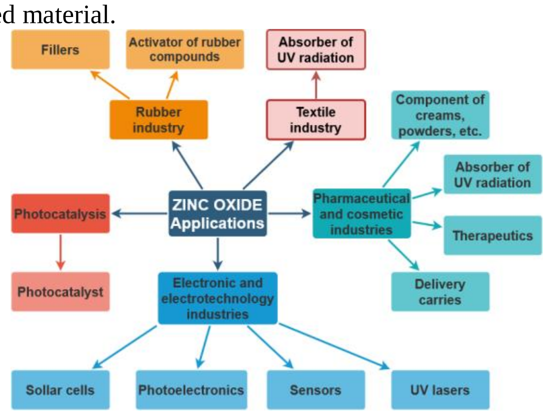

Figure 1. Domains of use of structures based on ZnO.

The main goal of this work is to test the reliability of gas sensors based on Eu-doped ZnO films. These sensors are chemical based, can be used to detect the concentration or presence of a gas [4]. Their sensing mechanism is based on the change of electrical properties of the sensor surface, by adsorption of different molecules. These reactions on the surface of the sensor lead to a change in the number of charge carriers that can move in a crystalline network of the detecting material.

II. METHOD OF OBTAINING

Eu-doped ZnO films were deposited using chemical synthesis from the solution method [4], using $ZnSO_4$ and NaOH as precursors. Different quantities of $EuCl_3$ were added to obtain different doping concentrations in layers. After deposition samples were thermal annealed in air at different temperatures (450, 550, 650 °C) for 2 hours to improve crystallinity and sensor properties. Surface functionalization of ZnO: Eu films with Pd was achieved using $PdCl_2$, to improve selectivity, and gas response and decrease the working temperature, compared to non-functionalized ZnO: Eu [4,5]. Gold contacts were deposited afterward by sputtering.

III. EXPERIMENTAL AND DISCUSSIONS

Initially, volt-ampere characteristics of ZnO: Eu functionalized with Pd samples were measured using source meter Keithley 2400 controlled through Labview software on a computer [6]. Afterward, samples were tested to a series of gases: acetone, *n*-butanol, methane, ethanol, hydrogen, ammonia and 2-propanol at a different operating temperature range from room temperature, up to 350 °C, using a homemade setup.

Irradiation of sample is done by using a Caesium 137 source. At the same time, the resistance value is measured and recorded in real-time using the Keysight U1252B digital multimeter. The measurement process takes place as follows: for 30 seconds the electrical resistance of the sample is measured without irradiation, and then the sample is irradiated for 60 seconds, after which data are collected for a further 60 seconds to observe the tendency of the sample resistance to change its value.

Eu-doped ZnO film properties have been studied between irradiations with different periods between irradiations of 1, 2, 3, and 6 months.

Variation of irradiation dose was done using attenuators of 1000, 100, and 10, positioned in the way of gamma irradiation (fig. 2). For attenuator of 1000 times, the amount of radiation absorbed is about ≈512 nGy/min, 100 times ≈6430 nGy/min and 10 times attenuator is approximately 63 μGy/min. The measurements took place at a temperature of about 20 ℃.

The same radiation debit was achieved by placing the samples at the same distance for Caesium 137 (Cs-137) source. The debit was determined using the inverse-square law.

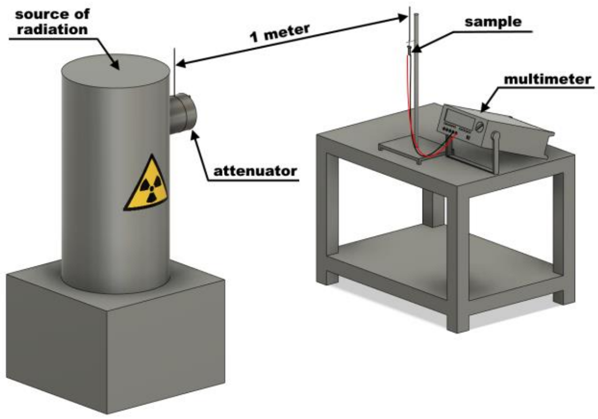

Figure 2. Schematic representation of sample measurements in gamma field

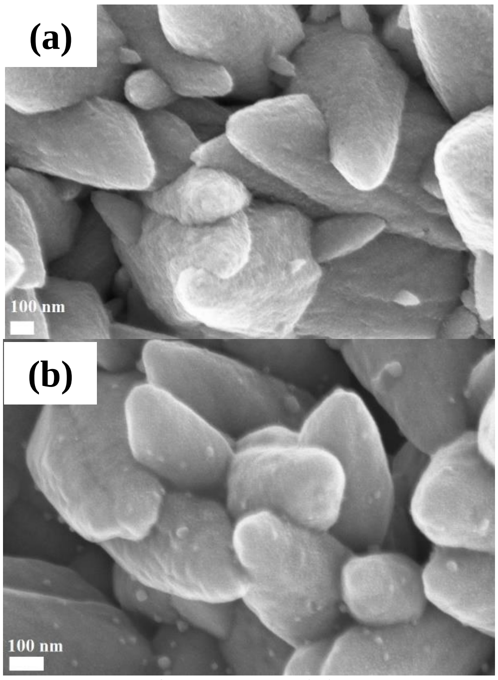

Figure 3. SEM images of thermally annealed at 550 °C Eu-doped ZnO Pd-functionalized films containing 0.2 at% Eu (Eu4 sample set).
(a) - before irradiation/initial. (b) - after first irradiation.

Morphology was studied using SEM before and after irradiation.

SEM images of ZnO: Eu films are presented in figure 3, where it was observed that nanostructures are well packed on the glass substrate, and at higher magnification, it was observed that they have columnar form and often interpenetrated.

No difference in morphology or change of form of nanostructures, because of low intensity, but a slight difference in surface roughness of the columnar structures after irradiation and different gas measurements.

The response curve of the sensor is characterized by the following five parameters (sensitivity, response time, recovery time, selectivity, and long-term stability) [8].

A high value of *S* for a particular gas indicates that the material is a very good sensor. Gas response (*S*) was determined using the ratio of electrical current measured in air and current at gas exposure as follows:

$$S = \frac{I_{gas}}{I_{air}} \quad (1)$$

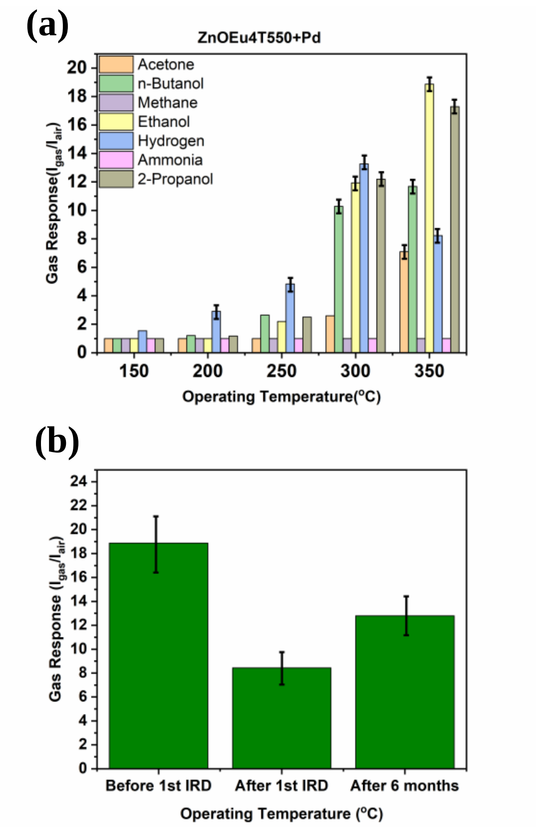

Figure 4. (a) Gas response of thermally annealed at 550 °C Eu-doped ZnO films (with 0.2 at% Eu (Eu4)) and Pd-functionalized measured to 100 ppm of different gases at different operating temperatures before irradiation; (b) Comparison of response to 100 ppm ethanol gas before first irradiation, after first irradiation and after 6 months at 350 °C operating temperature.

In figure 4 is represented the gas response before and after irradiation from a Cs-137 source of same samples, where it was observed a maximum gas response of ~19 (figure 4a), which was achieved at the operating temperature of 350 °C for 100 ppm ethanol vapor.

To study the stability of gas sensors between repeated measurements and irradiations, in Figure 4b is presented a response to 100 ppm ethanol vapor at 350 °C operating temperatures before first irradiation, after first irradiation, and after 6 months. Response value decreased after the initial gas test and after irradiation, but recovered after 6 months, with the tendency towards the initial values, with a maximum response value of ~13 at 350 °C for 100 ppm of ethanol gas. No improvement in selectivity was observed. In figure 5 is compared the dynamic gas response to 100 ppm of ethanol gas at 350 °C, where we determined gas response value (*S*), response (t_{resp}) and recovery times (t_{rec}), summarized in table 1.

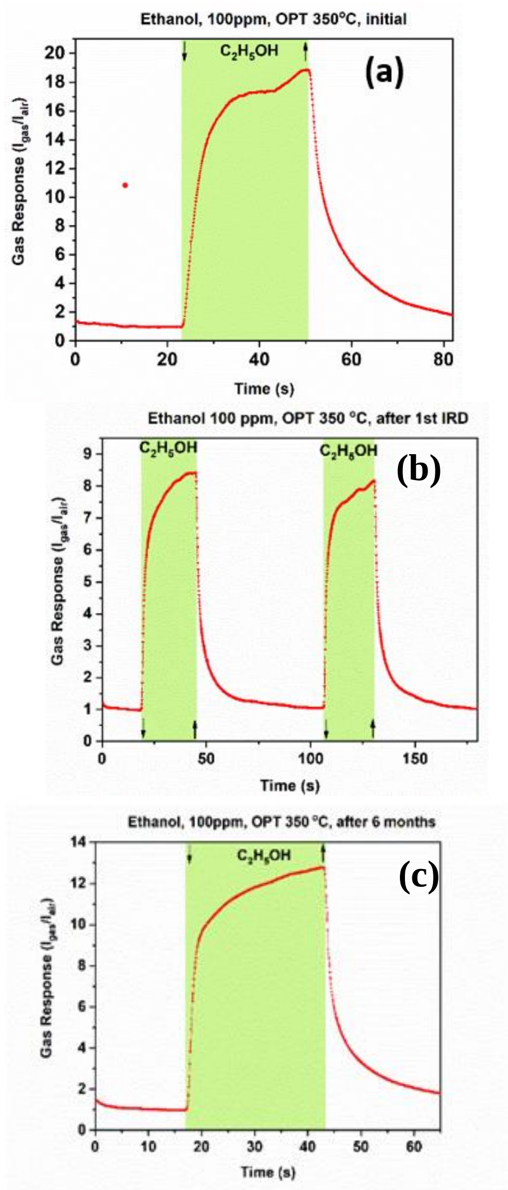

Figure 5. Dynamic response of thermally annealed at 550 °C Eu-doped ZnO films (with 0.2 at% Eu (Eu4 sample set)) and Pd-functionalized measured to 100 ppm of ethanol gas at 350°C operating temperature: (a) initial; (b) after first irradiation; (c) 6 months after first irradiation

Response time represents the time it takes for the response value to increase from 10% to 90% of the maximum response value, while the recovery time represents the time it takes for the response value to decrease from 90% to 10%, with an error rate of about ~0.5 s [7].

It was observed that the response value decreases after initial measurement for this VOC from about 18.9 down to 8.4 after first irradiation, with a slight recovery to ~12.8 after 6 months. It can be seen that sample properties are almost recovered after irradiation and this period. No correlation was found for response and recovery times between measurements, with the fastest response and recovery times of ~10 s and ~9.2 s, respectively, for the measurement after the first irradiation.

Table 1. Response value, response and recovery times for 100 ppm ethanol vapor at 350 °C

	Response value (*S*)	Response time (t_{resp})	Recovery time (t_{rec})
Initial	18.9	22.5 s	30 s
After first irradiation	8.4	10 s	9.2 s
After 6 months	12.8	11 s	15.8 s

To test the repeatability of the ZnO: Eu sensor, we applied 100 ppm ethanol gas a second time, as shown in figure 4b, where it was observed a similar response value of ~8, compared to the initial time.

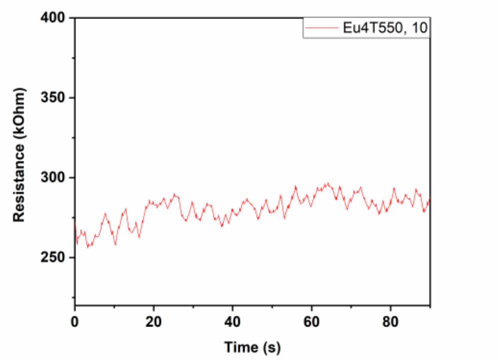

Figure 6. Variation of electrical resistance during first irradiation of thermally annealed at 550 °C Eu-doped ZnO films (with 0.2 at% Eu (Eu4 sample set)).

Measurements of electrical resistance of the samples took place during and after irradiations (figure 6) with a Cesium-137 source. A slight rise in resistance was observed for all experiments. Resistance values recover after a longer period between measurements, which can be an indication that sample properties can be recovered in time. This effect needs further theoretical and experimental investigations.

CONCLUSIONS

Morphological, electrical, and sensor properties of gas sensors based on Eu-doped ZnO columnar layers have been studied, observing the influence of irradiation under 60 seconds in gamma radiation fields. Minor changes in the surface morphology of sensors were observed between measurements. Sensors showed no selectivity to any test gas, with a maximum response of ~19 for 100 ppm ethanol vapor at 350 °C operating temperature. After the first irradiation response value to 100 ppm ethanol vapor decreased to ~8.4 at 350 °C. After repeated measurements, the sensor time response value and resistance value tend to be the initial values.

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The evaluation of the on-board computer architecture for TUMnanoSAT series of nanosatellites for carrying out missions

Viorel Bostan [1], ORCID: 0000-0002-2422-3538
Alexei Martiniuc [1], ORCID: 0000-0003-3407-3016
Nicolae Secrieru [1], ORCID: 0000-0002-9168-6049
Vladimir Vărzaru [1], ORCID: 0000-0002-5241-6265
Vladimir Melnic [1], ORCID: 0000-0003-4180-3654
Valentin Ilco [1], ORCID: 0000-0001-7210-3840
[1] Center of Space Technologies of Technical University of Moldova, Chisinau, Republic of Moldova,
viorel.bostan@adm.utm.md, alexei.martiniuc@sde.utm.md, nicolae.secrieru@cnts.utm.md,
vladimir.varzaru@cnts.utm.md, vladimir.melnic@mate.utm.md, valentin.ilco@cnts.utm.md

***Abstract*—In this paper, a brief overview of the nanosatellite on-board computer (OBC) functions will be described. The main advantages and disadvantages of the most common OBC architecture will be explained. A set of three different architecture variants for TUMnanoSAT series of CubeSat nanosatellites is proposed and described. A feature comparison is performed in order to highlight the improvements and advantages of the proposed on-board computer architecture designs over traditional CubeSat OBC architectures.**

Keywords— nanosatellite, CubeSat, on-board computer, TUMnanoSAT, microcontroller, OBC, architecture, scalability, reliability

I. INTRODUCTION

The on-board computer (OBC) is one of the key components of every satellite, including nanosatellites such as CubeSats. It is responsible for control and monitoring of all on-board subsystems, mission on-board scheduling control, detection and (whenever is possible) recovery of system errors, payload and system data logging and storage, telemetry data preparation, and in some cases, the attitude determination and control. Due to the many tasks assigned to and performed by the on-board computer, the design, testing and validation of an on-board computer module design and its software is very complex in order to develop a reliable key system component which will accomplish all those tasks flawlessly and with required performance.

Most common processor architecture used in today's on-board computer designs of CubeSat nanosatellites is ARM. This 32-bit architecture provide excellent combination of high computing performance at lower power consumption. Although the computing performance of ARM processors (of especially the ARM Cortex-M profile), is still lower than of traditional SPARC and x86 architectures, the ARM architecture is more power efficient, so for the same operation it consumes less power and dissipates less heat, while the speed performance is slightly lower. This makes ARM the architecture of choice for power and space constrained battery powered systems such as CubeSat nanosatellites (especially 1- and 2-unit configurations), where is no enough space for large and complex thermal control systems (TCS) and/or large energy storage and generators. Nevertheless, some semiconductor manufacturers have migrated some ARM based processor designs to radiation hardened/tolerant fabrication processes to leverage their power efficiency, scalability and large ecosystem in space applications.

The software running on most CubeSat platforms is developed on top of a real time operating system (RTOS). The RTOS allows to divide the entire application into separate, independent, simultaneously running threads or processes, each being responsible for a specific subsystem or task. On more demanding applications with heavy computational load, the full featured operating system such as a custom Linux distribution is used, running on a high performance single or multi-core processor with a memory management unit (MMU) for hardware accelerated virtual memory management.

The use of an operating system (real time or conventional) allows to create a modular software where a fault in a subsystem and/or its specific thread does not necessarily affect other running threads. The isolation of threads for each task and implementation of a deterministic inter-process communication with a unified interface makes the development of the entire software less prone to software errors introduced during software development stage, that may affect entire system. In addition, each process can be developed mostly independent of other processes and tasks.

In this paper the emphasis will be placed on the hardware architecture of an on-board computer for a CubeSat nanosatellite, namely the TUMnanoSAT series of nanosatellites. Several design variants will be proposed, which address different levels of complexity, reliability and performance. A comparative analysis of the feasibility of each variant also will be presented.

II. DEFINITION OF OBC ARCHITECTURE REQUIREMENTS

The CubeSat nanosatellites are in fact a high-density systems, packed in a very small form-factor. Due to increasing complexity of missions, the design and integration of all CubeSat subsystems required for successful mission deployment pose a big challenge for designers of the nanosatellite subsystems. In order to ensure the proper operation of whole nanosatellite system during entire mission duration, several design principles must be followed during overall design process:

1. Minimizing the interdependences between different modules as much as possible without compromising overall system functionality and performance;

2. Avoiding centralized control of resources by a single module;

3. Multiple redundancy of critical modules;

4. Multiple failure protection mechanisms for critical components and subsystems including fault detection, isolation and recovery (for example against unexpected power system failures, latch up);

5. Use of high reliability electronic components from verified suppliers and, if available, validated during lab testing and/or flight;

6. Implementation of design-for-test (DFT) approaches and techniques at early design stages and during entire design process.

The OBC hardware, as other nanosatellite subsystems, represents physically a module, which in turn consist of single main printed circuit board (PCB) in a derived PC104 form-factor, with or without one or several mezzanine printed circuit boards or cards mechanically and electrically attached to it. All the nanosatellite modules, including OBC are stacked vertically in order to save space. Another issue is the limited energy storage and power budget due to space limitations.

In order to satisfy both these limitations and mission requirements, the nanosatellite modules, including OBC, must be designed to satisfy the following requirements:

1. Use of a hardware computing architecture and platform that embeds integrity self-check mechanisms, error detection and correction during runtime in all data processing components (CPU/ MCU, internal and external memories, programable peripherals etc.)

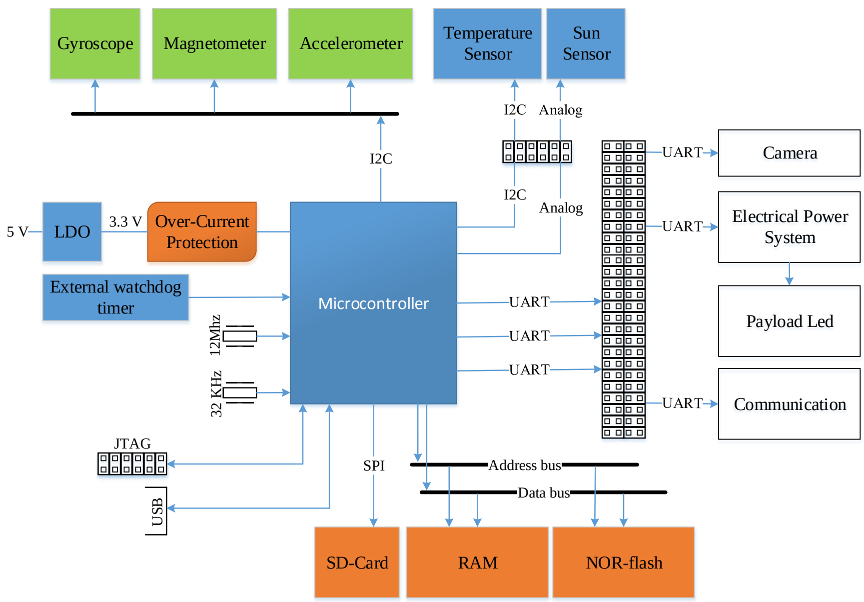

Figure 1. Common OBC structure used in CubeSat nanosatellites.

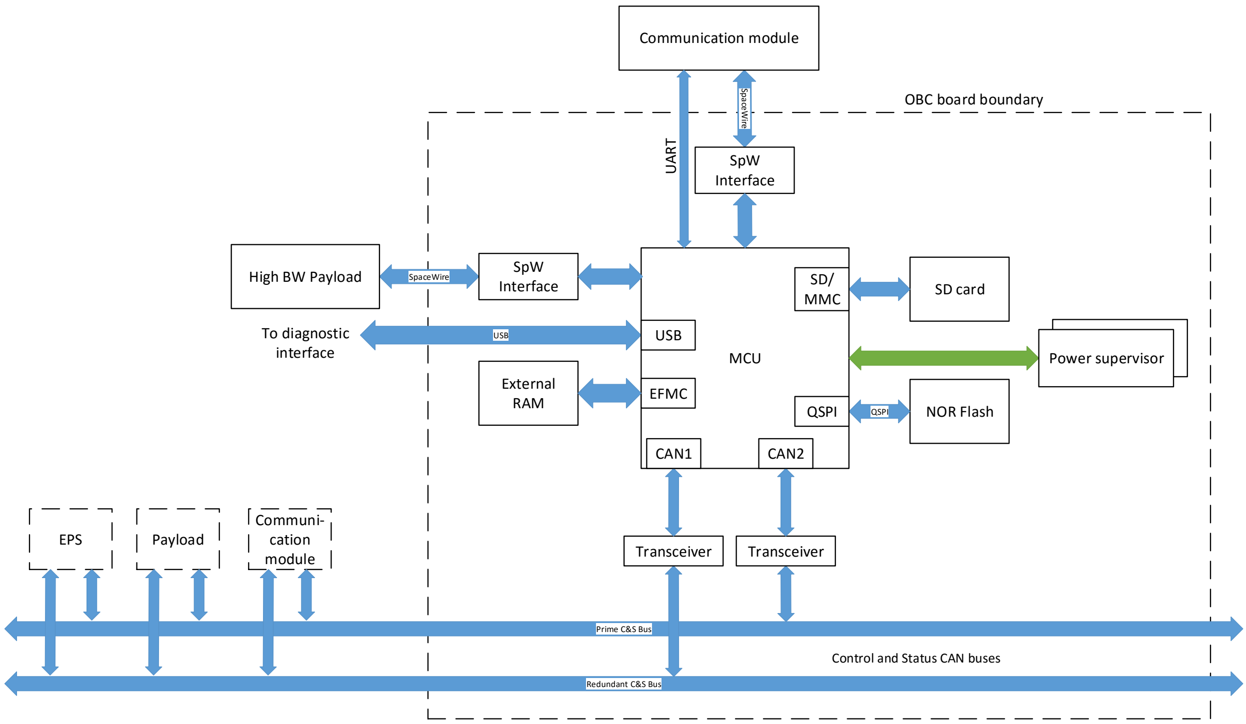

Figure 2. Basic variant of OBC architecture for TUMnanoSAT series of nanosatellites with one MCU.

2. Redundancy on critical components such power protection, control and monitoring communication interfaces, data storage units;

3. Lowest possible power consumption while maintaining required performance;

4. Use of high-density integrated circuits in high density, small packages;

5. Use of communication interfaces and protocols

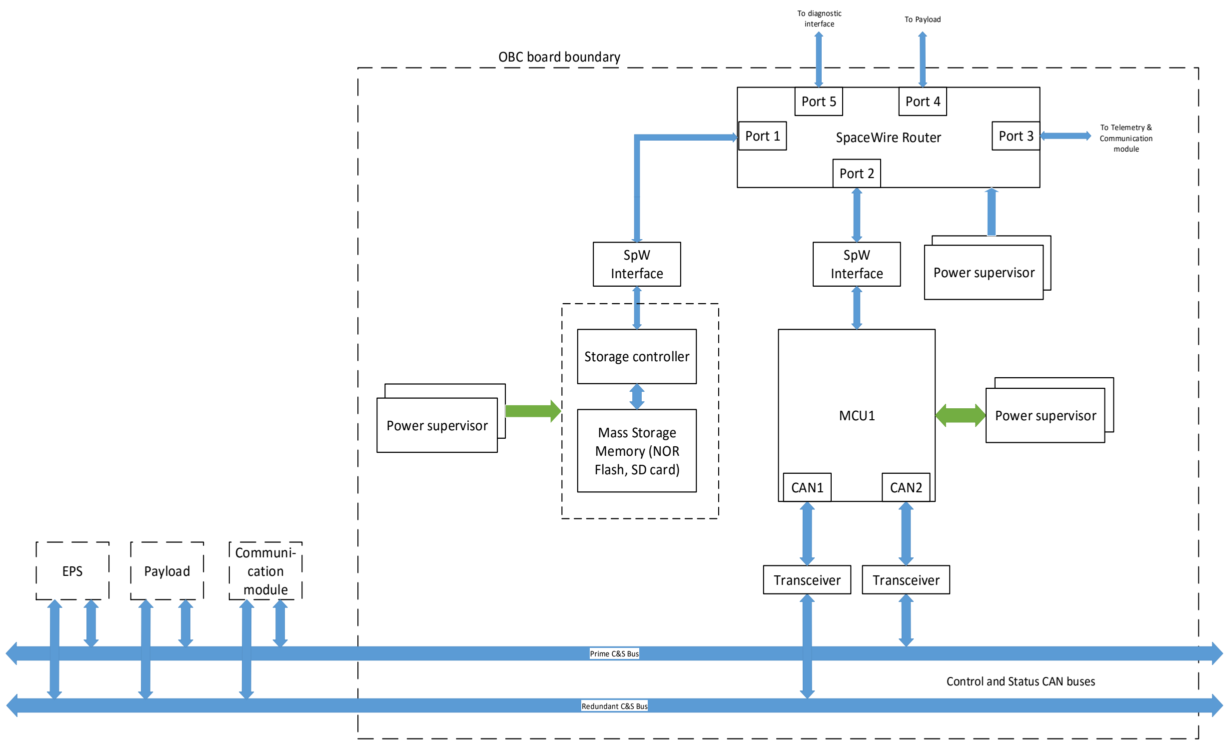

Figure 3. OBC architecture with a single MCU, a SpaceWire router and independent data storage unit.

with built-in error and fault detection and correction;

6. Performance scalability and modularity for a wide range of mission complexity.

III. PROPOSED OBC ARCHITECTURES

The basic OBC structure commonly used in educational CubeSats is shown in Figure 1. It incorporates both general OBC functionality and Attitude Determination and Control System (ADCS) on same microcontroller (MCU). For communication with other system modules, such as payloads, electrical power system (EPS) and RF communication module, it uses simple embedded interfaces and protocols such as UART, I2C and SPI, commonly used in standard embedded applications. All the electrical connections with other system modules of the satellite are routed to a PC104 header, which also serves as a backbone system bus that carries both power and shared signals from all nanosatellite modules. For debug purposes a JTAG or similar debug interface connector is also present.

The advantage of this architecture is a low cost and simple implementation. The drawbacks of this design are the centralized approach, in which the OBC microcontroller controls exclusively the access to data storage and other critical modules such as EPS and RF communication, the use of non-fault-fault-tolerant communication interfaces (SPI, I2C, UART) and the ADCS system, including the inertial data acquisition shares same CPU/MCU that has exclusive access inertial sensors. In case of failure of one communication channel or entire MCU, the system loses both OBC, data storage and ADCS functionalities. This example of a OBC design also has limited or no possibility to scale to different mission requirements because of a lack of unified standardized fault tolerant high interface which can connect multiple similar modules in a decentralized system network. Thus, this design cannot be used for future missions without partially or even fully redesigning it. Finally, it does not provide a high-speed reliable interface for high bandwidth data transfers between OBC and potentially high bandwidth data producers (for example high performance payloads such high resolution camera) or data consumers (for example high bandwidth downlink RF transmitter).

The three proposed OBC architectures for future TUMnanoSAT missions mitigate the disadvantages of the simpler common OBC design, although they are more complex. The primary goals for these designs are the improved reliability, performance, scalability and reusability. The first variant is the least complex among all three and is shown in Figure 2. It also has the lowest cost of implementation. The main distinctive features of this architecture are the use of double-redundant shared multidrop fault tolerant CAN based buses for system control and monitoring, multiple (two) high speed SpaceWire interfaces for high bandwidth data transfers up to 100 Mbps between OBC and payloads or communication subsystem, separate interfaces for commands, status and data between OBC and communication subsystem, and double-redundant power supervisors for protection against latch up and safe state backup in case of short duration power interruption. The

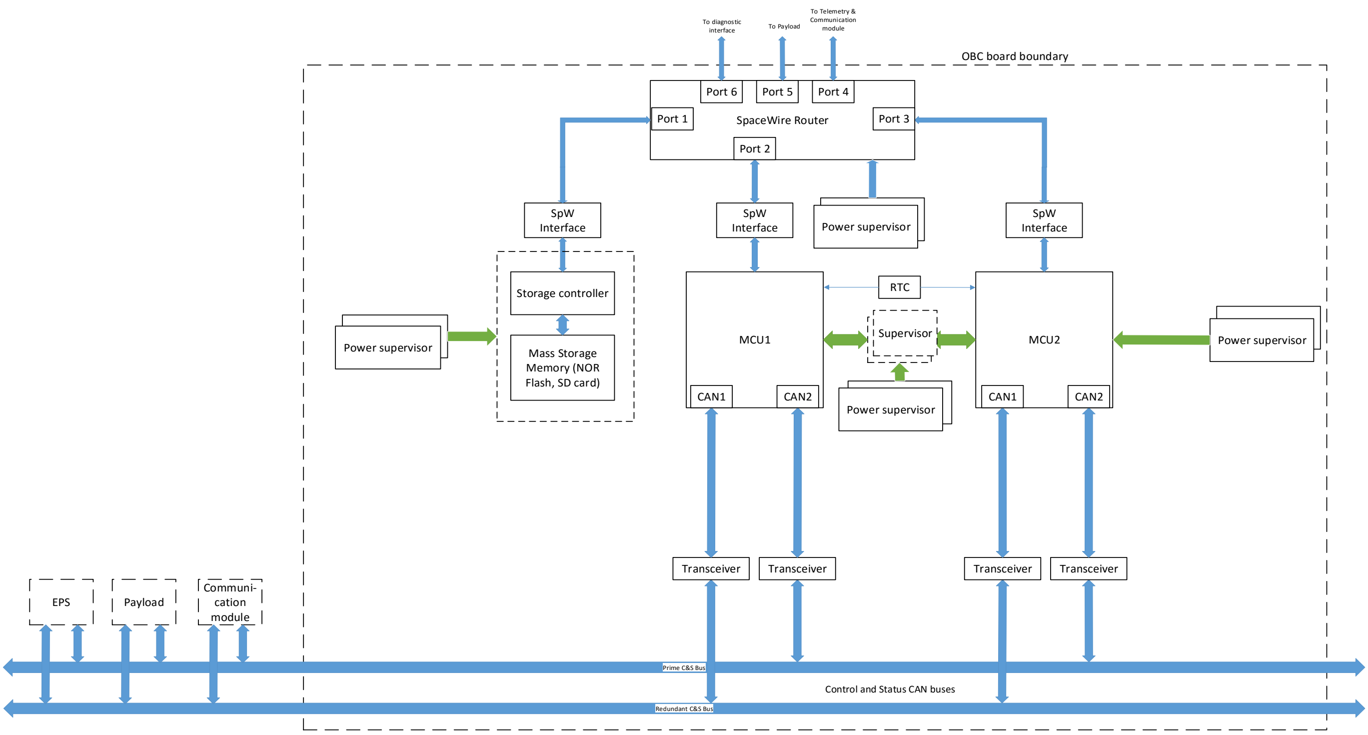

Figure 4 OBC architecture with two MCUs, a SpaceWire router and an independent data storage unit.

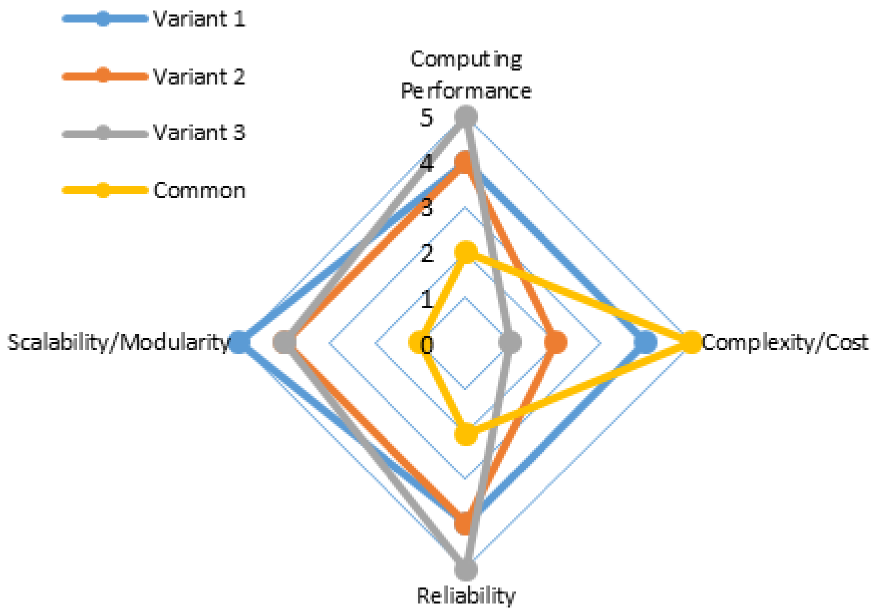

Figure 5. Comparison of features for all described OBC architectures on a scale from 1 to 5.

presence of multiple CAN control and status data exchange interfaces (which are multidrop) allows a unified standardized control interface for system monitoring, regardless of the system configuration or hardware module design. The number of modules connected to the unified control and status CAN buses is limited only by bus physical specifications. All control and status information are broadcasted on both buses and each subsystem module filters the messages and collects only the information it needs. Even if a bus is blocked by a faulty module connected to it, the secondary redundant bus can be used for data exchange. All the control commands and status information are exchanged on the bus using CAN messages, eliminating the need for separate control and status signal lines routed from one module to other via backbone connector. This allows to make the system decentralized and hence to minimize the impact of one module failure over another subsystems (except main power system). The SaceWire ports of the OBC may be connected directly to another subsystems such as payload or communication module, or via an external SpaceWire router as an auxiliary module.

The second variant, shown in Figure 3, is more complex. It inherits the features of the first variant, including the high speed SpaceWire interfaces and decentralized control and status CAN buses, and contains an integrated SpaceWire with two ports connected locally router and a data storage unit, both with their own double-redundant power supervisors. The advantages over previous variant is the possibility to access data storage independently of the main MCU/CPU of the OBC, even if the second fails to operate properly. SpaceWire router allows subsystems to communicate in a concurrent way with each other when the source and destination are different.

The third variant, shown in Figure 4 is the most complex. It inherits all the features from the first two variants and adds a redundant MCU/CPU to the OBC with a double-redundant supervisor for synchronization and monitoring the operation of both processors. The processor supervisor detects abnormal operation of one processor via dedicated signal lines and protocol, and switches the execution to secondary processor. To accomplish this, the supervisor monitors the execution address and state of the current running processor, and contains a data cache for runtime context. It is also possible to configure the MCU supervisor to enable the operation of each MCU in tandem, thus dividing the computational workload between them. In this case the supervisor’s data cache memory are used also for shared data, and the supervisor itself maintains shared data coherence between the MCUs. This mode of operation is called hot redundancy of MCUs while the mode with only one active MCU at a time is called cold redundancy of MCUs.

The comparison chart of all 4 OBC architectures described in this paper, shown in Figure 5, summarizes the advantages and disadvantages of each architecture.

From cost and complexity perspective, the common OBC architecture has the best value. However, it lacks in scalability and modularity due to absence of unified standardized data and control interfaces. Because of its centralized approach, the reliability also is relatively low compared to the architectures proposed. The performance of the common OBC architecture is moderate because there it depends greatly upon the performance of the MCU chosen.

On the other hand, all three proposed OBC architectures feature a high level of scalability, modularity and reliability, thanks to decentralized system design, multiple standardized redundant system interfaces and built-in component redundancy. However, the complexity, and hence the cost, are higher than for common OBC architecture variant. The first proposed variant is the best tradeoff between all the features used for comparative analysis. On the other hand, the best performance and reliability is possible to achieve with third variant due to hardware parallelism and computing unit redundance.

IV. CONCLUSIONS

The reliability of the nanosatellite, hence the mission success strongly depends by the intrinsic reliability of its component subsystems including the main computing unit, the on-board computer, which has a key role in maintaining the successful operation of the entire nanosatellite. Furthermore, as the nanosatellite subsystem reusability for multiple missions allows lower design, manufacturing integration costs per mission and faster mission deployment, the modularity and scalability of the OBC become a major requirement rather than an option. This can be achieved only if the key nanosatellite subsystems, and particularly the OBC, are designed at the architecture level with these features in mind. In this paper was shown that the proposed OBC architectures embed all the required features in terms of reliability, scalability and performance. Although the design and manufacturing costs per unit of these architecture variants are higher than for the common OBC architecture, the overall mission integration cost is lower and integration time is shorter due to reusability and scalability of the proposed architectures. As the TUMnanoSAT is a series of nanosatellites with different missions, one OBC variant can be used multiple times without redesigning the key module, focusing mainly on integration of missions, not the main nanosatellite hardware platform. This leads to faster mission deployment without compromising reliability.

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CuO-plate decorated ZnO nanostructures and their sensing performances

Dinu Litra [1], ORCID: 0000-0002-5603-7510
Cristian Lupan [1], ORCID: 0000-0003-2268-6181
Tudor Zadorojneac [1], ORCID: 0000-0002-4079-252X
Maxim Chiriac [1], ORCID: 0000-0003-2163-8735
Nadine Depri [2], ORCID: 0000-0002-8226-5912
Oleg Lupan [1,2,3], ORCID: 0000-0002-7913-9712
Rainer Adelung [2], ORCID: 0000-0002-2617-678X
Leonard Siebert [2], ORCID: 0000-0001-5316-7240

[1] Center for Nanotechnology and Nanosensors, Department of Microelectronics and Biomedical Engineering, Technical University of Moldova, 168 Stefan cel Mare str., MD-2004, Chisinau, Republic of Moldova,
[2] Chair for Advanced Materials, Department for Materials Science, Kiel University, Kaiserstr. 2, D-24143, Kiel, Germany,
[3] Department of Physics, University of Central Florida, Florida, Orlando, Florida 32816-2385, United States.
e-mails: lesi@tf.uni-kiel.de, oleg.lupan@mib.utm.md, ra@tf.uni-kiel.de

***Abstract* — In this paper, we report on the gas sensing properties of mixed oxide Zn-Cu nanostructures obtained by self-organized chemical deposition are presented. The nanosensors are made from individual ZnO whiskers and are coated with CuO/Cu_2O. They exhibit selectivity towards H_2 and NH_3 over other tested gases. Measurements were made in the temperature range between 20 - 175 ^oC. In order to determine the crystalline phases of the studied nanostructures, XRD diffractogram was measured, and SEM images were obtained for the morphological analysis.**

Keywords* — *gas sensor, mixed oxides, nanostructures.

I. Introduction

In recent years, the concerns about environmental pollution, medical applications as well as the need for industrial safety have increased and made it necessary to continuously monitor the level of air pollution. The use of vapor or gas sensors for detection of small quantities of hazardous substances becomes important for various aspects of modern daily life. The main task of the gas sensors is to quickly and stably indicate the presence of harmful or explosive gases to create a warning that could save lives and ensure safety.

With the intensive development of nanotechnologies, the metal-oxide semiconductor sensor becomes a very versatile and easy to manufacturing study object of research. Especially, copper oxides and zinc oxides have been abundantly studied due to their applications in catalysis, gas sensors, biosensors, batteries, solar energy conversion, temperature superconductors, etc. [1], [2]. Ammonia (NH_3) gas detection by such nanomaterials is in researchers attention, since NH_3 is a common reagent produced and used in various domains. [4]. Recently, around 20% of NH_3 has been produced for pharmaceuticals, cleaning products, explosives, and refrigeration by the Haber-Bosch process which employs the reaction between H_2 and N_2 with an Fe-based catalyst under temperatures of ~500°C [5] That's why it is important to develop sensors based on metal oxides to detect both gases, like H_2 and NH_3.

In this work we report on Zn-Cu nanostructures for integration in nanosensors for H_2 and NH_3.

II. Experimental

Synthesis of ZnO, CuO, CuO/Cu_2O and Characterization

Zinc oxide whiskers were produces as tetrapodal particles first via the flame transport synthesis. The ZnO powder was treated for one hour in a 0.1 mM solution of $CuSO_4$. Platelets of copper oxide grew in a self-organized manner with shorter reaction time leading to smaller plates. Scanning electron microscopy (SEM) was performed before and after a heat treatment of the samples at 650 °C.

III. RESULTS

Morphological characterization

Figure 1 and 2 show the SEM images of the CuO-platelet-coated ZnO, before (Fig. 1) and after (Fig. 2) the heat treatment. The coated nanowire was contacted to two gold plates serving as conductors. The connection between the nanowire and the conductor plates was done with platinum in a focus ion beam (FIB) SEM dual set-up as reported before by Lupan et al. [6].

The inside of the quasy-1D heterostructure is made of single crystalline ZnO and it is coated with nanoplates of CuO and Cu_2O, thus increasing the surface of the wire which leads to increased sensitivity. Below we can see Figure 1, which represents the SEM image of the nanowire before thermal treatment [7].

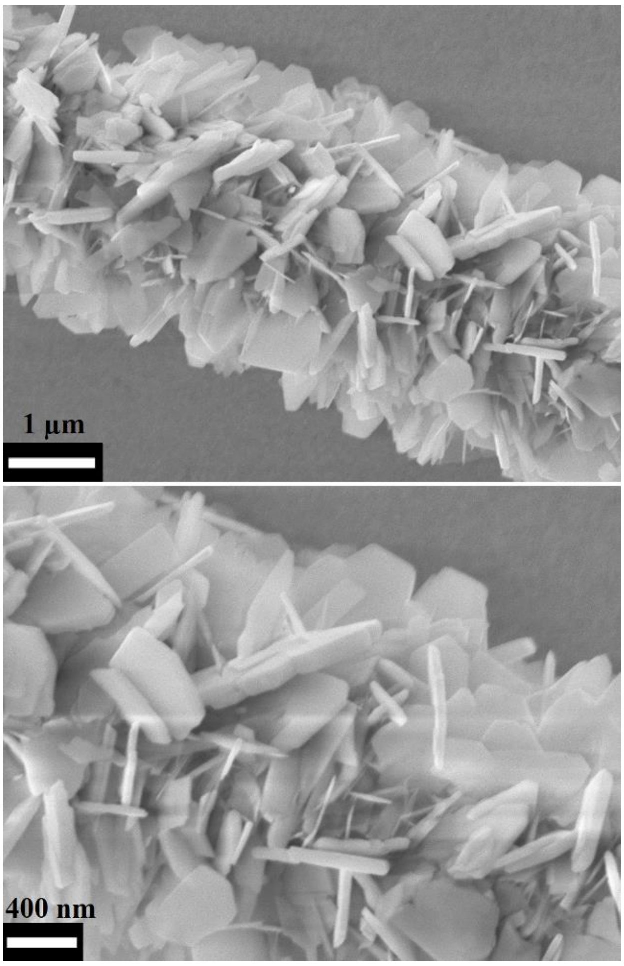

Figure 1. SEM image of ZnO, CuO and Cu_2O/CuO nanowire at the scale of (a) 1 µm and (b) 400 nm before heat treatment.

In order to determine the geometric configuration and the level of influence after the heat treatment on the nanowire, SEM images were taken (fig.2), from which the length of the nanowire was determined, being around 25 µm, the length between the Au contacts is around 14.5 µm. The diameter of the nanowire is around 1.8 µm. From Figure 2d, CuO/Cu_2O nanostructures with a granular surface can be observed, this is due to the heat treatment, thus increasing the porosity in turn and the surface/volume ratio [8]. Such a morphology is beneficial for sensor devices. Since XRD has been performed after the heat treatment, it is likely that the platelets themselves consisted of CuOH and the heat treatment led to an oxidation and additional shrinkage of the material. Thus, it became porous.

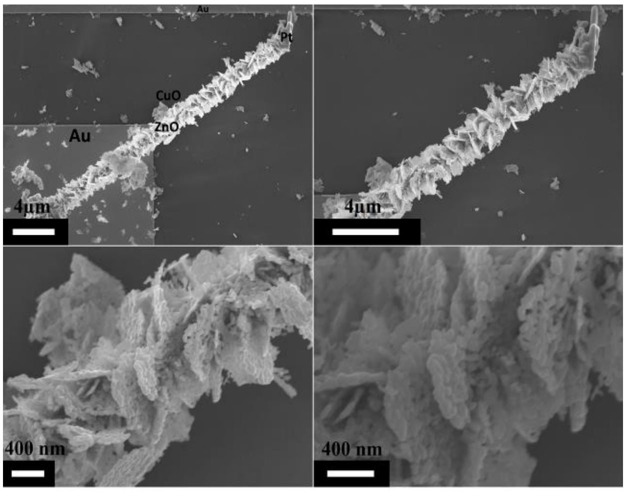

Figure 2. SEM image of ZnO, CuO and Cu_2O/CuO nanowire at the scale of (a, b) 4µm and (c, d) 400 nm after heat treatment at 650 °C.

The samples were studied in the measurement range of 2θ values 10-130°, with the scan step 0.01°. Figure 3 shows the XRD diffractogram for the ZC sample (ZnO mixed with CuO) in the range 30-80°, where the XRD peaks for ZnO, CuO and Cu_2O are observed. The peaks of zinc oxide are of higher intensity than those of copper oxide. The maximum intensity was observed at the (101) peak of zinc oxide, for CuO at the (111) peak, and for Cu_2O at (220).

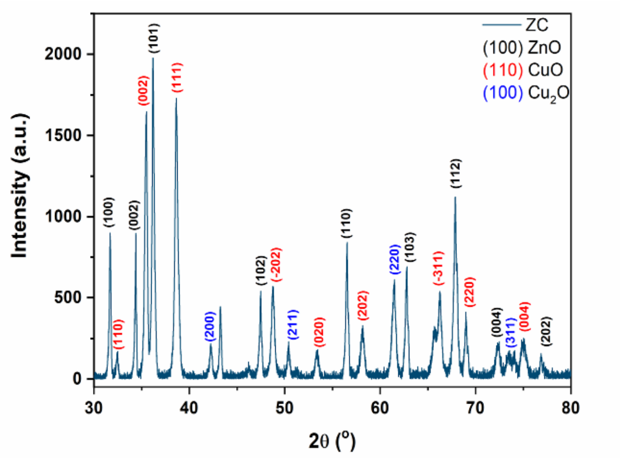

Figure 3. XRD diffractogram in the range 30-80°.

Sensing properties

Gas response is the rate at which the sensor's resistance changes when gas is applied [9]. This is a very important factor, the high sensitivity value for a particular gas indicates that this sensor is quite good for detecting that gas. It is determined by the formula:

$$S = \frac{I_{air}}{I_{gas}} \quad (1)$$

Where S is the response, I_{air} the value of the current when exposed to air and I_{gas} the value of the current when exposed to gas [10].

Figure 4 shows the dynamic response of mixed nanostructures of Zn and Cu to H_2 with a concentration of 100 ppm at an operating temperature of 125 °C and 150 °C, thus the maximum response value S = 4 was obtained at pulse 1 for 125°C. The response time i.e. the time interval in which the increase of the value from 10% to 90% takes place is approximately 0.88 s, and the recovery time i.e. the time interval in which the decrease of the value occurs from 90% to 10% is approximately 19.67 s. A voltage of 200 mV was applied for 20 seconds after which the gas is applied for the next 30 seconds during this time the increase in current can be observed. When the gas is disconnected, the current gradually returns to the initial value. To obtain more pulses the procedure was repeated.

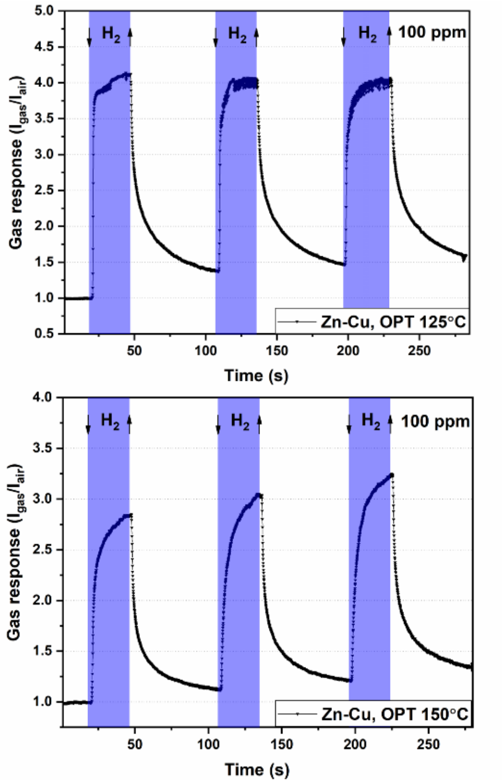

Figure 4. Dynamic response to 100 ppm H_2 at 125 °C and 150 °C working temperature of Zn-Cu nanostructures.

Figure 5 shows the dynamic response of the studied nanostructures to NH_3 with a concentration of 100 ppm at an operating temperature of 175 °C and the maximum response value S = 1.6 was obtained at pulse 2. The response time means the time interval in which it occurs the increase of the value from 10% to 90% is about 12.38 sec, and the recovery time, i.e. the time interval in which the decrease of the value from 90% to 10% takes place, is about 57.64 sec. A voltage of 50mV was applied for 20 seconds after which the gas is applied for the next 30 seconds during this time interval, as in the previous case the increase in current can be observed. When the gas is disconnected, the current gradually returns to the initial value. To obtain more pulses the procedure was repeated.

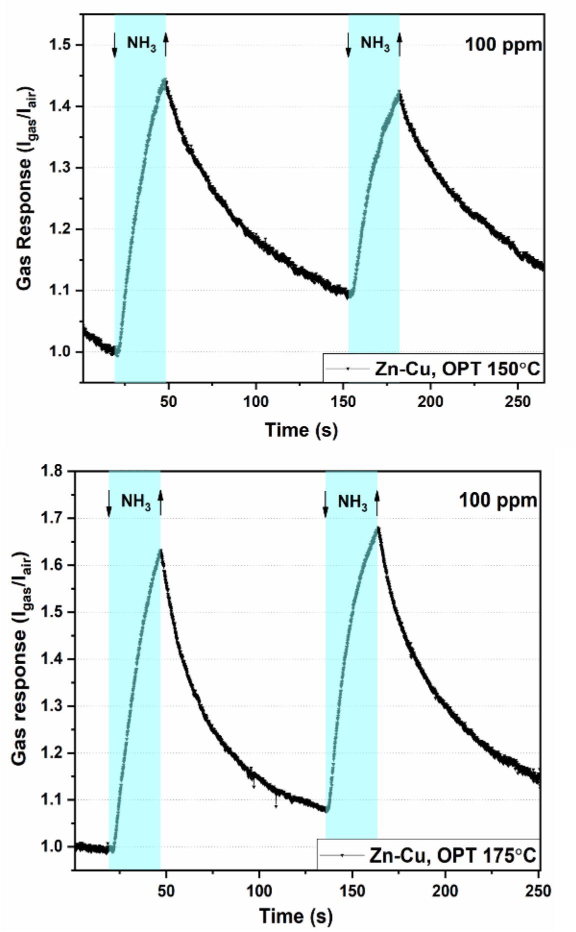

Figure 5. Dynamic response to 100 ppm NH_3 at 150 °C and 175 °C working temperature of Zn-Cu nanostructures.

Figure 6 represents the response to the investigated gases (Hydrogen, Ethanol, Methane, n-Butanol, 2-Propanol, Acetone and Ammonia) with a concentration of 100 ppm depending on the operating temperature where it is observed that the maximum response is S = 6, at operating temperature 100°C for hydrogen, which demonstrates high selectivity.

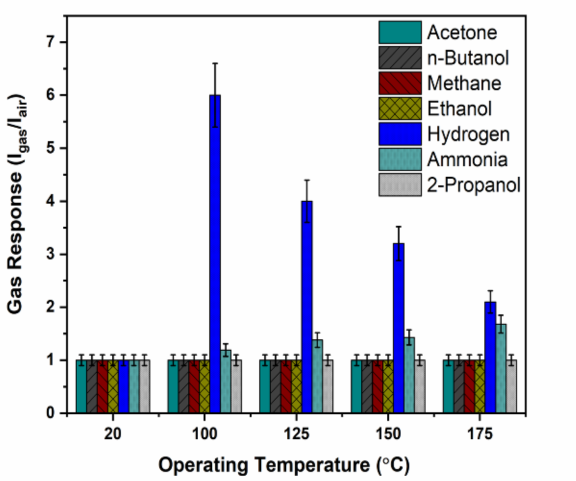

Figure 6. The response to the investigated gases (Hydrogen, Ethanol, Methane, n-Butanol, 2-Propanol, Acetone and Ammonia) at the operating temperatures of 20 °C, 100 °C, 125 °C, 150 °C and 175 °C for the investigated Zn-Cu nanostructures.

IV. Conclusions

This paper presents the data obtained experimentally following the research of the morphological, structural, sensory properties of mixed Zn-Cu oxides [11]. A hydrogen and ammonia response value of 100 ppm concentration was observed, having an operating temperature between 100°C - 175°C and a high selectivity generating response to H_2 and NH_3. Another property of the sensor investigated was the response and recovery times, a more impressive result was obtained for hydrogen gas. In some areas gas detection time plays a significant role, especially for highly flammable gases such as hydrogen [12]. From the X-ray diffractograms, XRD peaks were observed in the range 30-80° for ZnO, CuO and Cu_2O, with the maximum intensity at the (101) peak of zinc oxide, for CuO at the (111) peak, and for Cu_2O at (220).

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Algorithms of Overmodulation Regulation of Neutral Clamped Inverters for Photovoltaics

Valentin Oleschuk, ORCID: 0000-0002-7413-4867
Institute of Power Engineering
Str. Academiei 5, Chisinau, MD-2028, Republic of Moldova

***Abstract*—This manuscript presents results of study and research of synchronous adjustment in the overmodulation control zone of three neutral-clamped inverters (NCIs) of the specific configuration of three-phase grid-connected photovoltaic system. It has been proved, that the corresponding modification of techniques and algorithms of pulsewidth modulation (PWM) for control of NCIs, assure symmetry and advanced harmonic composition of inverter-side winding voltage of multi-winding power transformer, thereby helping to reduce losses in windings of the transformer, and to improve the efficiency of photovoltaic installations.**

Keywords—control, modulation, converter, photovoltaics, voltage, harmonics, spectrum

I. Introduction

New structures and topologies of multi-level and multi-phase converters of the parameters of electrical energy, with the help of which rational and economical modes of operation of systems of various functional purposes are provided, are increasingly being used in the field of electric drives, electric transport, and renewable sources of electric energy [1] – [4].

Photovoltaic systems are ones of the most common renewable energy installations [5] - [6]. Currently, there are a large number of structures of PV installations of transformer-based and transformer-less types [7] - [8]. In this case, various configurations of inverters can be used in PV systems [9] – [11].

The efficiency of the functioning of inverter-based PV systems is highly dependent on the methods and techniques of control and pulsewidth modulation (PWM) used to adjustment of inverters of the corresponding installations [12] - [14]. To provide improved spectral composition of the basic voltages of PV system with three neutral clamped inverters (NCIs) operating in the zone of overmodulation, specialized PWM algorithms for adjustment of NCIs have been elaborated and investigated in this paper.

II. Structure of Three-NCI-Based PV System

Recently, inverter-based grid-tied photovoltaic installation with three two-level inverters and with specific interconnection between outputs of PWM inverters and windings of power transformer has been described (Fig. 1 [9], [10]).

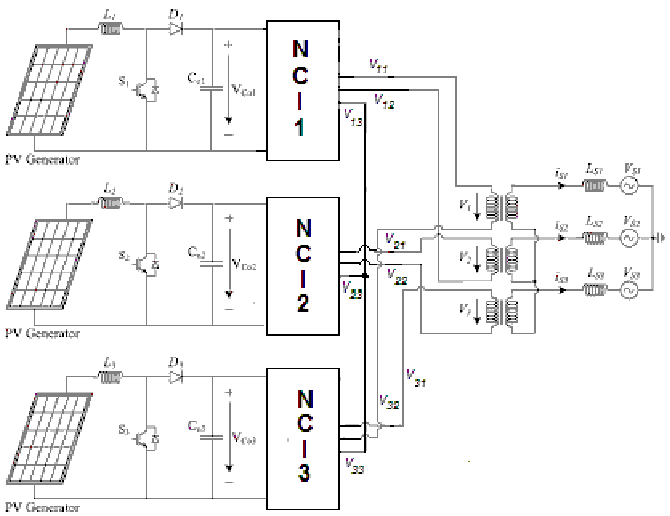

Figure 1. Basic power circuits of PV system with three Neutral Clamped Inverters (**NCI1** – **NCI3)** with special interconnections with power transformer.

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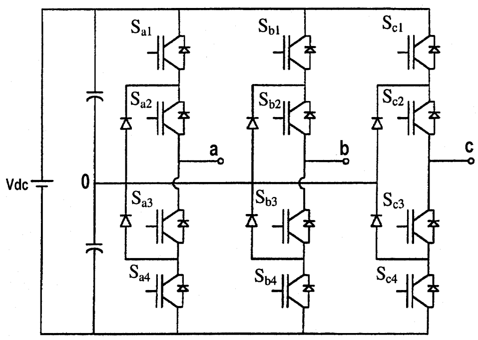
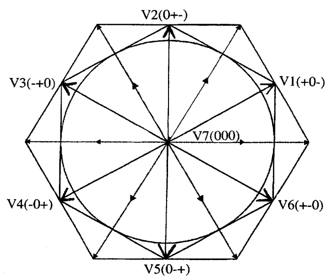
Fig. 1 presents slightly modified topology of the PV installation [9] based on three neutral clamped inverters (**NCI1**, **NCI2**, and **NCI3**), polar voltages of which $V_{11} - V_{32}$ are applied specifically to the corresponding windings of power transformer. This structure of PV system assures the increase of the maximum voltage applied to the multi-winding transformer (in comparison with two-inverter-based PV systems), reducing its weight and volume [9].

III. Switching Scheme of Neutral Clamped Inverters

Fig. 2,a shows structure of power circuits of NCI, Fig. 2,b presents basic voltage vectors **V1** ÷ **V7** (seven vectors, marked by the big arrows) of each NCI. Control and PWM scheme is based in this case on the using of six basic vectors (large vectors **V1** ÷ **V6),** and of the zero vector **V7**, assures providing minimization of value of common-mode voltage in power conversion systems with NCIs [8]. As an additional fact, it assures also to provide balanced neutral-point voltage of each NCI due to the fact that the presented **V1** ÷ **V7** vectors of voltage of diode clamped inverters do not have influence at the fluctuation of the neutral point voltage because the neutral-point **0** in this case is not connected to the NCI output [15].



a)



b)

Figure 2. Structure of power circuits of diode clamped inverter (a), and its basic voltage vectors **V1÷V7** (b).

IV. Features of Synchronous Control of NCIs of PV Installation in the Overmodulation Zone

To insure symmetry of the output voltage of NCI, modified techniques of synchronous space-vector PWM can be disseminated for regulation of neutral clamped inverters of the analyzed photovoltaic installation [4], [13]. Fig. 3 presents (inside the clock-time 0^0 - 60^0) diagrams of switching state sequence, and pole and line voltages of NCI controlled by the technique of continuous synchronous PWM, assuring symmetry of NCI output voltage over the whole adjustment range [12].

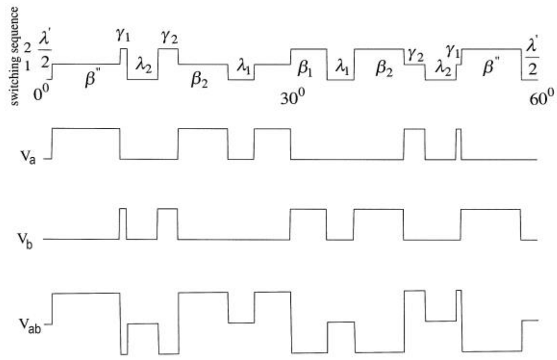


Figure 3. Switching sequence, and basic voltages V_a, V_b,, V_{ab} of NCI with synchronous PWM inside the clock-time 0^0 - 60^0.

Control of inverters of PV installations in the zone of the high and the highest coefficients of modulation *m* of inverters (in the zone of overmodulation, when *m>0.907*), has some specific features. Boundary values of two coefficients of modulation of inverters for the case of conventional two-stage adjustment in the zone of overmodulation are correspondingly equal to $m_{ov1} = 0.907$ and $m_{ov2} = 0.952$ [14] ($m_{\max} = 1$ in this case). Particularly, basic control dependences of voltage source inverters with synchronous PWM for determination of parameters of control signals include two specialized indices of overmodulation $K_{ov1} = [1-(m-m_{ov1})/(m_{ov2}-m_{ov1})]$ and $K_{ov2} = [1-(m-m_{ov2})/(1-m_{ov2})]$:

If *0.952>m>0.907*:

$$\beta_1 = \tau \quad (1)$$

$$\beta_j = \beta_1 \cos[(j-1)\tau K_{ov1}] \quad (2)$$

$$\gamma_j = \beta_{n-j+1}\{0.75 - 0.55\tan[(n-j)\tau]\} \quad (3)$$

$$\lambda_j = \tau - (\beta_j + \beta_{j+1})/2 \quad (4)$$

If *1>m>0.952*:

$$\beta_1 = \tau \tag{5}$$

$$\beta_j = \beta_1 \cos[(j-1)\tau K_{ov2}] \tag{6}$$

$$\gamma_j = \beta_{n-j+1}\{0.75 - 0.55\tan[(n-j)\tau]\}K_{ov2}, \tag{7}$$

where m – index of modulation of NCI, $\beta_1 - \beta_j$ - (see Fig. 3) duration of total active switching state during sub-cycle, γ_j - minor part of duration of active switching state, λ_j - duration of notches, τ - switching sub-cycle.

V. Operation of Three NCIs of PV Installation in the Zone of Overmodulation

A. *System Control at the First Stage of the Over-modulation Zone of Neutral Clamped Inverters*

Winding voltages V_1, V_2, V_3 of inverter-side windings of multi-winding power transformer of photovoltaic installation (Fig. 1) can be determined as functions of the corresponding pole voltages of three NCIs [9]:

$$V_1 = V_{11} - V_{13} - V_{32} + V_{33} \tag{8}$$

$$V_2 = V_{21} - V_{23} - V_{12} + V_{13} \tag{9}$$

$$V_3 = V_{31} - V_{33} - V_{22} + V_{23} \tag{10}$$

In accordance with the used PWM strategy, control signals of three NCIs are shifted by 120^0, and additional mutual phase shift between control signals of inverters is equal to 1/3 of the width of switching sub-cycle.

During the first control part of operation of NCIs of PV installation in the zone of overmodulation (modulation index m of inverters is $0.952>m>0.907$ in this sub-zone), control and modulation process is characterized by a smooth quasi-linear enlargement of duration of total active control signals of inverters (β - parameter in (2)) until its width will be equal to duration of switching interval τ [14]. Simultaneously, smooth decrease of duration of all notches λ (4) until close to zero value is observed in this control sub-zone.

Fig. 4 – Fig. 5 present results of simulation of PV installation with NCIs controlled by algorithms of synchronous discontinuous PWM (PWMD), described in [8], and show, in the relative scale, pole voltages V_{11}, V_{12} and V_{13} of the first NCI, line voltages of NCI1 and NCI2 ((V_{12} - V_{13}) and (V_{21} - V_{23})), and winding voltage V_2 of power transformer. It presents also (Fig. 5) spectra of the line (V_{21} - V_{23}) voltage, and of the winding voltage V_2. Fig. 6 – Fig. 7 present the corresponding diagrams for system controlled by algorithm of "direct-direct" PWM (PWMDD, [8]). The fundamental frequency of system is equal to $F = 50$ *Hz*, switching frequency of NCIs is equal to $F_s = 1000$ *Hz*, and its modulation index $m = 0.945$.

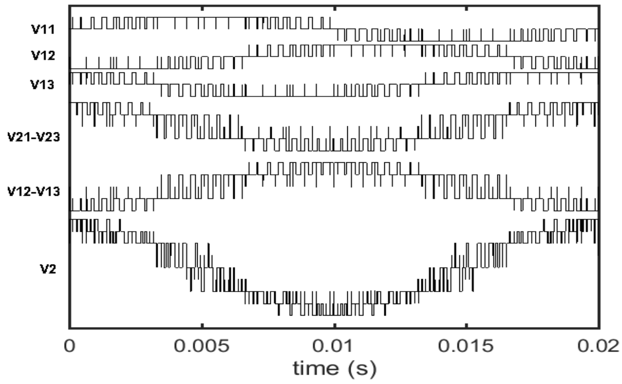


Figure 4. Pole voltages V_{11}, V_{12} and V_{13}, line voltages, and winding voltage V_2 of PV system adjusted by the scheme of PWMD ($m = 0.945$).

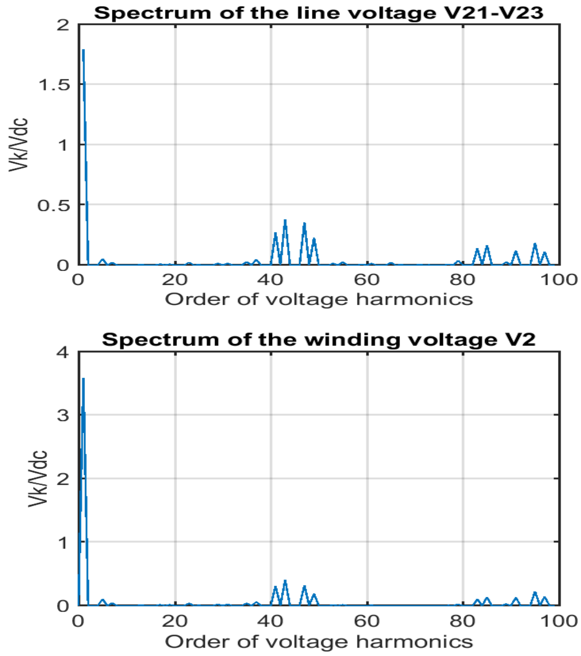


Figure 5. Harmonic composition of voltages of PV installation with discontinuous PWM (PWMD, $F = 50$ *Hz*, $F_s = 1000$ *Hz*, $m = 0.945$).

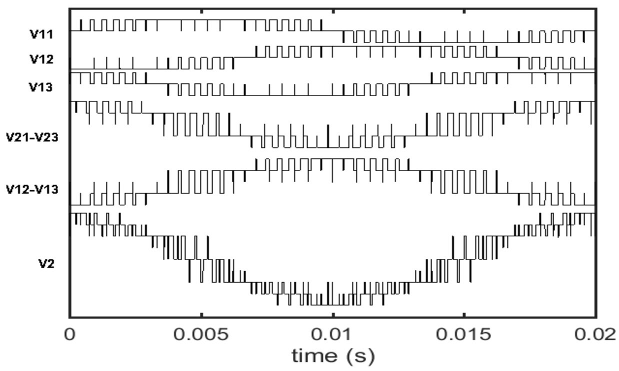


Figure 6. Pole voltages V_{11}, V_{12} and V_{13}, line voltages, and winding voltage V_2 of PV system adjusted by the scheme of PWMDD ($m = 0.945$).

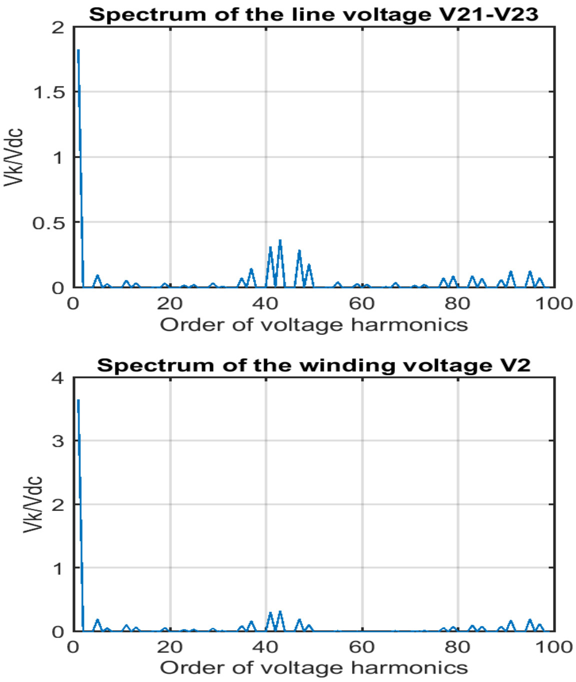


Figure 7. Harmonic composition of voltages of PV installation with 'direct-direct' PWM (PWMDD, *F = 50 Hz*, *F_s = 1000 Hz*, *m = 0.945*).

B. System Control at the Second Stage of the Overmodulation Zone of NCIs

During the second stage of operation of neutral clamped inverters of transformer-based grid-tied PV installation in the zone of overmodulation (modulation index *m* of NCIs is $1>m>0.952$ in this sub-zone), control and modulation process is characterized by a smooth reduction of the widths of the γ -parameters (7) until close to zero value in regime characterized by the maximum value of index of modulation of NCIs ($m = 1$) [8].

In order to illustrate processes of control and pulsewidth modulation in PV system with three NCIs (adjusted by the two basic schemes (PWMD and PWMDD) of synchronous PWM for NCIs) during the second sub-zone of overmodulation control diapason, Fig. 8 – Fig. 11 present basic voltage waveforms of the analazyed photovoltaic installation, and also spectral characteristics of the line voltage (V_{21} - V_{23}) and winding voltage V_2.

Fig. 8 – Fig. 9 show the corresponding diagrams for PV system with NCIs, adjusted by the scheme of discontinuous synchronous modulation (PWMD), Fig. 10 – Fig. 11 present the corresponding diagrams for PV installation with NCIs, regulated by techniques of 'direct-direct' synchronous PWM (PWMDD). Coefficient of modulation of NCIs in this case is equal to *m=0.985*, average switching frequency of power switches of neutral clamped inverters is equal to *1000 Hz*.

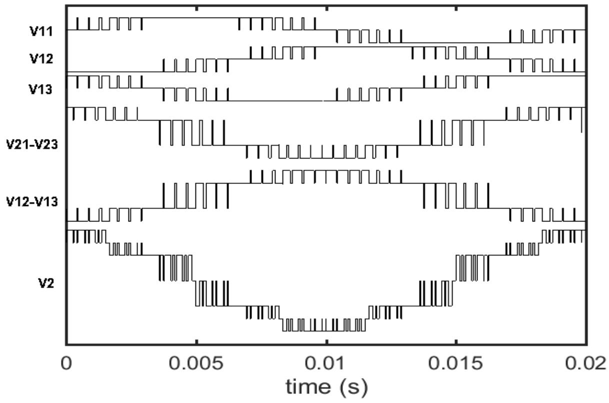


Figure 8. Pole voltages V_{11}, V_{12} and V_{13}, line voltages, and winding voltage V_2 of PV system adjusted by the scheme of PWMD (*m = 0.985*).

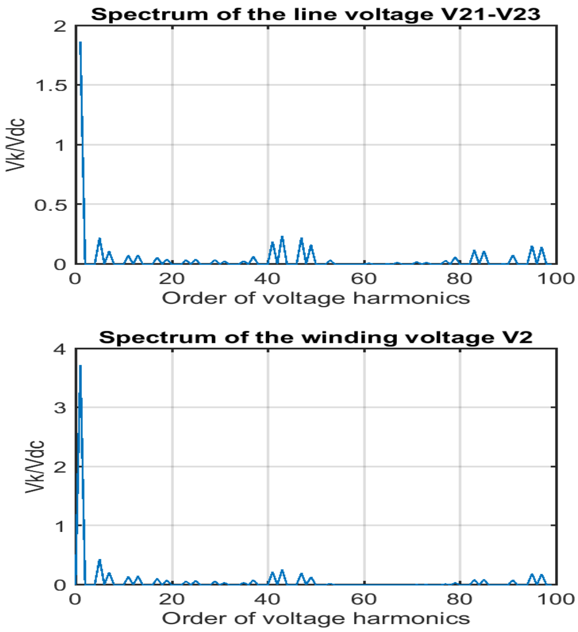


Figure 9. Harmonic composition of voltages of PV installation with discontinuous PWM (PWMD, *F = 50 Hz*, *F_s = 1000 Hz*, *m = 0.985*).

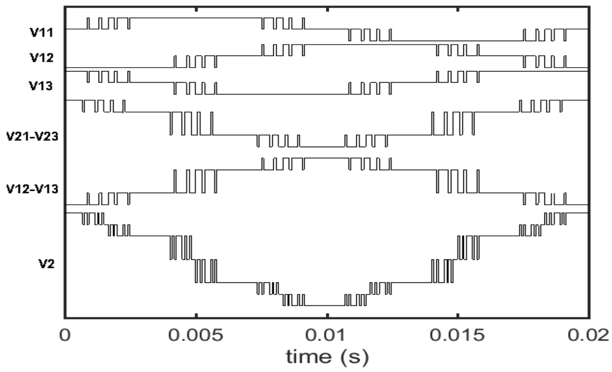


Figure 10. Pole voltages V_{11}, V_{12} and V_{13}, line voltages, and winding voltage V_2 of PV system adjusted by the scheme of PWMDD (*m = 0.985*).

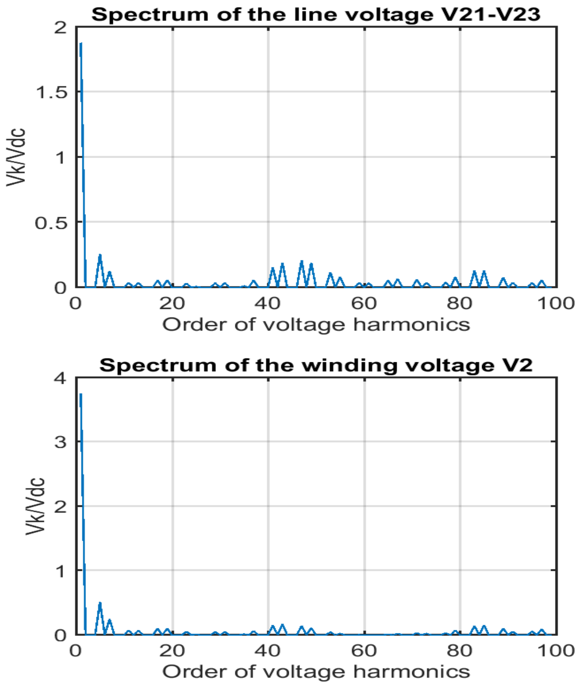


Figure 11. Harmonic composition of voltages of PV installation with 'direct-direct' PWM (PWMDD, $F = 50$ *Hz*, $F_s = 1000$ *Hz*, $m = 0.985$).

Shown in Fig. 4 - Fig. 11 diagrams and spectrograms illustrate the fact that in the analyzed three-NCI-based PV installation, modified techniques and algorithms of synchronous space-vector modulation, disseminated for regulation of three neutral clamped inverters, can successfully assure the symmetry and advanced harmonic composition of the winding voltage of multi-winding power transformer (without even-order harmonics and subharmonics in spectra of the winding voltage) during control of NCIs in the zone of overmodulation.

So, improved harmonic composition of the winding voltage of transformer of grid-tied PV system insures to decrease losses in the inverter-side windings of multi-winding power transformer.

Total Harmonic Distortion (*THD*) factor is an important indicator for study and comparison of integral spectral composition of winding voltage V_2 of the analyzed PV installation with triple NCIs, adjusted by algorithms of synchronous PWMD and PWMDD, with switching frequency of power switchs of neutral clamped inverters equal to *1000 Hz*, determinate (and presented in Fig. 12) for the case of two values of the maximum number of the calculated low order harmonics (*k*-th harmonics) – $k = 100$, and $k = 1000$:

$$THD = (1/V_{2_1})\sqrt{\sum_{k=2}^{100} V_{2_k}^2} \tag{11}$$

$$THD = (1/V_{2_1})\sqrt{\sum_{k=2}^{1000} V_{2_k}^2} \tag{12}$$

The presented in Fig. 12 diagram shows a relatively big dependence of the value of the *THD* factor of the winding voltage on number of low order voltage harmonics, taking into account during determining *THD*. But for the both cases of determining of the *THD* factor, presented in Fig. 12 ($k = 100$ and $k = 1000$), better values of *THD* factor can be assured by the using of algorithms of the "direct-direct" scheme of synchronous pulsewidth modulation for specific control of three neutral clamped inverters of the analyzed PV installation in the zone of overmodulation.

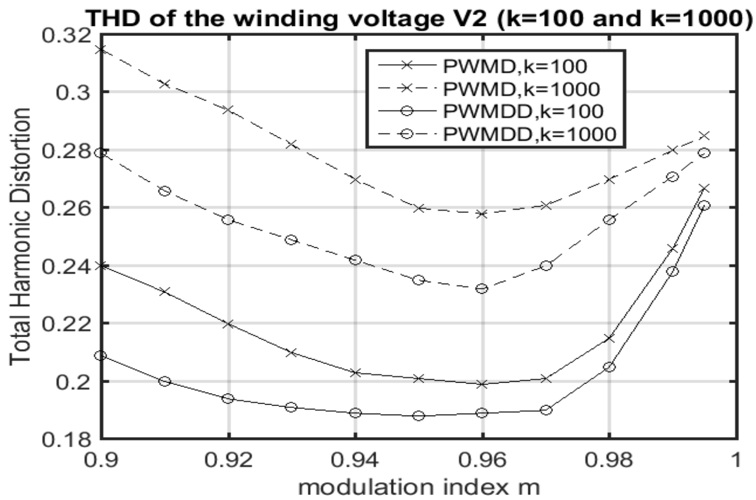


Figure 12. *Total Harmonic Distortion (THD)* factor of the winding voltage V_2 of PV installation based on triple NCIs.

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CONCLUSION

It is shown that the modified control scheme and algorithms of synchronous space-vector PWM can be successfully used to control of three neutral clamped inverters of a transformer-based PV installation with a special interconnection between windings of the power transformer with output circuits of the inverters, ensuring the symmetry of the voltage waveforms on the inverter-side windings of the power transformer under specific operating conditions of the inverter block of the system in the overmodulation zone.

Presented in Figs. 5, 7, 9, and 11 characteristics of the spectral composition of the line voltage of inverters, regulated on the basis of modified algorithms of synchronous space-vector PWM, and of the resulting winding voltage of the power transformer, emphasize the fact that there are no even order harmonics and subharmonics (of the fundamental frequency of system) in spectra of these basic voltages over the entire range of two-stage regulation of inverters in the overmodulation control zone, including cases of fluctuation of the operating frequency of the PV system connected with a three-phase grid.

On the basis of a comparative analysis of the integral spectral characteristics of the base voltages in the system, it was determined that improved (reduced) values of the distortion factor of the resulting winding voltage of power transformer are provided by regulating neutral clamped inverters on the base of modified algorithms of the "direct-direct" scheme of synchronous PWM.

Improving the harmonic composition of the winding voltage of the power transformer of the analyzed system makes it possible to reduce losses in the transformer, thereby contributing to an increase in the efficiency of the functioning of three-phase transformer-based photovoltaic installations.

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Microprocessor Protection Relay Based on Amplitude-Phase Measurements of Signals

Vladimir Jdanov [1], ORCID: 0000-0002-0732-154X
Tatiana Sestacova [1], ORCID: 0000-0002-6995-4254
Technical University of Moldova, MD-2004, Chisinau, bd. Stefan cel Mare si Sfânt, 168, vladimir.jdanov@sde.utm.md, tatiana.sestacova@sde.utm.md,

***Abstract*—Microprocessor-based relay protection devices enable efficient operation of the electrical infrastructure of high voltage power lines and substations under emergency conditions. This is achieved by using high-speed fault detection algorithms and advanced electronic components. The paper deals with the elaboration of a such algorithm which novelty lies in the fact that it is based on amplitude-phase measurements of asymmetrical components of current and voltage signals, which detects accidents with symmetrical and asymmetric overloads significantly faster. The algorithm is implemented in microprocessor protection in the LIRA device.**

Keywords*— Relay protection; microcontroller; amplitud-phase measurements; alarm waveforms.

I. Introduction

Microprocessor protection relays (MPR) is a relay protection device, the control part of which is implemented on the basis of microprocessor elements (microcontroller).

Currently, the development of MPR are the main direction of development of relay protection [1], [2]. In addition to the main function - emergency shutdown of power systems, its have additional functions in comparison with other types of relay protection devices (for example, electromechanical relays), that is - emergency registering.

MPR have the following advantages:

- Improved performances of speed, sensitivity and reliability in comparison with relay protection devices based on electromechanical relays.
- The presence of many service functions, such as: self-diagnostics, registration and oscillography of signals (Fig. 1. [3]), the ability to integrate MP RPA into the SCADA of an energy facility, etc.

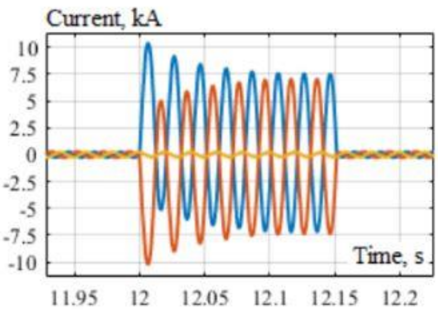

Figure 1. Emergency oscillograms of three-phase currents.

To make decisions about the appearance of an emergency mode, the MPR compares the measured and calculated values with the settings-threshold emergency levels (Fig. 2. [4])

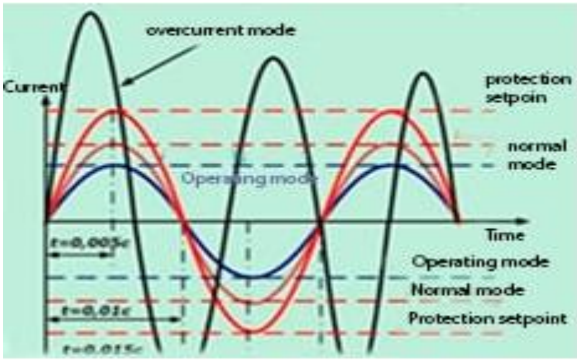

Figure 2. Detection of emergency mode

The main influence on the speed of the measuring elements of microprocessor protection of electrical installations is exerted by two factors. The first of them is associated with the appearance of damage in the measured signals of aperiodic and harmonic components due to transients and the nonlinearity of the elements of the electrical installation. The second one is due to the inertia of information processing algorithms, in particular analog and digital filtering. This leads to the fact that the time of signal establishment at the output of the measuring body is delayed to unacceptable values. This in some cases makes the high-speed protection of electrical equipment *ineffective*. There are known methods for determining the emergency mode based on the calculation of the effective values of currents and voltages, as well as the fast Furie transform (FFT). However, the fault detection time is from one half cycle to one cycle, which requires high performance processors.

The main tasks in the development of the MPR are to ensure high speed when detecting emergency modes and reliability of operation, which should be provided by fault tolerance and by ability to quickly replace of failed devices. To solve these problems, a simple high-speed ***MPR LIRA*** (*Local Integrated Relay Advanced*) was designed and manufactured.

II. MAIN PART

A. Theoretical background

The *LIRA* device uses an amplitude-phase method of calculating values to make a decision about the occurrence of an accident. Unlike the known methods for calculating the effective (*root mean square, r.m.s.)* values of currents and voltages for a quarter (0-45°) of the signal period, the calculation of instantaneous values of the signal amplitudes at points with phases i + 30° is used (Fig. 3).

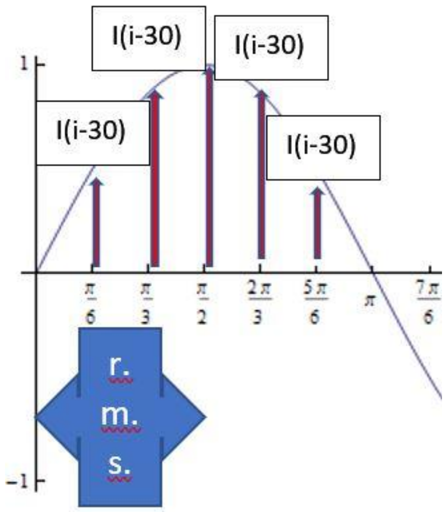

Figure 3. Amplitude phase measurements

This allows to make a decision about the occurrence of an alarm during 1/24 of the period (15°) in comparison with the measurement of the effective values of currents and voltages for half a period. The measured values are divided into two groups: *direct* measurements and *calculated* measurements. The first group includes input signals processed directly by the ADC, and the second group includes signals processed by the processor unit.

To obtain instantaneous signal values, the measurement channels are scanned by a 10-bit ADC. When the device is started, measurements are made at a frequency of 1200 Hz.

To detect accidents (such as *Line-Line*, *Line-Phase*, *Phase-Phase*, *Line-Ground*), symmetrical components are calculated on the basis of asymmetric decomposition system with three symmetrical components - direct (ABC_1), reverse (ABC_2) and zero (ABC_0) sequences for calculating the modes of a three-phase asymmetric network with short circuits [4], [5].

The essence of the method of symmetrical components is that any asymmetric three-phase system of current or voltage vectors can be replaced by the sum of three symmetrical systems:

$$\begin{aligned}
\dot{A} &= \dot{A}_1 + \dot{A}_2 + \dot{A}_0 \\
\dot{B} &= \dot{B}_1 + \dot{B}_2 + \dot{B}_0 = \underline{a}^2\dot{A}_1 + \underline{a}\dot{A}_2 + \dot{A}_0 \\
\dot{C} &= \dot{C}_1 + \dot{C}_2 + \dot{C}_0 = \underline{a}\dot{A}_1 + \underline{a}^2\dot{A}_2 + \dot{A}_0
\end{aligned} \tag{1}$$

The components of inverse sequence $3I_2$, $3U_2$ appear when any asymmetry occurs in the network: a single-phase or two-phase short circuit, phase breakdown, load unbalance. The components of the zero sequence $3I_0$, 3Uo occur during ground faults (one or two) or when one or two phases are broken.

The measurement frequency is adjusted so that there are exactly 24 measurements per period of the measured signal (15° between measurements).

B. Calculation formulas

For comparison with the settings, the values of the corresponding parameters are calculated every 10ms using the formulas.

The effective values of phase currents and voltages (I_{abc},U_{abc}), as well as voltages $3U_0$ are calculated by the formula :

$$(I_{abc}, U_{abc}, 3U_0) = \sqrt{\sum X_i^2/12} \tag{1}$$

where X_i is the instantaneous value of the measured signal.

The effective current $3I_0$ is calculated by formula:

$$3I_0 = \sqrt{\sum(I_{ai} + I_{bi} + I_{ci})^2/12} \tag{2}$$

where I_{ai} is the instantaneous value of the current (voltage) of phase ***a***;

I_{bi} is the instantaneous value of the current (voltage) of phase ***b***;

I_{ci} is the instantaneous value of the current (voltage) of phase ***c***.

The effective current $3I_2$ and voltage $3U_2$ are calculated by the formula:

$$3X_2 = \sqrt{\sum 3X_{2i}^2/12} \qquad (3)$$

where: $3X_2$ - effective current $3I_2$ (voltage $3U_2$);
$3X_{2i}$ - instantaneous value of current $3I_2$ (voltage $3U_2$), calculated by the formula:

$$3X_{2i} = \sqrt{3(X_{ci} - X_{bi}) + X_{a(i-30^0)} + X_{b(i-30^0)} - 2X_{c(i-30^0)}} \qquad (4)$$

where X_{ci} is the instantaneous value of the current (voltage) of phase ***c***;
X_{bi} is the instantaneous value of the current (voltage) of phase ***b***;
$X_{a(i-30^\circ)}$ is the instantaneous value of the current (voltage) of phase ***a*** 1/12 of the period ago;
$X_{b(i-30^\circ)}$ - instantaneous value of the current (voltage) of phase ***b*** 1/12 of the period ago;
$X_{c(i-30^\circ)}$ - instantaneous value of the current (voltage) of the phase ***c*** 1/12 of the period ago.

For accurately determining of the phase shift, every minute automatic frequency adjustment and hardware phase 0° detector are used.

C. Practical implementation

Digital processing in MPR LIRA [6] is carried out on the basis of an industrial microcontroller INTEL **87C196CA**. The device was developed in collaboration with the company SA Sandrologic Chishinau(www.sandrologic.md).The 87C196CA is based on Intel's MCS 96 16-bit microcontroller architecture and is manufactured with Intel's CHMOS process. The scheme for connecting the LIRA device to the measuring and executive circuits is shown in Fig.4. [5].

MPR LIRA performs the following functions:

- measurement of effective values of currents, voltages and then their transfer every 15 seconds to the SCADA supervisory control system;
- measurements and calculation of emergency values of currents and voltages;
- in the event of an accident in the network, an emergency oscillogram is recorded in the flash memory.

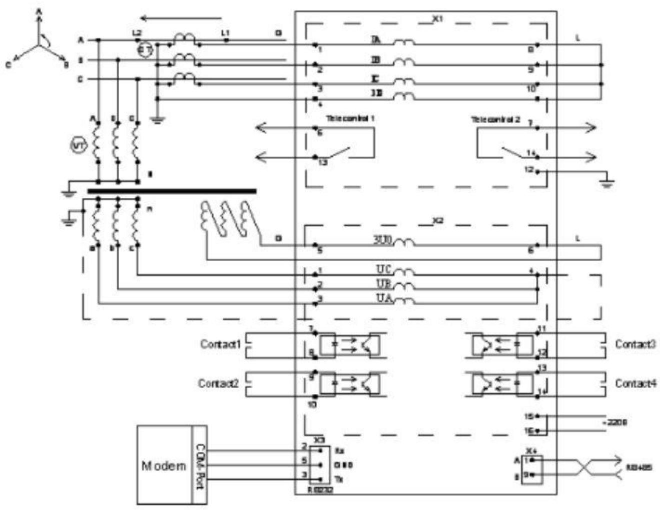

Figure 4. Scheme of connection to the measuring and executive circuits

To increase the speed of values calculation according to formulas (1)-(4) tabular methods are used.

The fault tolerance of the device is provided by Error Correcting Coding (ECC) methods based on the Hamming code for restoring information in the flash memory of programs in case of its failure. This allows to ensure long-term operation of the device at remote sites. To implement ECC, a hardware encoder-decoder based on the ALTERA MAX V FPGA is used.

The LIRA uses *alarm setpoints* for selecting the operating modes, beyond which the device recognizes the measured values as an alarm situation.

The alarm setpoints are set by the user as "trip" and "return" thresholds as valid secondary quantities

If the effective values of I_a, I_b, I_c, $3I_2$, $3U_2$, $3I_0$, $3U_0$ exceed the specified thresholds (settings), then an accident is recorded in the line.

An example of settings is presented in Table 1.

TABLE I. ALARM SETTINGS

Values	*Direction*	*Trigger*	*Processing*
I_{abc}	higher	5.25A	measurement
U_{abc}	higher	67.0V	measurement
U_{abc}	lower	48.0V	measurement
$3I_0$	higher	0.8A	calculation
$3U_0$	higher	15.0V	dimension
$3I_2$	higher	0.8A	calculation
$3U_2$	higher	15.0V	calculation
freq.	lower	49.0Hz	measurement

Alarm waveforms. An oscillogram of the instantaneous values of currents and voltages before the accident (10 periods) and after the occurrence of the accident (30 periods) is recorded in the flash memory.

In this case, an alarm is recorded for I_a, I_b, I_c, $3I_2$, $3U_2$, $3I_0$, $3U_0$, Ua, U_b, U_c. For each alarm, the following parameters are recorded: start time, end time, emergency settings flags (Fig. 5).

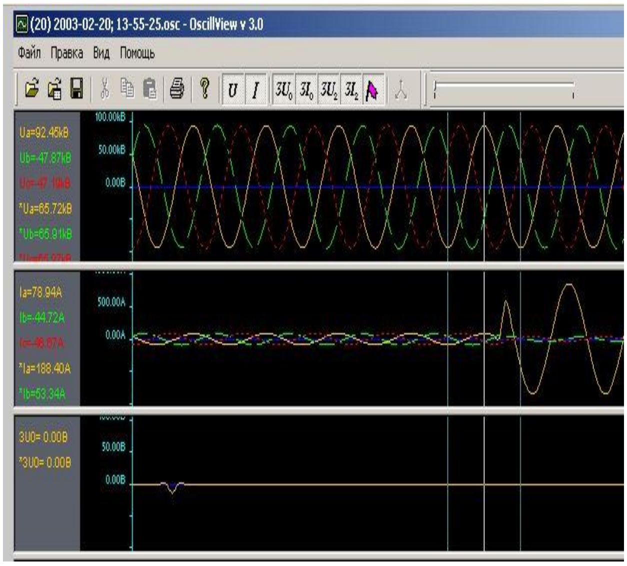

Figure 5. Alarm waveform of the LIRA device

LIRA devices are installed in HV grid PM objects, shown in Fig. 5 (with permission Sandrologic). During the testing of these devices, 12 accidents were recorded due to overcurrent, which completely coincided with the results detected by standard relay protection devices (electromechanical relays). There were no device failures. Pilot operation confirmed the high reliability and efficiency of the developed device.

Figure 5. LIRA device in a 110 kV substation

III. Conclusion

As a result of carried out research, the following conclusions can be drawn:

1. Amplitude-phase measurements of instantaneous values of three-phase currents and voltages ***I_{abc}, U_{abc}, $3I_o$, $3U_o$, $3I_2$, $3U_2$*** *allow to quickly (1/24 of the period) detect accidents with symmetrical and asymmetric overloads.*

2. The proposed algorithm ***is the first to be implemented*** on a microcontroller with standard architecture without the use of digital signal processors.

3. The carried out and observed Pilot operation of LIRA devices confirmed the reliability of accident detection algorithms and applied design solutions.

4. During the testing of these devices, 12 accidents were recorded due to overcurrent, which completely coincided with the results detected by standard relay protection devices (electromechanical relays).

Acknowledgements

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The method of measuring the parameters of nanostructured sensors

Valeri Verjbitki [1], ORCID: 0000-0002-5008-9141
Alexei Martîniuc [1], ORCID: 0000-0003-3407-3016
[1] Center for Nanotechnology and Nanosensors, Department of Microelectronics and Biomedical Engineering, Technical University of Moldova, 168 Stefan cel Mare str., MD-2004, Chisinau, Republic of Moldova,
valeri.verjbitki@adm.utm.md

Abstract — **In this paper, the data obtained from the research on the development of methods for measuring the parameters of nanostructured sensors, which is based on the use of 2 amplifiers and 2 analog-digital converters for measuring the voltages at the reference voltage source and the voltage drop on the additional resistor, which eliminates the shunt effect of the resistance of the structures investigated by the resistance input of the amplifier.**

Keywords* —*nanostructured sensors, reference voltage, input impedance

I. INTRODUCTION

In recent years, the concern about environmental pollution as well as the need for industrial safety have increased and made it necessary to continuously monitor the level of air pollution. The use of vapor or gas sensors is necessary in various aspects of modern daily life. The main task of gas sensors is to quickly and stably indicate the presence of harmful or explosive gases to create a warning that could save lives and ensure safety.

With the intensive development of nanotechnologies, copper and zinc oxides have been abundantly studied due to their applications in catalysis, gas sensors, biosensors, batteries, solar energy conversion, temperature superconductors, etc. [1].

When measuring the electrical parameters of nanostructured sensors, there are limitations on the values of the currents flowing through them, the applied voltages and the dissipated power.

Instruments for measuring high resistances are applied to the measured element sufficiently but large uncontrolled voltages and powers, which can lead to a change in the parameters of nanosensors or to their failure.

Devices that measure sensor resistances by the value of the flowing current and the voltage drop across the sensor require the use of amplifiers with sufficiently large input resistances that significantly exceed the resistances of the sensors, which, in particular, causes certain difficulties for nanostructures.

The proposed device is free from the above disadvantages.

II. EXPERIMENTAL

Development of a measurement technique, a circuit diagram and a laboratory sample of a measuring device

III. RESULTS

The device belongs to the field of measuring technology and can be used in various measuring devices where nanostructural sensors are used that change theirresistance under the influence of various physicaquantities such as; gas concentration, temperature,humidity.

To measure the resistance of nanostructured sensors, measuring bridges [2] are most often used, the outputs of which are connected to the inputs of measuring amplifiers.

The closest solution is a precision analog-to-digital interface for working with resistive micro and nano sensors, which contains a measuring bridge, the power diagonal leads of which are connected to a voltage source, and the measuring diagonal leads are connected to the differential inputs of instrumental amplifiers [2].

A significant disadvantage of this method of measuringresistance is that in order to measure high resistancesofnano and microstructures, it is necessary to use differential instrumental amplifiers with high input resistances.

The main problem solved by the invention is to provide the possibility of measuring high resistances of micro andnanostructures using general-purpose differential amplifiers.

The task is achieved in that to determine the resistance of nanostructured sensors, the voltage of the reference voltage source and the voltage across an additional resistor connected in series with the measured resistance are measured, and the value of the additional resistor and the input resistance of the measuring amplifier can be significantly less than the resistance of the nanostructures.

The result of the proposal is to eliminate the influence of the input impedances of instrumental amplifiers on the measurement results and replace them with general purpose amplifiers with relatively low input impedances[3].

The proposal is illustrated by the drawing in Fig. 1, which shows the structure of the measurement method.

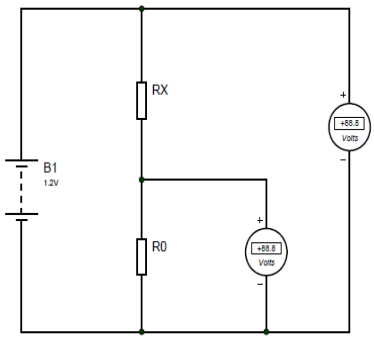

Figure 1. Two voltmeter meter

The circuit contains a reference voltage source B1. the nanostructure under study, an additional reference resistance and two voltmeters, according to the measurement results of which it is possible to calculate the resistance of the investigated nanostructure.

The basis of the proposed method for measuring the resistance of nanostructures is the rejection of the immediate the actual measurement of the voltage drop across the measured element and, as a result, the rejection of the changing amplifiers with high input impedance.

The measurement principle is explained in Fig.1.

As can be seen from Fig.1. two voltages Ub are measured - the source voltage and Uro-voltage across the additional resistor. Voltage on the measured nanostructure:

$$URx = Ub - URo \qquad (1)$$

Current flowing through the structure:

$$IRx = URo/Ro \qquad (2)$$

Now the resistance value of the nanostructure can be calculated by the expression:

$$Rx = (Ub - Uro)Ro/URo \qquad (3)$$

This eliminates the need to measure the voltage drop across the high-resistance resistance of the nanostructure, which, in turn, makes it possible to use to amplify the measured voltage amplifiers assembled on conventional operat

The method refers to the field of measurement technology and can be used in a variety of devices where nanosensors based on nanostructured oxides that change their resistance are used[4],[5]. The method for measuring the parameters of nanosensors and sensors based on nanostructured oxides is proposed which includes reference voltage source , operational amplifier 4, additional resistor , two voltmeters 5 and the measured nanosensor or nanostructured sensor . The resistance of the nanosensor or of the sensor based on nanostructures is determined from the value of the voltage indicated by the voltmeters.

A block diagram illustrating the proposed idea is shown in Fig.2

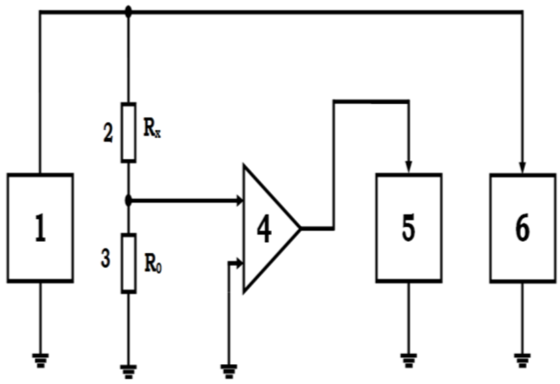

Figure 2. Principle of measurement of nanostructure parameters

It contains a series-connected reference voltage source 1, measured nanostructural sensor 2 - Rx, an additional resistor 3 to the connection point of which with a nanostructural sensor is connected to the input of amplifier 4, and its output is connected to the input of a voltmeter 5, voltmeter 6 is connected to the reference voltage source, in addition , resistor 3, the common points of the reference voltage source 1, amplifier 4, voltmeter 5and voltmeter 6 are connected to ground.

The process of measuring the resistance of a micro and nanostructured sensor is carried out as follows: at the first stage, the voltage across the additional resistor 3 Ur3 is determined, which is equal to the voltage measured by the voltmeter 4 Uv4 divided by the gain of the amplifier 4 Ku4

$$Ur3=Uv4/Ku4 \quad (4)$$

at the second stage, the voltage on the nanostructured sensor is determined, which is equal to the voltage of the reference voltage source 1 measured by the voltmeter 6 U6 minus the voltage across the additional resistor 3

$$Urx=U6-Ur3 \quad (5)$$

At the third stage, the current value through the nanostructured sensor is calculated

$$Irx=Ur4/R4 \quad (6)$$

At the fourth stage, the resistance value of the nanostructured sensor is calculated

$$Rx=Urx/Irx=(U6Ur4)*R4/Ur4= =(Uv6*Ku4Uv5)*R3/Uv5 \quad (7)$$

As an example of use in practice, you can use a practical case of implementation with the following parameters of the elements: the value of the reference voltage source U6=30V, the resistance of the additional resistor 3 R3=1000 Om, the voltmeter reading 5 U5=20V, the voltmeter reading 6 U6=29.98V
Rx=(29.98*1000-20)*1000/20=1498000 Om

The block diagram of the device is shown in Fig.3.
The flowchart includes:
- reference voltage source;
- researched nanostructured sensor Rx;
- additional stable resistor Ro;
- DC amplifiers;
- analog-to-digital converters;
- microprocessor;
- indication device - display;
- control scheme;
- source of power.
- the reference voltage source is designed to generate a stable thermo-independent voltage value supplied to the measuring circuit
- an additional stable resistor is used to measure the current flowing through the nano-structural sensor
- DC amplifiers lead the measured voltages to the levels necessary for normal small operation of analog-to-digital converters
-Analog to digital converters are used to convert measured voltages into digital form, which is necessary for the operation of the microprocessor (usually included in the micropro-assignor)
- the microprocessor processes the received data, calculates the resistance value of the nanostructure
a tour sensor and converts it into codes supplied to the indicator
- indicator (display) displays the calculated value of the resistance of the nanostructure
- the control scheme is designed to select the operating modes of the device: on / off. calibration, measurement

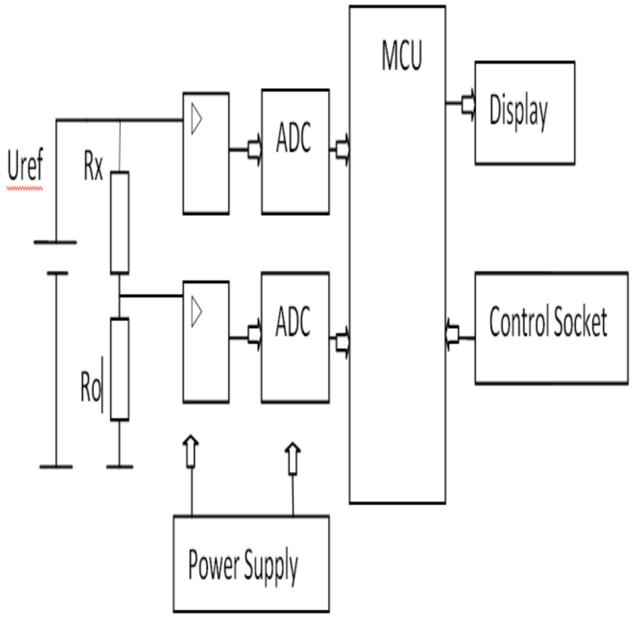

Figure 3. Device block diagram

The schematic diagram of the device is shown in Fig.4.

The investigated structure Rx together with the series calibrated resistance Ro is under-connected to the reference voltage source B1. UB1 source voltage and voltage drop on a calibrated resistance URo using operational amplifiers U2.A and U2.B amplify are normalized and normalized to levels in the range (0 - 5) V, which is necessary for the operation of the analog - digital converter ADC0/ADC1 of microprocessor U1.

The calculated value of the nanostructure resistance is converted into control codes of four digit seven-segment LED indicator. Port C outputs (PC0 - PC7)
Processors U1 determine the displayed digit, and outputs PD0 - PD3 of port D switch digits
dynamic indicator.

Elements X1, C1, C2 are part of the crystal oscillator; R1b, C3 - initial reset circuit microprocessor. Control buttons 1 and 2 are used to select the operating mode of the device.

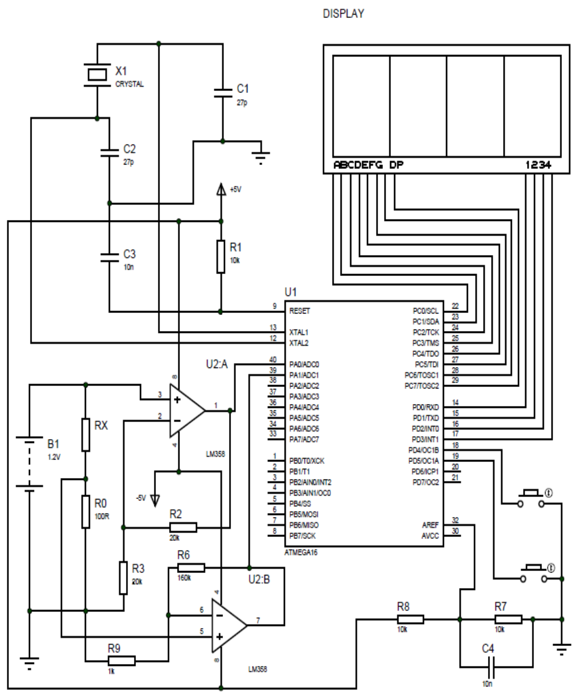

Figure 4.Electrical diagram of the device

IV. Conclusions

The method of measuring the resistance of nanosensors based on micro and nanostructured oxides, which allow excluding the effect of the input resistances of the differential instrumentation amplifiers on the measurement results, which consists in measuring the voltage at the measured resistance in series connected of the reference voltage source and the additional resistor and calculations of these measured resistance data.

Acknowledgment

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Prospects Overview of the Superconducting Neural Networks

Maria Lupu [1], ORCID: 0000-0001-6768-9357
[1] D.GHITU Institute of Electronic Engineering and Nanotechnologies, Technical University of Moldova, Chisinau, Moldova, e-mail: simplex.prof.nanotech@gmail.com

Abstract—**The long-term efforts of many research groups have led to the fact that by now a large number of different "learning rules" and architectures of neural networks, their hardware implementations and methods of using neural networks to solve applied problems have been accumulated. These intellectual inventions exist in the form of a "technopark" of neural networks. Each network from the technopark has its own architecture, training rules and solves a certain set of tasks. Moreover, specialized high-speed devices can be created on its basis. There are several levels of alienation of a neural network from a universal computer: from network learning on a universal device and the use of rich possibilities in manipulating a task book, learning algorithms and modifying architecture, to complete alienation without learning and modification capabilities, only the functioning of a trained network.**

Keywords— ***superconducting neural networks; dynamic processes; physics-based models; deep neural networks***

I. INTRODUCTION

For progress in the field of high–performance computing and artificial intelligence, it is necessary to improve the energy efficiency and density of integration of existing circuits, which can be realized only with the use of a new element base - superconducting neurons and synapses. The proposed study is relevant due to the possibility of developing new energy-efficient computers with non-von Neumann architecture based on elements of superconducting spintronics.

Indeed, the best modern systems on specialized semiconductor microprocessors simulate the work of about 1 million neurons and a quarter of a billion synapses. However, the largest and most ambitious projects state the goals of 10^{10} neurons and 10^{14} synapses. The key problem on the way to such goals is the reduction of energy release in all active elements of a neuromorphic computing system.

For this reason, the use of superconducting materials seems to be the most promising direction that meets these tasks. Traditionally, in superconducting logic and memory, information is associated with a quantum of magnetic flux, which, firstly, limits the degree of integration (a cell must contain one quantum of flux), and secondly, determines the localization of information, which complicates the physical implementation of information processing parallelization algorithms. These limitations lead to a low functional density of existing superconducting circuits and make it difficult to develop circuits based on non-classical principles of information processing, such as deep neural networks, which are key components in the creation of artificial intelligence.

II. PHYSICAL REALIZATION OF NEURONS AND CONNECTIONS IN THE ANNS

Neural network (also artificial neural network, INS) — a mathematical model, as well as its software or hardware implementation, built on the principle of organization and functioning of biological neural networks — networks of nerve cells of a living organism. This concept arose when studying the processes occurring in the brain, and when trying to simulate these processes. The first such attempt was the neural networks of U. McCulloch and W. Pitts.

After the development of learning algorithms, the resulting models began to be used for practical purposes: in forecasting tasks, for pattern recognition, in control tasks, etc.

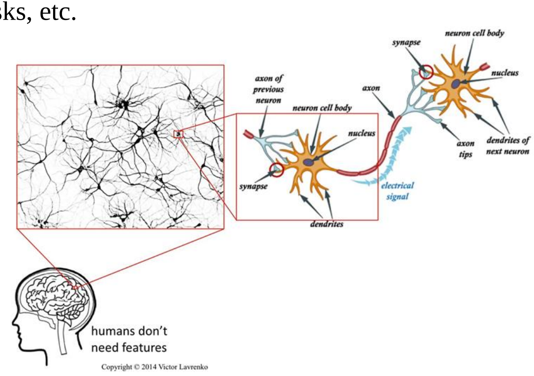

Figure 1. Biological and artificial neural networks [2].

From the point of view of machine learning, a neural network is a special case of pattern recognition methods, clustering methods, etc. From the point of view of mathematics, training neural networks is a multiparametric problem of nonlinear optimization. From the point of view of cybernetics, a neural network is used in adaptive control tasks and as algorithms for robotics. From the point of view of the development of computing and programming, a neural network is a way to solve the problem of effective parallelism. From the point of view of artificial intelligence, ANN is the main direction in the structural approach to study the possibility of constructing (modeling) natural intelligence using computer algorithms [9].

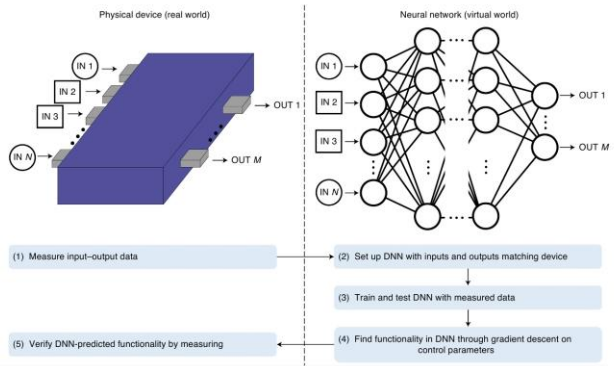

Figure 2. Examples of ANNs [4].

Neural networks are not programmed in the usual sense of the word, they are trained. The possibility of learning is one of the main advantages of neural networks over traditional algorithms.

Technically, learning consists in finding the coefficients of connections between neurons. During the learning process, the neural network is able to identify complex dependencies between input and output data, as well as perform generalization. This means that in case of successful training, the network will be able to return the correct result based on data that was missing in the training sample, as well as incomplete and/or "noisy", partially distorted data.

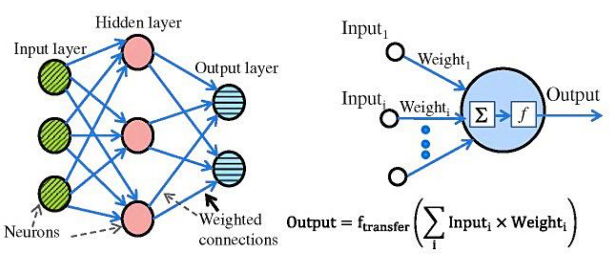

Figure 3. Technical realization of ANNs [6].

Neurons interact through a series of pulses lasting several milliseconds, each pulse is a frequency signal with a frequency of several units to hundreds of hertz. This is unimaginably slow compared to modern computers, but at the same time, the human brain can process analog information much faster than a machine, such as: recognize images, taste, recognize sounds, read someone else's handwriting, operate with qualitative parameters. All this is realized through a network of neurons connected by synapses. In other words, the brain is a system of parallel processors that works much more efficiently than the now popular sequential computing.

A neural network is a collection of neurons connected to each other in a certain way. Each neuron is an element that calculates the output signal (according to a certain rule) from a set of input signals. That is, the main sequence of actions of one neuron is as follows:

- Receiving signals from previous network elements;
- Combination of input signals
- Output signal calculation
- Transmission of the output signal by the next element of the neural network

Neurons can be connected to each other in absolutely different ways, this is determined by the structure of a particular network. An output signal (or several output signals) is generated based on the totality of the signals coming to the network input.

A neuron is characterized by its state and, by analogy with a real neuron, can be either excited or inhibited.
The neuron has a group of synapses – unidirectional input connections connected to the outputs of other neurons, and also has an axon – the output connection of this neuron, from which the signal (excitation or inhibition) enters the synapses of the following neurons. Each synapse is characterized by the magnitude of the synaptic connection or its weights.

In physical terms, the weight of a synaptic connection is the electrical conductivity of a given synapse.

The current state of a neuron is defined as the weighted sum of its inputs. The value at the input of the synapse is multiplied by the weight of this synapse, then all these values are summed up and we get the current state of the neuron (Fig. 1, 2)

In artificial neural networks, the activation function of a neuron determines the output signal, which is determined by an input signal or a set of input signals.

A standard computer chip can be considered as a digital network of activation functions, which can take the values "ON" (1) or "OFF" (0) depending on the input. This is similar to the behavior of a linear perceptron in neural networks. However, only nonlinear activation functions allow such networks to solve non-trivial problems using a small number of nodes. In artificial neural networks, this function is also called a transfer function.

Each function has its own distinctive properties, advantages and disadvantages. None of the functions is universal, it is impossible to say unequivocally in which case a linear rectifier, a sigmoid or a hyperbolic tangent should be used.

Knowing some characteristics of the function to be approximated, you should choose an activation function that approximates the desired function as accurately as possible and will lead to rapid learning [8].

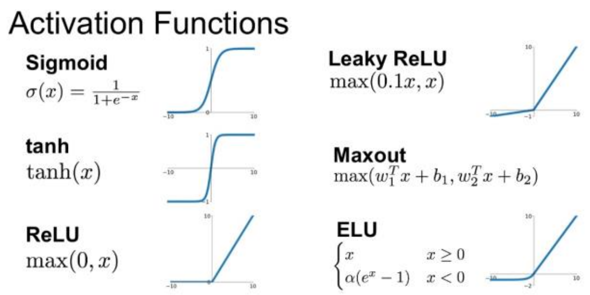

Figure 4,5. Examples of the activation functions [7].

Energy efficient memory has been the main detractor for multiple superconducting digital projects in the past. Recently, fundamental physics research in superconductor-ferromagnet thin-film tunnel structures created a new opportunity to solve this long-standing problem. Superconductivity and ferromagnetism, two deeply antagonistic electronic properties, can co-exist in form of Magnetic Josephson Junctions (MJJs). The superconducting-ferromagnetic MJJs are electrically compatible with traditional superconductor-insulator-superconductor (SIS) Josephson junctions (JJs) used for digital energy-efficient single flux quantum circuits. Both MJJ and JJ circuits have similar fabrication process and can be integrated on a single chip. As a result, a combination of MJJs and JJs can be used to form addressable memory cells, energy-efficient memory periphery circuits and programmable logic elements [9].

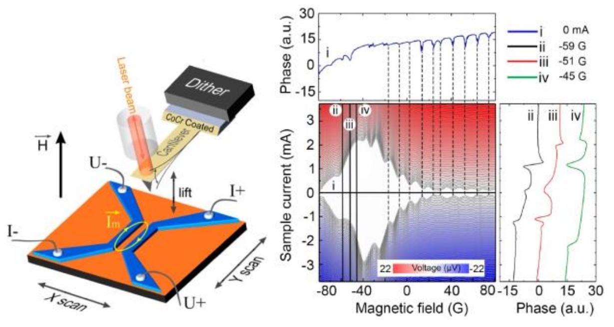

Figure 6. Reducing the size of the base elements [2].

III. APPLICATION OF ANNS

Classification of images. The task is to indicate whether the input image (for example, a speech signal or a handwritten symbol) represented by a feature vector belongs to one or more predefined classes. Well-known applications include letter recognition, speech recognition, electrocardiogram signal classification, and blood cell classification.

Clustering/categorization. When solving the clustering problem, there is no training sample with class labels. The clustering algorithm is based on the similarity of images and places close images in one cluster. There are known cases of clustering for knowledge extraction, data compression and data properties research.

Approximation of functions. Suppose there is a training sample $((x_1,y_1), (x_2,y_2)..., (x_n,y_n))$ (input-output data pairs), which is generated by an unknown function (x) distorted by noise. The task of approximation is to find an estimate of an unknown function (x). Approximation of functions is necessary when solving numerous engineering and scientific modeling problems.

Prediction/forecast. Let n discrete samples $\{f(t_1), f(t_2)..., f(t_n)\}$ be given at consecutive time points $t_1, t_2,...,$ tn . The task is to predict the value of $f(t_n+1)$ at some future time t_n+1. Prediction/forecast has a significant impact on decision-making in business, science and technology. Stock exchange price prediction and weather forecast are typical applications of prediction/forecasting techniques.

Optimization. Numerous problems in mathematics, statistics, engineering, science, medicine and economics can be considered as optimization problems. The task of the optimization algorithm is to find a solution that satisfies the system of constraints and maximizes or minimizes the objective function. The traveling salesman problem is a classic example of an optimization problem.

Memory addressable by content. In the von Neumann model of computation, memory access is available only through an address that does not depend on the memory content. Moreover, if an error is made in calculating the address, completely different information can be found. Associative memory, or memory addressable by content, is available at the direction of the specified content. The contents of memory can be called even by partial input or distorted content. Associative memory is extremely desirable when creating multimedia information databases.

Management. Consider a dynamic system given by the set $\{f_1(t), f_2(t)\}$, where $f_1(t)$ is the input control action, and $f_2(t)$ is the output of the system at time t. In control systems with a reference model, the purpose of control is to calculate such an input impact $f_1(t)$, in which the system follows the desired trajectory dictated by the reference model. An example is optimal engine management [1,3,5].

IV. Practical Implementations: Reducing the Size of the Basic Elements, Scientific Novelty

The developed cells of adiabatic Josephson transmission lines as part of neural network signal processing units allow for four orders of magnitude (up to attojoule scales) to reduce the release of energy during the functioning of neurons.

The technique of analyzing macroscopic quantum effects in multi-contact and multi-circuit superconducting quantum interferometers was used for the first time to study the possibilities of integrating artificial neural networks into digitized signal processing systems with built-in magnetic Josephson memory (Fig. 5)

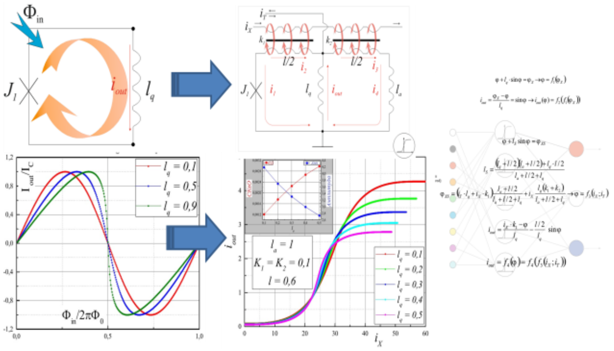

Figure7. Expression for the activation function [2].

The developed compact neurons allow for one operation (on subnanosecond time scales) "calculate" the activation function of a neuron. The developed compact synapses allow for four orders of magnitude (up to attojoule scales) reduce the energy release during the passage of a single pulse.

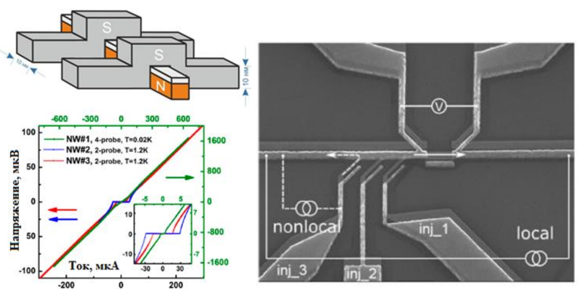

Figure 8. Development of technological solutions [2].

Methods have been developed and tested for the analysis of charge transfer processes in compact Josephson cells and phase batteries (taking into account the peculiarities of the influence of topology during the transition to nanoscale structures), which are part of both the SHP ADC and the signal processor, neural network and quantum signal processing unit (Fig. 6) [1,3,5].

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Determination of the critical thickness of Nb superconducting layers coupled proximiti with Co.

Boian Vladimir [1] ORCID - 0000-0001-5708-4098

[1] *Institute of Electronic Engineering and Nanotechnology " D. Gitsu , Technical University of Moldova, Chisinau, Moldova ,,*

Abstract **- Contemporary technological progress is achieving new results due to current needs in microelectronics, superconductivity and nanotechnology. An important feature of high-speed, low-power microelectronics is the spin valve, which is made up of superconducting nanoscale layers such as niobium and cobalt. These two orders superconductivity and ferromagnetism, which at first sight have diametrically opposite tangents and in the natural state are virtually never next to each other - due to the Larkin - Ovchinnikov - Fulde - Ferrell (LOFF) state, demonstrate quantum phenomena quite exciting for further development with applications in: computer technology, chemistry, biology, pharmacology, artificial intellect etc. In this context of ideas we present research on Nb/Co hybrid structures with superconducting properties and the determination of the critical thickness of the superconducting Nb layer in contact with Co.**

Keywords: superconductor/ferromagnet proximity effect, FFLO pairing, critical thickness.

I. INTRODUCTION

Since the work of Ginzburg [1], the problem of the coexistence of two long-range orders - superconductivity (S) and ferromagnetism (F) - has been intensively discussed. Ginzburg concluded that the two antagonistic orders cannot coexist in a homogeneous material because superconductivity requires the conduction electrons to form Cooper pairs, i.e. pairs of electrons with antiparallel spins, while ferromagnetism forces the electron spins to align parallel. If superconductivity and ferromagnetism cannot exist in a homogeneous material, they can be spatially separated at the nanoscale, forming a natural or artificial layered material. This scenario has been realized in multicomponent magnetic superconductors [2] and in artificially created S/F bilayers and layered materials [3]. The latter system has the advantage that the thickness and/or sequence of the S and F layers can be modified during fabrication. Garifianov et al. [4] suggested the use of immiscible metal pairs, such as Pb and Fe, to avoid the diffusion problem. However, a detailed analysis showed [5] that in this case the transparency of the S/F interface is reduced due to the electrostatic potential barrier (band shift) created by adjusting the electrochemical potential of the contacting metals.

S/F pairs should not consist of immiscible metals to avoid the formation of islands due to lack of wetting at the interface. Rather, metals with limited solubility and narrow intermetallic compound formation intervals should be used.

Substrate type, surface quality and film growth regimes should ensure that the roughness of the F-layer interface is as low as possible compared to the F-layer thickness.

Measurement of F-layer thickness and roughness should provide accurate and reliable data within a thickness range of approximately (1 nm).

II. MAGNETRON DEPOSITION OF SUPERCONDUCTING STRUCTURES

The structure was deposited at a temperature of 200°C in the magnetron Z-400 sputtered on commercial silicon substrates (111). The sample size is: 80 mm × 10 mm. In the magnetron chamber, the base vacuum pressure was about 2 × 10-6 mbar. Three targets, Si, Nb and Co, with a diameter of 75 mm were used. Pure argon - 99.999%, "Messer Griesheim" - at a pressure of 8 × 10-3 mbar was used as the spray gas. Before the actual sputtering, all targets were pre-cleaned in Ar plasma for 2-3 minutes in a static position to remove any contamination. Then, without interrupting the vacuum, a wedge-shaped layer of Nb was deposited by moving the target 5 cm from the symmetry axis of the Nb substrate. To subsequently fabricate S/F samples with identical parameters - with varying thickness of the superconducting layer, so that the deposition conditions for all samples in the series are the same, we applied our deposition technique described in detail [6, 7, 8]. The growth rate of the Nb layer directly under the magnetron is about 3 - 4 nm /s. Thus, the silicon surface was sputtered homogeneously with superconducting material - the deposition time is 11.3 sec at a voltage of 380 V, DC.

Subsequently, the Nb wedge layer was coated with ferromagnetic material - Co with a thickness of about 2.5 nm. Cobalt was deposited at a cathodic current of 120 mA. After deposition of the Nb/Co double layer, it was encapsulated with an amorphous silicon layer to eliminate oxidation.

The figure below shows the Z - 400 magnetron at which the thin films were coated:

Fig 1. Magnetron type: Z - 400

To determine the critical thickness of Niobium in contact with Cobalt, an 80mm*10mm sample was coated on a Si substrate, which was placed asymmetrically to the magnetron target by 5 cm, and the superconducting layer (Nb) was deposited as a wedge as shown below:

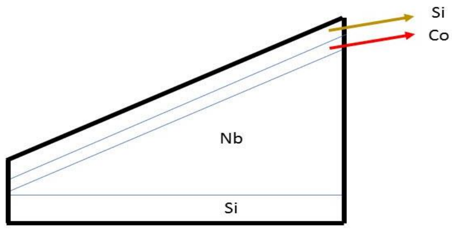

Fig 2. Profile diagram of the magnetron sputtered structure.

For hybrid S/F (Nb/Co) structures, the following issues persist:

a) in the magnetron sputtering process the possibility of island formation of the material must be excluded,
b) the energy of the Fermi levels must have approximately the same value,
c) high vacuum conditions.

The structure of dimensions: 80 mm * 10 mm is cut into 20 pieces. Each of these 20 pieces is measured by the 4-pin method and glued onto the printed circuit board for insertion into the cryostat. We follow figure 3 below:

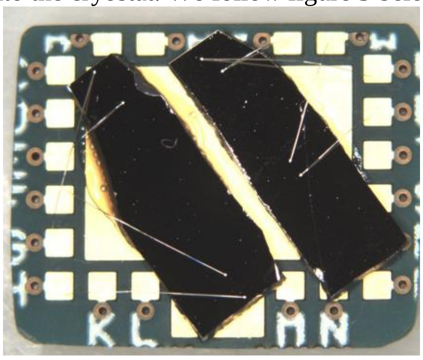

Fig 3. PCB plate, on which two samples are bonded before being inserted into the cryostat.

For this purpose, the PBC in Figure 4 is mounted on the rod that is fixed inside the cryostat:

Fig 4. PCB board, already mounted on the rod for insertion into the cryostat.

Placing samples in the 17 Tesla cryostat to measure superconducting properties:

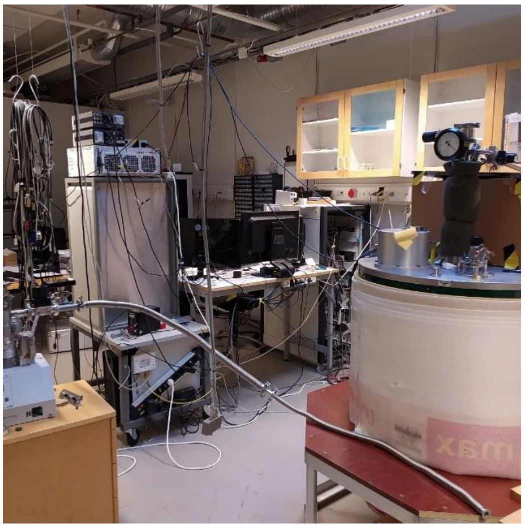

Fig 5. The 17 Tesla cryostat.

The experiment showed that at a constant thickness of 2.5 nm of Cobalt, coupled in close proximity to Niobium, as the thickness of the superconductor decreases - the critical temperature of the hybrid structure decreases. At a thickness less than 17.5 nm of Niobium coupled in proximity to Cobalt, whose critical temperature is 1.28 K, superconductivity disappears. The results are shown in the figure below:

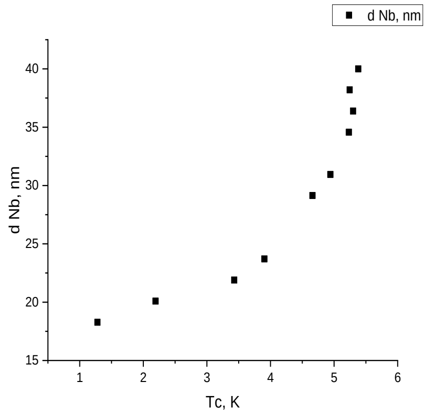

Fig 6. Critical temperature dependence of Niobium thickness.

Figure 6 shows that at 17.5 nm thickness of the Niobium layer the superconducting transition of Niobium in contact with Cobalt occurs.

An important characteristic of our magnetron sputtered nanometer layer samples is - the residual resistivity coefficient, and is shown by the following mathematical relation:

$$R_{300}/R_{10} = 2,5$$

where, R300 - sample resistance at room temperature (T = 300K), R10 - sample resistance at liquid helium temperature.

In figure 6 we can clearly see the transition from the normal state of a 100 nm Cobalt nanostrate to the superconducting state at a temperature of 8K

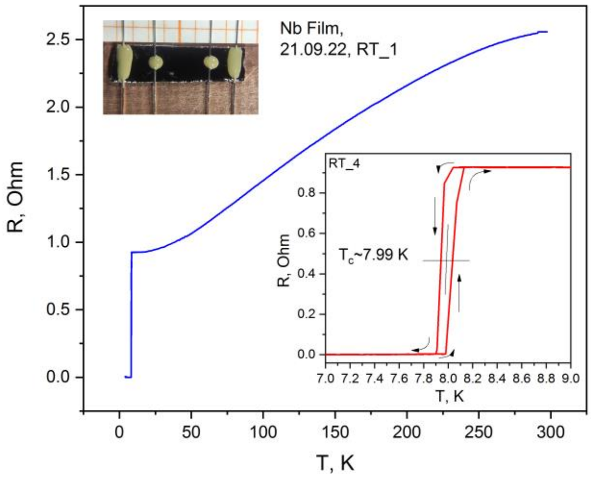

Fig 6. Conductive state transition of 100nm Co nanostrate.

Samples that for some reason are not of good quality - material impurities, or have not been cleaned well, because they do not register the ratio: Rn/Rs in the range of 2 - 2.5 have a low critical temperature, which is not interesting for practical applications because these samples require more cooling, but this is also due to higher economic costs, not being a prospective direction.

III. RESULTS AND DISCUSSION

We determined the superconducting coherence length ξ_S of the Nb layer, which is part of the proximity effect theory, from the linear dependence of Bc2⊥(T) near the superconducting transition temperature. The representative slope value for the sample on the thick side of the Nb wedge (dNb ≈ 51 nm, Tc =6.6 K) is -(dBc2⊥(T)/dT)=0.58 T/K. To obtain the coherence length ξ_S from the Bc2⊥(T) data, we first determine the Ginsburg-Landau coherence length, $\xi_{GL}(0)$, using [9]:

$$\xi_{GL}(0) = [-(dB_{c2\perp}(T)/dT)(2\pi T_c/\phi_0)]^{-1/2}, \qquad (1)$$

where φ_0 = 2.07 × 10^{-15} T*m2 is the magnetic flux quantum. Calculation of the parameter $\xi_{GL}(0)$ ≈ 9.3 nm. For a "dirty" superconductor (short free electron path, $l_S << \xi_{BCS}$, with Bardin-Cooper-Schriffer coherence length ξ_{BCS} = ħ γ/(π2kBTc0) , where γ ≈ 1,781 is the Euler constant and is the Fermi velocity) the coherence length ξ_S is defined as follows [10, 11]:

$$\xi_S = \left(\hbar D_S / 2\pi k_B T_{c0}\right)^{1/2} = \sqrt[2]{\pi/6\gamma} * \sqrt[2]{l_S \xi_{BCS}} \qquad (2)$$

where Ds = $l_S v_S/3$ is the electron diffusion coefficient in the superconductor. Comparison with the Ginsburg-Landau theory allows the relationship to be established [12]:

$$\xi_S = (2/\pi)\xi_{GL}(0) \qquad (3)$$

from which we obtain ξ_S ≈ 5.9 nm.

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Active Filter on RC element with Distributed Parameters Sensitivity Analyze

Ion Avram [1], ORCID: 0000-0002-5931-4165
[1] Technical University of Moldova, Chisinau, MD2008, The Rebublic of Moldova, ion.avram@rc.utm.md

***Abstract*—This article presents the results of research of the stability of characteristics of the active filter on element with distributed parameters through the calculate the sensitivity of the Amplitude - Frequency Characteristic (AFC) of the filter on change the value of each element of the electronic circuit of active filter.**

***Keywords*— Active Filler, RC element with distributed parameters, Amplitude - Frequency Characteristic, transfer function .**

I. INTRODUCTION

The characteristics of transmission and reception channels in telecommunications and information networks are formed on the basis of diverse types of active filters, made on various active and passive elements. Active filters based on RC elements with distributed parameters (turned to be most effective $\overline{\boldsymbol{RC}} - elements$).

$\overline{\boldsymbol{RC}} -$ elements represent some elements, which contain in a single volume a structure (a component), which has parallel resistor properties with resistance R and capacitor properties with capacity C. These elements can be obtained based on several technologies, such as be the technology of thin films or the method of obtaining resistive microwire with glass insulation according to the Taylor-Ulitovschi technology and the coaxial microwire based on it. By choosing the composition of the resistive material, the dielectric and the composition of the conductive layer material with approximately equal values, but opposite in sense (meaning positive and negative), very high stabilities are obtained in the very high temperature band and time of the 10exp(-6) level 1/degree. These elements also have a high priority: they make it possible to greatly reduce the volume and mass of the electronic devices in which they are used, and relative decrease the energy consumption and the price of the devices.

The basic peculiarity of all electronic circuits based on $\overline{\boldsymbol{RC}} -$elements consists in the fact that all their functions are described by transcendental equations, in which the argument of the variable

$$\Theta = \sqrt{p\tau} = \sqrt{pRC}$$

represents an irrational function of a complex variable. This fact limits the possibilities of direct use to these circuits with $\overline{\boldsymbol{RC}} -$ elements of the classical theory of analysis and synthesis of circuits with non-distributed elements. Therefore, when calculating the characteristics of the devices based on $\overline{\boldsymbol{RC}} -$ elements arises the problem of presenting the transfer functions of such devices in a rational form. It is necessary to mention that the rational form, found as a result of solving the approximation problem, only approximately describes the characteristics of circuits based on $\overline{\boldsymbol{RC}} -$ elements. Therefore, in order to evaluate the authenticity of the results of the analysis and synthesis of the mentioned circuits, it is necessary to know the degree of difference (error) of the approximate function compared to the exact transcendental function of the circuit based $\overline{\boldsymbol{RC}} -$ elements. At present, several methods are used to solve this problem.

The trivial method consists in approximating the hyperbolic functions in Maclauren series and when limiting the series with two terms the error does not exceed 10%, and when limiting the series with three terms the error does not exceed 4% [1].

Another method consists in decomposing the hyperbolic functions into continuous series and depending on the required accuracy of the calculations to limit the number of terms of the series. For example, if only two terms of such a series are used, then the error of the approximation of the frequency characteristics for the passband of the filters does not exceed the value of 8%, and when the terms of the decoupling series increase, the approximation error suddenly drops. In the work given to perform the approximate analysis of the circuits based on $\overline{\boldsymbol{RC}} -$ elements the decomposition of hyperbolic functions into continuous series of two or three terms was used [2].

It is necessary to mention that $\overline{RC}$ – elements in various electronic circuits they can be connected in several variants of dipole or tripole and depending on this, a decomposition of the hyperbolic functions with a smaller or larger number of terms of the approximating series may be required in order not to exceed the predetermined approximation error.

The filters in the composition of telecommunications and information networks operate in different climatic conditions and therefore are subject to the action of various types of destabilizing factors such as: temperature, humidity, radiation, natural degradation of the components, etc., which can change the values of the components parameters. As a result of these destabilizing actions, after some time interval, the actual characteristics of the filters may differ from the characteristics calculated during the design.

Because of this, in order to evaluate the stability of the filter characteristics as a result of the action of destabilizing factors, but also to evaluate the possible tolerances of the nominal components, the sensitivity of the corresponding characteristics is carried out in the field of the multidimensional space of the parameters of the filter components.

Usually, to assess the action of the X parameter on the Y characteristic of the filter, the logarithmic or relative sensitivity of the Y characteristic to the change of the X parameter value is most frequently used, which is denoted S_X^Y, introduced by Bode [3] and calculated from the relation:

$$S_X^Y = \frac{\partial\,(lnY)}{\partial\,(lnX)} = \frac{X}{Y}\cdot\frac{\partial Y}{\partial X} \qquad (1)$$

The S_X^Y value, calculated in this way, represents a complex quantity. In the theory of electronic circuits it is demonstrated that the real part of the sensitivity function $Re\,S_x^{T(x,p)}$ of the transfer function of the electronic circuit (of the filter, in the given case) describes the sensitivity of the Amplitude - Frequency Characteristic (AFC) of the filter, and the imaginary part $Im\,S_x^{T(x,p)}$ describes the sensitivity of the Phase-Frequency Characteristic (PFC) of the filter.

II. AFC SENSITIVITY ON THE REAL FILTER

The AFC sensitivity of the filter to the change in the value of an element of the electronic circuit of the filter indicates the value of the change in the signal level in the pass and hold bands of the filter when the value of the indicated element changes and is called the AFC sensitivity to this element, but taking into account the changes in the values of all In the elements of the electronic circuit, the summary sensitivity of the AFC of the filter is obtained, which can be calculated according to the relationship:

$$S_\Sigma = \sum_{i=1}^{n} Re\left[\frac{X_i}{T(p,X_i)}\cdot\frac{\partial T(p,X_i)}{\partial X_i}\right] \qquad (2)$$

In the project, the relations for the sensitivity of the Amplitude - Frequency Characteristic to each element of the electronic circuit of the filter in figure 1, which represents the scheme of a low-pass filter (LPF), are obtained.

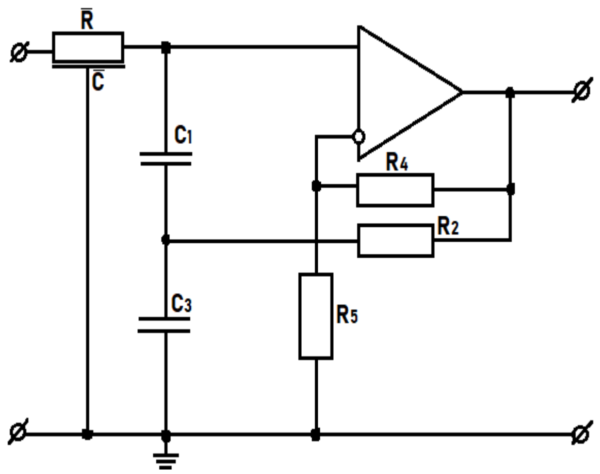

Figure 1. Analyzed circuit

The transfer function of the filter in figure 1 is described with the following relation [4]:

$$T(\theta) = \frac{1+(1+n)\alpha\theta^2}{[1+(1+n)\theta^2]ch\theta+\beta\theta(\alpha n\theta^2-\gamma)sh\theta)} \qquad (3)$$

$where\ \theta = \sqrt{p\overline{RC}};\qquad p = j\omega\,;\qquad n = \frac{C_3}{C_1};$
$\beta = \frac{C_1}{C};\ \gamma = \frac{R_4}{R_5};\ \alpha = \frac{C_1 R_2}{CR}.$

To calculate the sensitivity of the transfer function of the filter with respect to the parameter α, which will be noted by $S_\alpha^{T(\Theta,\alpha)}$ it is necessary to calculate the first partial derivative of the transfer function of the filter with respect to the parameter α which has the following form:

$$\frac{\partial T(\theta,\alpha)}{\partial\alpha} = \frac{\beta\theta^3[\gamma(1+n)+n]sh\theta}{\{[1+(1+n)\alpha\theta^2]ch\theta+\beta\theta(\alpha n\theta^2-\gamma)sh\theta\}^2} \qquad (4)$$

The result we obtain:

$$S_{\alpha}^{T(\theta,\alpha)} = \frac{\partial T(\theta,\alpha)}{\partial \alpha} \cdot \frac{\alpha}{T(\theta,\alpha)} = \frac{A(\theta)}{B(\theta)} \quad (5)$$

where

$$A(\Theta) = -\alpha\beta\Theta^3[\gamma(1+n)+n]sh\Theta \quad (6)$$

$$B(\Theta) = [1+(1+n)\alpha\Theta^2]^2 ch\Theta + \beta\Theta(\alpha n\Theta^2-\gamma)sh\Theta \quad (7)$$

Therefore the AFC sensitivity of the analyzed filter $S_{\alpha}^{T(\theta,\alpha)}$ obtain the form:

$$S_{\alpha}^{|T(j\omega,\alpha)|} = \frac{ReA*ReB+ImA*ImB}{(ReB)^2+(ImB)^2} \quad (8)$$

where:

$$ReA = -alx\beta[\gamma\left(\frac{1}{n}+1\right)+1] \quad (9)$$

$$ImA = blx\beta[\gamma\left(\frac{1}{n}+1\right)+1] \quad (10)$$

$$ReB = c - \beta x(yb-la) - k[kc+2d+\beta x(lb-ya)] \quad (11)$$

$$ImB = d + \beta x(lb-ya) + k[2c-kd-\beta x(yb-la)] \quad (12)$$

and

$$a = shx\cos x + shx\,sinx;\ b = shx\,cosx - chxsinx;$$

$$l = 2\alpha nx^2;k = 2(1+n)\alpha x^2;c = chxcosx;$$

$$d = chxsinx;\ x = \sqrt{0{,}5\omega RC}.$$

In analogical mode, the expressions of the Amplitude - Frequency Characteristic sensitivity of the analyzed filter to changing the values of its other elements were calculated. The corresponding sensitivities are calculated from the relations:

— on the β parameter, which indicates the stability of capacitor capacities C_1 and capacity of $\overline{RC}$ – element and more importantly indicates the stability of the relationship of these capacities

—

$$S_{\beta}^{T(\theta,\beta)} = \frac{K}{Lch\theta+K}; \quad (14)$$

where:

$$K = \beta\theta(\alpha n\theta^2-\gamma)sh\theta \quad (15)$$

$$L = 1+(1+n)\alpha\theta^2; \quad (16)$$

-on the $\boldsymbol{n}$ parameter, which indicates the stability of the capacities of capacitors C1 and C3 and their ratio

-

$$S_{n}^{T(\theta,n)} = \frac{\alpha\beta n\Theta^3(1+\gamma+\alpha\Theta^2)sh\Theta}{L(L\,ch\Theta+K)} \quad (17)$$

- on the variable $\boldsymbol{\theta}$ (the sensitivity of the transfer function of the filter to the change in the value of the time constant of the RC-element with distributed parameters

$$S_{\Theta}^{T(\Theta)} = \frac{Z+Q}{L(Lch\Theta+K)} \quad (18)$$

$$\text{where } Z = \Theta[2k\alpha(1+n)\Theta - L] \quad (19)$$

$$Q = [Kcoth\Theta + (L+3\alpha\beta n\Theta^2-\gamma\beta)]sh\Theta\,. \quad (20)$$

- on the γ parameter :

$$S_{\gamma}^{T(\theta,\gamma)} = \frac{\gamma\beta\theta sct\theta}{Lch\theta+K} \quad (21)$$

Where are used the notes from equation (3).

III. CONCLUSIONS

The calculation of the Amplitude - Frequency Characteristic sensitivity of the filter according to expressions 8, 14, 17, 18,21 was carried out by numerical methods on the computer.

According to the obtained values of Amplitude - Frequency Characteristic sensitivities to the change in the values of the components of the electronic circuit, the deviation (difference) of the Amplitude - Frequency Characteristic of the filter compared to the calculated Amplitude - Frequency Characteristic can be evaluated.

To generate the results obtained from the analysis of the concrete electronic circuit with real values of all its components, namely: the $\overline{RC}$ element, capacitors C_1 and C_3 and resistors R_2, R_4 and R_5 the results obtained in a frequency band, described by a more generalized frequency $\boldsymbol{\lambda = pRC}$, which allows the results obtained to be extended to circuits with various values of the components.Some results of dependency calculations $S_{x_i}^{|T(j\omega)|}$ when creating the second-rank filter are indicated in figure 2. From the dependencies in the figure it can be seen that the Amplitude - Frequency Characteristic sensitivity is directly proportional to the value of the parameter **α** and inversely proportional to the parameter value **γ**.

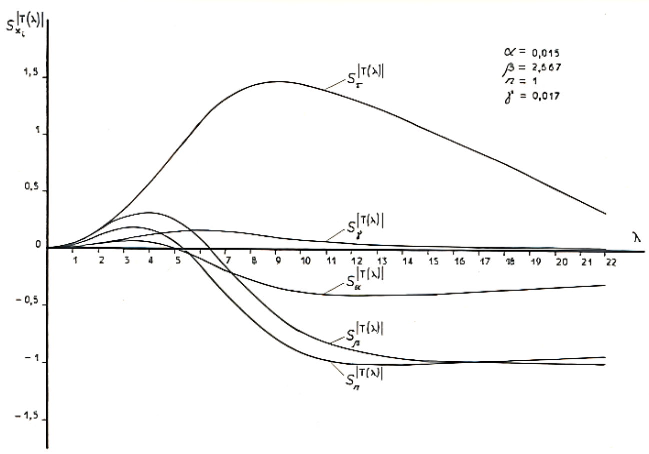

Figure 2. Amplitude - Frequency Characteristic sensitivity of the analyzed Low Pass Filter

At the same time, the maximum values of the sensitivity functions on each element of the Amplitude - Frequency Characteristic are found near the cutoff frequency of the Low Pass Filter.

The analysis of the graphs in figure 2 allows us to conclude that the Amplitude - Frequency Characteristic sensitivities values to the Low Pass Filter elements of the second degree are in the band (-1, +1.47). It should be noted that the maximum sensitivity of the analyzed Low Pass Filter (i.e. +1.47) manifests itself precisely at changes in the nominal values of the $\boldsymbol{RC}$ element.

The realization of the poles of the transfer function of the analyzed Low Pass Filter with quality factors $Q_p>1$ always results in the increase of the values of the sensitivities of the Amplitude - Frequency Characteristic towards each element and the sum sensitivity of the Amplitude - Frequency Characteristic. Theoretical and practical research has shown that, for example, if it is necessary to increase the Amplitude - Frequency Characteristic level for the analyzed second-order filters by +3 dB, this results in an increase in the level of Amplitude - Frequency Characteristic sensitivities to each element up to values of +2.3. The maximum summary sensitivity of the Amplitude - Frequency Characteristic reaches the value of +4.69 for the second degree Low Pass Filter analyzed.

Based on the obtained results, it can be concluded that the second-degree Low Pass Filter made on the basis of the electronic circuit in figure 1 has small sensitivities to the change of nominal components that do not exceed the value of 1 on average, up to 1.47 for a single component of the Low Pass Filter. Therefore, on the basis of the electronic circuit in figure 1, Low Pass Filters with a fairly high stability of the Amplitude - Frequency Characteristic can be realized, which will result in a prescribed operation of the transmission and reception channels of the telecommunications and information networks.

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LED Grow Lights

Vitalie Secrieru [1], ORCID: 0000-0002-1475-1943
Andrei Dorogan [1], ORCID:0000-0002-0518-035X
[1] Micro-Optoelectronics Laboratory, Technical University of Moldova, Chisinau, Republic of Moldova,
primcastgm@gmail.com

***Abstract.*— Lighting source based on 0.5W superluminescent light-emitting diodes. The destination of the light sources. The existing emission spectra, and the proposed one. The list of components, the modules used, the current prices on the domestic and foreign markets, the opportunities for assembling light emitters in the Republic of Moldova. The possibility of creating new jobs, reducing prices and increasing the reliability of light emitters.**

Keywords: LED, plant lighting, emission spectrum, price, economy, jobs.

I. INTRODUCTION

Plants need several conditions to grow, one of which is adequate lighting. With the help of lamps for plants, one can increase the duration of daylight hours, accelerate the growth of plants, and ensure photosynthesis. The use of artificial lighting allows you to achieve the desired result. A phytolamp is used for artificial lighting for plants, which can provide high efficiency and the necessary radiation spectrum, being universal or specialized for certain plants.

At the present time, great attention is paid to increasing the energy efficiency. Energy efficiency is one of the key aspects of any economic activity. The emergence of a new market of LED devices for lighting purposes has become possible due to the significant progress in the field of LED technologies and related technologies.

Successes in creating power sources (for LEDs) with an efficiency of 90% or more, ensuring an adequate thermal regime, producing efficient optical systems have served to create a market for LED lighting.

We aimed to create an universal spectrum, to analyze the prices of some components and modules that can be manufactured here or abroad and to adapt the concept of organizing the final assembly on the territory of the Republic of Moldova.

II. LED MANUFACTURERS

Currently, there are no manufacturers of superluminescent LEDs on the territory of the Republic of Moldova, however, these components can be easily purchased on the international market, with technical characteristics necessary for our needs at a reasonable price. In the world, there are several companies producing LEDs that account for the vast majority of the component market. Especially these companies are situated in Asia. The difference is in the technical characteristics and price [1-3]. In order to ensure the light efficiency and the necessary emission spectrum, we are obliged to use a combination of LEDs produced by world-renowned brands such as Samsung, Osram, but also low-cost LEDs produced in the People's Republic of China. In this paper, the case of assembling LED lamps based on 0.5W SMD technology is analyzed, which can offer an uniform filling of the PCB and ensure increased efficiency.

For example (white color), the LM301BEVO series LEDs can be used as white LEDs [4]:

b) Electro-optical Characteristics (I_F = 65 mA, Ts = 25°C)

Item	Unit	Rank	Bin	Min.	Typ.	Max.
Forward Voltage (V_F)	V	KA	AY	2.6	-	2.7
			AZ	2.7	-	2.8
			A1	2.8	-	2.9
Reverse Voltage (@ 5 mA)	V			0.7	-	1.2
Color Rendering Index (R_a)	-			80	-	-
Thermal Resistance (junction to solder point)	°C/W			-	7.5	-
Beam Angle	°			-	120	-

Figure 1. Electro-optical Characteristics, the opening voltage of the p-n junction

LEDs with Bin AY should be chosen, because these LEDs have the lowest opening voltage of 2.6-2.7V and therefore ensure the lowest losses at the potential barrier of the p-n junction.

We opted for CCT color temperatures of 4000K. If we analyze the electro-optical characteristics of these LEDs, it is obvious that the LEDs with a maximum luminous flux of 42 lumens must be chosen. These will ensure the maximum efficiency of the developed lamp.

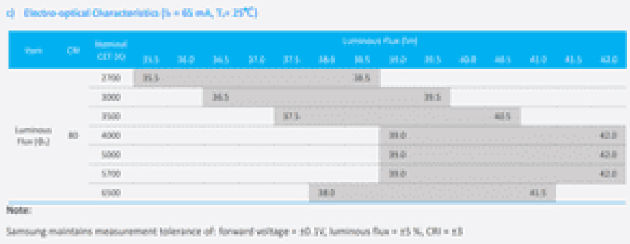
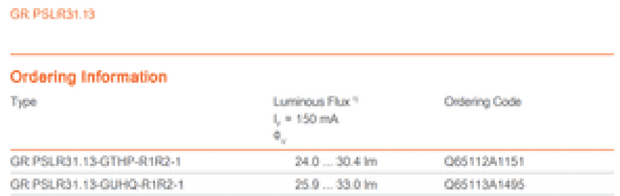


Figure 2. Electro-optical Characteristics, luminous flux for different color temperatures (CCT)

GR PSLR31.13 from Osram can be used for red color [5].



GR PSLR31.13

Ordering Information

Type	Luminous Flux, I_F = 150 mA, Φ_V	Ordering Code
GR PSLR31.13-GTHP-R1R2-1	24.0 ... 30.4 lm	Q65112A1151
GR PSLR31.13-GUHQ-R1R2-1	25.9 ... 33.0 lm	Q65113A1495

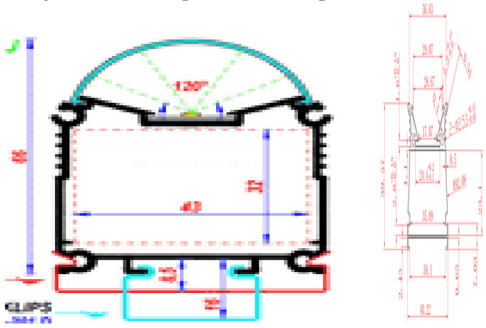
Figure 3. Osram LEDs and their luminous flux

We will give more details about these LEDs when we talk about the light spectrum of the developed lamp, and how a spectrum desired by the user can be obtained.

III. MANUFACTURERS OF PARTS, THE COMPLETE SET

The vast majority of parts manufacturers are located in China and, as a rule, they do not show much difference in quality from European or American ones (in case we are talking about LEDs), on the other hand, the price is very advantageous. Component parts can be found directly from the manufacturer (requires bulk orders ≥500 pieces) or from assembly or distribution companies.

Let's look, in particular, at the profiles for led lamps. In the figures below, three profiles will be considered, two of aluminum produced in the People's Republic of China and Turkey and one of plastic mass produced in Turkey.



a) b)

Figure 4. Aluminum profiles. Turkey (a) with a cost of $9.33 and China (b) with a cost of $8.6

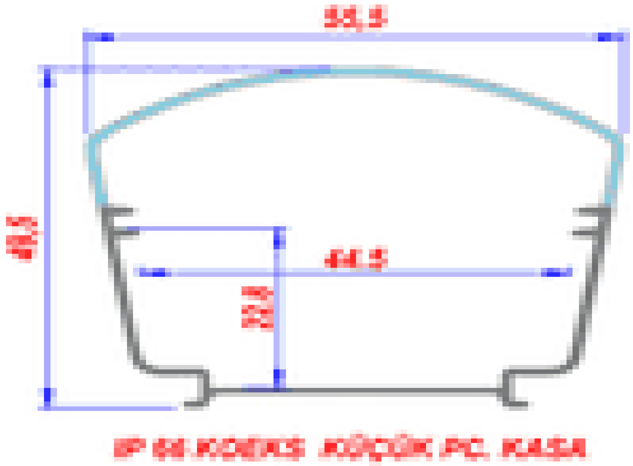


Figure 5. Plastic mass profile, Turkey at a cost of $6.62

From an economic and practical point of view, it is much better to use plastic mass profiles in ordinary greenhouses and in vertical greenhouses. They are up to 50% cheaper, provide an IP66 degree of protection and do not require grounding (to avoid electrocution).

When we talk about another component of phytolamps, the power block, a lot of manufacturers intervene. They differ according to technical characteristics and cost. We are most interested in the yield. Next, we present some manufacturers and the costs of the power supply blocks:

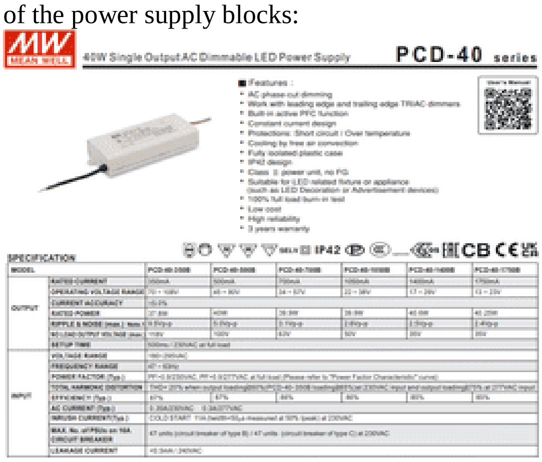


Figure 6. PCD-40-350B

This is a power supply block from the manufacturer MEAN WELL (one of the most well-known manufacturers on the world market). It has the following interesting features for us: Efficiency (Typ.) - 87%, Operating Voltage Range - 70 ~ 108V, cost up to $28.

Figure 8 shows another power supply unit CTC 39-350-110-1-П-Б IP20 001.01 This is a power supply unit from a Russian manufacturer. It has the following features: Efficiency (Typ.) > 90%, Operating Voltage Range - 60 ~ 110V, cost up to 7$.

Figure 7. Power block СТС 39-350-110-1-П-Б IP20 001.01

Power supply blocks of own production can also be used, for example a variation of the one presented in [6]. Such a power supply block can have sufficiently good performance characteristics and a lower net cost than those presented above, of only $3-4.

IV. Types of lamps used for plant growth. The emission spectrum of phytolamps

There are some technologies for making lamps for plants, which are classified as fluorescent, gas-discharge and LED [7].

However, the above technologies have their drawbacks. For example, fluorescent lamps for plants have been used for a long time, they have good light transmission, low cost and low heating. The disadvantage of these lamps is the influence of the light spectrum on the vision of humans and animals. Prolonged use can cause headaches.

Gas-discharge phytolamps are used exclusively in greenhouses, as they offer great heating, which provides heat and illumination. However, there is a high probability of increased humidity in the greenhouses, moisture falling on these lamps can lead to their explosion. Gas-discharge lamps have a short service life and high cost, and are considered dangerous to use.

LED bulbs for plants can be considered the best option in artificial lighting. They can be used in greenhouses, for domestic (indoor) plants, for an aquarium, for seedlings.

Until recently, only red and blue LEDs were used to illuminate plants [8]. It was believed that plants had enough of these two colors for their growth and development, and there was no need for a full spectrum of radiation. Subsequently, it became clear that this was not the case. Firstly, it is unpleasant for the working staff. Using only the red and blue parts of the spectrum adversely affects people's vision. Also, this does not fully reveal all the possibilities for the growth and development of plants.

Figure 8. Phytolamps using only red and blue spectrum

According to new research, LED grow lights can be made using only white LEDs because they contain a full spectrum including lots of blue and red light [9]. The use of only white LEDs is a compromise option, since they are technologically advanced, have high efficiency and low cost.

Figure 8. Phytolamps using white spectrum

However, the best results can be obtained using the combined use of LEDs. Phytolamps can be equipped with LEDs with a frame spectrum of luminescence, in which it is possible to achieve the development of a rhizome, a deciduous base, or the formation of fruits.

V. The emission spectrum of developed phytolamps and it's cost

The emission spectrum is one of the most important components of phytolamps, along with efficiency and cost. Consider the existing emission spectra, how we can improve them with minimal cost.

It is important to know what photosynthesis is and how it is characterized.

Photosynthesis is the conversion of light energy into the energy of chemical bonds in organic substances with the participation of special pigments.

In total, photosynthesis reactions look like this:

$$6CO_2 + 6H_2O + Qlight \rightarrow C_6H_{12}O_6 + 6O_2$$

Special pigments are built into thylakoid membranes - several types of chlorophylls, the main of which is chlorophyll a. They are green in color because they reflect green light and absorb blue-violet and red.

Chlorophylls are organized into photosystems of types I or II, differing in preferences for light of a certain spectrum and wavelength (the optimum of the second system is shifted to a redder region and is 700 nm, the first - 680 nm) [10]. It becomes clear that we need to get a red maximum at the level of 680-700nm.

Figure 9. The spectrum of a cheap Chinese lamp

This model consumes 36W (presented in figure 9), rather low efficiency, red maximum around 645nm.

Figure 10. Intermediate model of phytolamp

The lamp which spectrum is shown in figure 10 is improved. Here we used white LEDs from Samsung [1] and colored Chinese LEDs. The consumption decreased by 3W, which is 10%, but the maximum red light is at 650nm wavelength value.

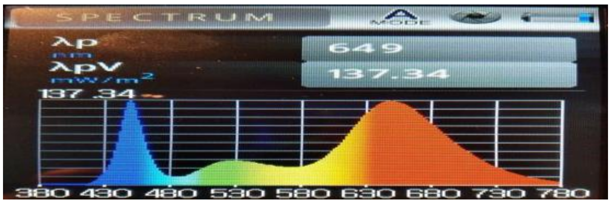


Figure 11. The spectrum of the developed phytolamp

It can be seen that this is 75% of the maximum of the red peak at 680nm. At 700nm this is about 50% of the maximum. Such results were obtained using LEDs from Osram [2]. Also, the consumption of this lamp is 28.5W, which is about 20% lower than that of the Chinese lamp. This means that using these lamps one can significantly improve the results of plant growth and development, while saving up to 20% on electricity.

LED	OR OR R R R R B B G G W W W W W
OR	Osram Red, Been HP/HQ
R	China Red
B	China Blue
G	China Green
W	Samsung White 4000K

Figure 12. LEDs in one cluster

The cost of such a phytolamp produced in the Republic of Moldova is $27 without VAT.

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A Differentiated Beneficiary Cybersecurity Approach

Ion Bolun [1], ORCID ID: 0000-0003-1961-7310
Svetlana Cojocaru [1], ORCID ID: 0000-0002-1187-4294
[1] Technical University of Moldova; 168, Stefan cel Mare Bd., MD-2004, Chisinau, Republic of Moldova;
ion.bolun@isa.utm.md, https://utm.md/

***Abstract*. The considerable losses caused by the low level of infospace's cybersecurity and the limited financial resources available imply the need to found effective ways to improve the implementation of measures counteracting cyber-attacks. First, some aspects regarding the situation in the field are characterized, including: industries most targeted by cyber-attacks, common types of cyber-attacks, industries' readiness to counteract cyber-attacks, and causes of cybersecurity breaches. Reducing the costs with cyber-securing the beneficiaries may be achieved by typifying the solutions. For this purpose, criteria are selected and categories of beneficiaries are defined. Then the necessary actions for the differentiated cybersecurity (by categories) of beneficiaries are formulated.**

Keywords: cyber-attack; cybersecurity breache; criteria; cybercrime costs; categories of beneficiaries.

I. INTRODUCTION [1]

Information has always been, is and will be a strategic resource: "Who owns the information - controls the situation". This motivates intruders to obtain illegal access to informatics (IT) resources and to operate for their own benefit with the owners' information. In such conditions, the owners of informatics resources are forced to take measures to counteract such actions.

The development and upward use of informatics means by businesses, organizations, institutions, and the population, especially of the Internet, has facilitated obtaining new information and operating with it. According to report [1], the total global data storage in the world is projected to exceed 200 zettabytes ($200x10^{21}$) by 2025. Worldwide there will be 29.3 billion networked devices by 2023, that is 3.6 networked devices per capita [2]. At 30 June 2022 they were 5.47 billion Internet users in the World [3] and IP traffic has reached an annual run rate of 2.3 zettabytes in 2020 [4].

But with the facilitation of obtaining new information and operating with it, the problem of cybersecurity in all areas of human activity has become more acute. From both sides (intruders – owners), efforts are being made and resources are being spent (human, financial, etc.) increasingly.

According to Cybersecurity Ventures, cybercrime will cost the world in excess of $7 trillion in 2022 and $10.5 trillion in 2025 [4], that is approx. 8.5% of global GDP of $129.7 trillion [5]. Cybercrime will propel global spending on cybersecurity products and services to $1.75 trillion (cumulatively) for the five-year period from 2021 to 2025, including $459 billion in 2025 [4]. For example, in august 2021 was announced that Microsoft will invest $20 billion to advance the security solutions over the next 5 years and Google will invest $10 billion over the next five years in cybersecurity [6].

So, both the global losses caused by the low cybersecurity of infospace and the costs of securing it are considerable. Obviously, costs reduction at a high quality of cybersecurity is possible by typifying the solutions - aspects that will be partially addressed in this article. But, first, some aspects regarding the situation in the field will be systematized.

II. SOME CYBERSECURITY ASPECTS

A. Industries Most Targeted by Cyber-Attacks

According to [8], to types of businesses or organizations most targeted (vulnerable) by cyber-attacks refer:

- **Banks and financial institutions** (credit card information, bank account information, and personal customer or client data);
- **Healthcare institutions** (repositories for health records, clinical research data, and patient records such as social security numbers, billing information, etc.);

[1] Research is supported by the National Agency for Research and Development of the Republic of Moldova, project 20.80009.5007.26.

- **Corporations** (product concepts, intellectual property, marketing strategies, client and employee databases, contract deals, client pitches, etc.);
- **Higher education** (information on enrollment data, academic research, financial records, and personally identifiable information like names, addresses, and billing info).

Also, at state level they are distinguished critical cybersecurity infrastructures, which incapacitation would have a debilitating effect on overall security, national economic security, national public health or safety. For example, in United States they are defined 16 critical infrastructure sectors, including: Communications, Critical Manufacturing, Energy, Financial Services, Government Facilities, Transportation Systems, and others [9].

Based on 2647 separate interviews conducted by Ponemon Institute in 355 companies in eleven countries, approx. 68 percent of business leaders feel their cybersecurity risks are increasing [10]. Cyber-attacks on all businesses, but particularly small to medium sized businesses (SMBs), are becoming more frequent - more than half of all cyber-attacks [11].

According to study [10], 43% of cyber-attacks are aimed at small businesses. This situation is caused to some extent by the fact that such businesses are not always aware of the degree of related risks, respectively they do not make the necessary cybersecuring efforts; but also because they have fewer resources (human, financial, etc.) that could be directed towards ensuring adequate cybersecurity.

B. Most Common Types of Cyber-Attacks

The World Economic Forum Global Cybersecurity Outlook 2022 report [12] surveyed 120 global cyber leaders from 20 countries on their greatest concerns when it comes to cyber threats. They were identified that Ransomware attacks are number one, followed by Social-engineering attacks and Malicious insider (employees and contractors inside the organization) activity.

According to Ponemon Institute's report [13], most common types of attacks on small businesses include: Phishing - 57%, Compromised/Stolen Devices - 33%, and Credential Theft - 30%. No matter of the size of businesses, the most common types of cyber-attacks are considered:

- according to Krontech [14] - Malware, Ransomware, Phishing, DoS (Denial of Service) and DDoS (Distributed DoS), Man in the Middle (MITM), Credential Stuffing, Password Attacks, IoT-Based Attacks, Cross-Site Scripting (XSS), and SQL Injections;
- according to CrowdStrike [15] - Ransomware, Malware, DoS and DDoS, Phishing, MITM, XSS, SQL Injections, DNS Tunneling, Password Attacks, Birthday Attacks, Drive By Attacks, Cryptojacking, and IoT-Based Attacks;
- according to Fortinet [16] - DoS and DDoS Attacks, MITM, Phishing, Ransomware, Password Attacks, SQL Injections, URL Interpretation, DNS Spoofing, Session Hijacking, Brute force attacks, Web Attacks, Insider Threats, Trojan Horses, Drive-by Attacks, XSS, Eavesdropping Attacks, Birthday Attacks, and Malware;
- according to Cisco [17] - Malware, Phishing, MITM, DoS and DDoS, SQL injections, Zero-day exploit, and DNS Tunneling.
- according to Varonis [18]: Ransomware, Malware, Phishing, and DoS.

One can observe that there are many common types of cyber-attacks in these estimations, including: Malware, Ransomware, Phishing, DoS and DDoS, MITM, Credential Stuffing/Password Attacks, IoT-Based Attacks, XSS, and SQL Injections.

C. Industries' Readiness to Counteract Cyber-Attacks

Organized cybercrime entities are joining forces, and their likelihood of detection and prosecution is estimated to be as low as 0.05 percent in the U.S., according to the World Economic Forum's report [25]. Only 14% of small businesses under cyber-attacks are prepared to defend themselves [10].

As a result of a survey were found [12] that 59 percent of all respondents would find it challenging to respond to a cybersecurity incident due to the shortage of skills within their team. About 46 percent of Cisco survey [26] respondents feel they are unable to effectively protect their data today. At the same time, according to the Cisco report [27] based on a survey of almost 500 SMBs (250-499 employees), less than 1 percent of SMB do not have anyone dedicated to security; 72 percent have employees dedicated to threat hunting; 56 percent have a daily or weekly patch routine; and an impressive 86 percent have clear metrics for assessing the effectiveness of their security.

D. Causes of Most Cybersecurity Breaches

Of course, cybersecurity breaches are caused by cyber-attacks. At the same time, a considerable part of these are also caused by unsuccessful actions of the owners of informatics resources, including:

- human errors - about 95 percent [19];
- Weak passwords, Application vulnerabilities, Back doors, Social engineering, Improper permission management, User errors, Insider threats, and Physical threats [20];

- Weak and stolen credentials, Back doors, Application vulnerabilities, Social engineering, Too many permissions, Insider threats, Physical attacks, Improper configuration, User errors [21];
- Weak and stolen credentials, Application vulnerabilities, and Insider errors [22];
- Human errors, Physical Theft/Loss of Devices, Stolen/Weak credentials, and Application/OS vulnerabilities [23].

By many of these estimations, such factors that cause cyber security breaches are common as: User/Human errors, Weak and stolen credentials, Application vulnerabilities, Improper permission management; Insider threats, and Physical threats.

It should also be mentioned that according to [24] mobile devices account for more than 60 percent of digital frauds.

III. Organization of Works to Cybersecuring the Beneficiaries

There are theoretical results and relatively effective practical means of cybersecurity in the world. They constitute a strong support for the determination of cybersecurity policies and means of beneficiaries. Under conditions of an acute shortage of financial resources, characteristic for the Republic of Moldova, it is opportune to typify related solutions by categories of beneficiaries with their subsequent adaptation to implementation.

For this purpose, it is necessary, first of all, to define the criteria and categorize (with the respective characterization) the beneficiaries of cybersecurity actions and measures. As beneficiaries, it is appropriate to examine the enterprises/organizations/institutions [28], hereafter "***organizations***", but also the ***population***. In case of population, the use of informatics means by persons outside the organizations is considered. At the same time, the organizations and, also, individuals can differ considerably from the point of view of cybersecurity needs. Therefore, in order to define the categories of beneficiaries in question, it is necessary to establish additional criteria.

The Center for Internet Security in [29] proposes the implementation of cybersecurity controls, depending on the scale of organizations (the ***number of employees***):

- small (up to 10 employees)
- medium;
- large.

In [28], when estimating the degree of cybersecurity readiness, they were distinguished five categories of organizations by the number of employees:

- up to 10 inclusive;
- 11-50;
- 51-100;
- 101-500;
- over 500.

At the same time, according to [8] because of the nature of their business, some industries are more targeted by cyber-attacks than others. Therefore, it is opportune to differentiate the beneficiaries also by the ***degree of cybersecurity*** actions and measures needed. For the beginning, it will used the latter of the nominated above classifications of organizations by the number of employees. Of course, as a result of additional research, it may be modified. Also, they will be distinguished the following four types of degree of cybersecurity (see Table 1):

- high;
- enhanced;
- medium;
- ordinary.

TABLE 1. CATEGORIES OF ORGANIZATIONS-BENEFICIARIES (17)

Degree of cybersecurity	Number of employees				
	< 11	11÷50	51÷100	101÷500	> 500
High cybersecurity	-	-	+	+	+
Enhanced cybersecurity	-	+	+	+	+
Medium cybersecurity	+	+	+	+	+
Ordinary cybersecurity	+	+	+	+	+

With refer to the population, it is also appropriate to use as criteria the ***person's age*** and for adults – the ***social status***: employed or unemployed. Employees, even outside of the work place, sometimes operate with work information using informatics means; this imposes higher requirements of cybersecurity to the respective activities compared to the ones to those of unemployed persons. Thus, for the population it is proposed to use the following five categories:

1. Children (up to and including 11 years old).
2. Teenagers (12÷17 years old).
3. Adults (18+ years old) employed - enhanced cybersecurity.
4. Adults (18+ years old) employed - medium cybersecurity.
5. Adults (18+ years old) - ordinary cybersecurity.

Knowing the categories of beneficiaries, they are also necessary to:

a) identify and systemize the dangers, vulnerabilities and needs regarding the cybersecurity of beneficiaries (by categories);
b) define the priorities and stage the measures and actions for cybersecuring the beneficiaries, taking into account the approach [30];
c) systemize the cybersecurity means to be used, taking into account the priorities (b);
d) set up the models of cybersecuring the beneficiaries (by categories);

e) define the set of criteria characterizing the degree of cybersecurity provided by models (d);
f) explore and characterize the system of models (d);
g) implement step by step the models (d) in practice, taking into account the results obtained according to items (e) and (f).

IV. CONCLUSIONS

The systematization of major aspects of infospace cybersecurity in the world allows the formation of a clearer vision regarding the state of affairs in the field. Losses caused by cyber-attacks and the costs of counter-acting them are considerable. In order to reduce costs and implement as successfully as possible, it is opportune the differentiated cybersecuring (by categories) of enterprises/organizations/institutions and the population, using the typification of respective solutions with rigorous adaptations to their implementation in practice. Based on certain criteria, the categories of beneficiaries are defined. Also, the necessary actions and measures for the differentiated cybersecurity (by categories) of beneficiaries are broadly formulated.

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Privacy and Mutual Authentication under Temporary State Disclosure in RFID Systems

Ferucio Laurențiu Țiplea [1], ORCID: 0000-0001-6143-3641
Cristian Hristea [2], ORCID: 0000-0003-0132-9310
Rodica Bulai [3], ORCID: 0000-0002-7878-2431
[1] "Alexandru Ioan Cuza" University of Iasi, Iasi, Romania, ferucio.tiplea@uaic.ro
[2] Simion Stoilow Institute of Mathematics of the Romanian Academy, Bucharest, Romania, cristi.hristea@gmail.com
[3] Technical University of Moldova, Chisinau, Republic of Moldova, rodica.bulai@ati.utm.md

***Abstract*—Privacy and mutual authentication are two significant requirements for real-life applications of RFID schemes. These two requirements have been studied for a long time only for adversaries that cannot corrupt the temporary internal state of the tags. Recently, however, it has been shown that corrupting the temporary internal state of the tag is practically possible. This raises the question: do the current RFID protocols that ensure mutual authentication and privacy keep these properties in the temporary state disclosure model? The answer is negative and thus it justifies the effort to propose new RFID protocols that are secure under temporary state disclosure.**

In this paper, we amply discuss how temporary state disclosure affects mutual authentication and privacy of RFID protocols, and illustrate this on two well-known protocols. We argue then in favor of using the PUF technology in order to achieve mutual authentication and a reasonable enough level of privacy under temporary state disclosure. We close by presenting two RFID schemes that achieve destructive privacy, one of the most important levels of privacy in the context of the physical corruption of tags.

Keywords – Authentication, privacy, PUF, RFID system.

I. INTRODUCTION

The radio frequency identification (RFID) technology has been implemented in many significant areas such as toll collection systems, identification, and tracking of various kinds of objects, consumer products, or access control. With the increasing usage of healthcare, electronic passports, and personal ID cards, the potential security threats and compliance risks have become enormous. In such a context, the need for secure and private communication protocols between readers and tags becomes crucial. Moreover, when developing such protocols, an account must be taken of the adversary model to which they should resist.

Traditionally, the RFID adversarial models did not take into account the tag corruption capability revealing the temporary state of tags. However, it has recently been shown that temporary state disclosure is practically possible. This raises the alarm about the security of the existing RFID protocols: are they still secure and private? A quick analysis of the protocols in [1], which achieve mutual authentication, shows that none of them achieve the claimed privacy level under corruption with temporary state disclosure. This does not even happen [2] with newer protocols like those in [3] and [4].

Contribution: In this paper, we develop an analysis of the security and privacy properties of RFID protocols under temporary state disclosure in Vaudenay's model. Thus, we discuss two fundamental protocols that ensure mutual authentication but lose the property of privacy when the adversary can obtain the temporary states of the tags (Section 3). Our analysis highlights the essence of the problem we face.

We then turn our attention to PUF technology (Section 4), which is probably the only one that can help obtain mutual authentication property and a good level of privacy under temporary state disclosure.

Finally (Sections 5 and 6), we discuss the level of destructive privacy and briefly present two of our recently developed schemes.

Related work: The pseudo-random function (PRF) based RFID scheme in [1] achieves weak privacy and mutual authentication in Vaudenay's model. It is straightforward to see that the proof in [1] works even in the case of corruption with temporary state disclosure. The first PUF-based RFID scheme that achieves destructive privacy and mutual authentication in Vaudenay's model (where corruption does not disclose the temporary state of tags) was proposed in [2], as an extension of the scheme in [5], [6] (that only achieves unilateral authentication).

In [3], [4], two PUF-based RFID schemes have been proposed and claimed that they achieve (narrow) destructive privacy and mutual authentication in Vaudenay's model with temporary state disclosure. Unfortunately, neither of them reaches even the narrow forward privacy level [2]. The RFID scheme in [2] provides mutual authentication and destructive privacy in Vaudenay's model. Moreover, [7] proposes a general method by which the RFID schemes from [3] and [4] can be fixed in terms of privacy. Undoubtedly, the most efficient RFID scheme that provides mutual authentication and destructive privacy in Vaudenay's model with temporary state disclosure is the one in [8]. A new novel RFID scheme that achieves mutual authentication and destructive privacy in Vaudenay's model with temporary state disclosure was recently proposed [9].

II. RFID SYSTEMS

RFID schemes: Let R be a *reader identifier* and T be a set of *tag identifiers* whose cardinal is polynomial in some security parameter λ. An RFID *scheme over* (R,T) [1], [10] is a triple $S = (SetupR, SetupT, Ident)$ of PPT algorithms, where *SetupR* initializes the reader and its database *DB*, *SetupT* initializes a tag and stores a corresponding entry in *DB*, and *Ident* is an interactive protocol between the reader identified by R (with database *DB*) and a tag identified by *ID* (with state S). An *Ident* instance ends with output from both the reader (*ID* or $\perp$) and the tag ($\perp$ or *OK*).

For mutual authentication RFID schemes, *correctness* means that, regardless of how the system is set up, after each complete execution of the interactive protocol between the reader and a legitimate tag, the reader outputs the tag's identity, and the tag outputs *OK* with overwhelming probability.

Adversarial model: There have been several proposals for an adversarial model [1], [10], [11], [12], [13] for RFID schemes. In this paper, we follow *Vaudenay's model* [1], [10]. In this model, a tag can be either *drawn* or *free* based on adversarial access to the tag (proximity). An adversary can access a drawn tag only through a temporary unique identifier *vtag*.

The adversarial capabilities are modeled through oracles. The adversary can create tags (*CreateTag*), move a tag between the drawn and the free set of tags (*DrawTag*,*Free*), eavesdrop and manipulate de communication (*SendTag, SendReader*), obtain the internal state of a tag (*Corrupt*), and learn whether a particular protocol instance was successful (*Result*).

Based on access to the *Corrupt* oracle, adversaries are classified into: *weak* (no access to *Corrupt*), *forward* (no other oracles can be used after *Corrupt*), *destructive* (after corrupting a tag it is considered destroyed), and *strong* (no restrictions). Another class of adversaries, called *narrow,* is created when the adversary is denied access to the *Result* oracle. Combining this with the previous classes we obtain four more classes of adversaries: *narrow weak*, *narrow forward*, *narrow destructive*, and *narrow strong*.

Security: *Security* for RFID schemes is composed of two complementary notions: *tag authentication* and *reader authentication*. An RFID scheme has the property of *tag authentication* if no strong adversary has more than a negligible advantage in causing the reader to authenticate an uncorrupted legitimate tag in a protocol instance where the reader had no conversation with that tag to lead upon its authentication. An RFID scheme has the property of *reader authentication* if no strong adversary has more than a negligible advantage in causing an uncorrupted legitimate tag to authenticate the reader in a protocol instance where the tag had no conversation with the reader to lead upon its authentication.

Privacy: *Privacy* in Vaudenay's model generalizes anonymity (which means that the tag ID cannot be inferred) and untraceability (which means that the equality of two tags cannot be inferred). Thus, privacy requires that no adversary can infer non-trivial tag ID relations from the protocol messages. The information provided by a protocol is trivial when the adversary may learn it without making effective use of the protocol messages. To formalize this, Vaudenay's model introduces the concept of a *blinder* that simulates the protocol for adversary without knowing any secret information of the tags or the reader. If this simulation does not change the adversary's output compared to the case when the adversary plays with the real protocol, then the protocol achieves privacy.

III. PRIVACY AND MUTUAL AUTHENTICATION UNDER TEMPORARY STATE DISCLOSURE

When Vaudenay's model was proposed [10], it was somewhat unclear whether the *Corrupt* oracle returns the full (i.e., permanent and temporary) tag state or only the permanent one. This has also remained unclear in the next year's paper [1] on mutual authentication. While the distinction between full and permanent state did not have a negative impact on the results already obtained in the case of unilateral authentication, it highlighted several wrong results in the case of mutual authentication [14].

In the very interesting paper [14] a series of impossibility results were established, with respect to the privacy and mutual authentication in RFID schemes. One of them, namely Theorem 1, says that there is no RFID scheme that achieves both reader authentication and narrow forward privacy in Vaudenay's model with temporary state disclosure. The argument is as follows. Given a blinder B, one may construct an adversary A against reader authentication so that, if the scheme is narrow forward private then A has a non-negligible advantage to authenticate itself as a valid reader. Going inside the proof, we remark that it is crucial the *Corrupt* oracle returns the full state of a tag in order to allow an adversary to perform the test by which the tag authenticates the reader. By this test, the adversary distinguishes with a non-negligible probability between the real privacy game and the blinded one.

In conclusion, none of the random oracle (RO) or public-key cryptography (PKC) based RFID schemes in [1] achieves mutual authentication and the privacy level claimed in [1] if Vaudenay's model allows corruption with temporary state disclosure.

The RO-based RFID scheme in [1], [10] needs a detailed discussion in order to understand why Theorem 1 applies to this case as well. To define this scheme, two public random oracles F and G that run two random functions, one from $\{0, 1\}^{k+\ell}$ to $\{0, 1\}^k$ and the other one from $\{0, 1\}^k$ to $\{0, 1\}^k$, are needed. The *SetupT(pk, ID)* algorithm creates a tag with the identity *ID* and a (permanent) state consisting of a key $K \leftarrow \{0, 1\}^k$. The pair (*ID*, *K*) is stored in the reader's database *DB*. The reader and all tags are granted (secure) access to the oracles F and G. One may also think that copies of these oracles are distributed to the reader and all tags. The interactive protocol *Ident* is pictorially represented in Figure 1.

Now, we have to clarify what corruption means in the case of this protocol. As F and G are public random oracles, the adversary is granted access to them as well.

The *Corrupt* oracle returns only the tag state but not the internal structure of the oracles F and G (which are thought of as black boxes). Therefore, an adversary that corrupts a tag and gets a state $G(K)$ will not be able to "inverse" this value or to do any other computation derived from the internal structure of these oracles, except with negligible probability. This is somewhat opposite to pseudo-random functions whose internal structure is supposed to be known. For instance, if we consider the candidate pseudo-random function $DES = (DES_K)_{K\in\{0,1\}^{64}}$, a key K, and a cyphertext $c = DES_K(x)$, one may efficiently compute the plaintext x.

In conclusion, an adversary that corrupts a tag and gets its key K may get $F(K, x)$ and $G(K)$ by querying the oracles F and G (but not by corrupting them). Therefore, the tag can perfectly be simulated by an adversary, and Theorem 1 in [14] can be applied in this case (in fact, the adversary only needs to know w' in order to do the tag's test in the last step).

IV. RFID DESIGN BASED ON PUF TAGS

A *physically unclonable function* (PUF) can be seen as a physical object that, when queried with a challenge x generates a response y that depends on both x and the specific physical properties of the object. PUFs are typically assumed to be *physically unclonable* (indistinguishable on their challenge/response behavior), *unpredictable* (infeasible to predict the response to an unknown challenge), and *tamper-evident* (any attempt to physically access the PUF irreversible changes its behavior).

From a theoretical point of view, a PUF is a physical object with a challenge/response behavior that implements a function $P:\{0, 1\}^p \rightarrow \{0, 1\}^k$, where p and k are of polynomial size in λ, such that P is computationally indistinguishable from U and any attempt to physically tamper with the object implementing P results in the destruction of P (P cannot be evaluated any more).

The newest RFID technologies allow *PUF tags* that are tags with PUFs inside them. In order to adapt Vaudenay's model (with or without temporary state disclosure) to RFID schemes with PUF tags, we have to clarify what corruption means in this case. At least two main scenarios are possible:

1) Any corruption on a PUF tag destroys the tag. By corruption, one gets the (full) state except for the values computed by the PUF (assuming that they were not saved in the tag's memory);
2) The PUF tag is destroyed by corrupting it, but some values returned by its PUFs are obtained (an example in this sense is the *cold boot attack* in [15] according to which the tag may be frozen at some time to obtain the PUF value).

	Reader (DB, F, G)		**Tag** (F, G, K)
1	$x \leftarrow \{0,1\}^\ell$	$\xrightarrow{x}$	
2		$\xleftarrow{z}$	$z = F(0, K, x),\ w' = F(1, K, x),$ $K = G(K)$
3	If $\exists(ID, K) \in DB$ and $0 \leq i < t$ s.t. $z = F(0, G^i(K), x)$ then output $ID,\ K = G^i(K),\ K' = K$ else output $\perp,\ K' \leftarrow \{0,1\}^k$ $w = F(1, K', x)$	$\xrightarrow{w}$	
			If $w = w'$ then output OK else output $\perp$

Figure 1. RO based RFID scheme in [1]

The first scenario is the most used one and it is the one adopted in our paper. As the corruption of PUF-based tags does not reveal the full tag state, PUF tags cannot generally be simulated by adversaries. Working in this scenario, Theorem 1 in [14], at least in its present form, cannot be applied to RFID schemes with PUF tags. This leaves open the invitation to design RFID schemes that achieve mutual authentication and higher privacy levels than narrow forward in Vaudenay's model with temporary state disclosure. As we have already said, such schemes cannot be based on ordinary tags. A good choice is to use PUF tags, as it was done in [2], [3], [4], [5], [6]. However, the use of PUF tags does not mean that the schemes are immune to corrupting adversaries. This is because an adversary might not need the entire tag state to attack the scheme. An example in this sense is provided in [2] where it was shown that the RFID schemes proposed in [3], [4] do not achieve mutual authentication and (narrow) destructive privacy in Vaudenay's model with temporary state disclosure, as it was claimed by authors, although they use PUF tags. The proof exploits the fact that these schemes use volatile variables to carry values between protocol steps.

The second scenario was touched on by several research papers such as [3], [4], and [15]. We are not aware of any formal treatment of this scenario in Vaudenay's model. To implement this scenario in Vaudenay's model, the *Corrupt* oracle should be changed to return snapshots of the tag's state during its computation (recall that the standard *Corrupt* oracle returns the tag's state before or after a protocol step). A formal and complete treatment of such corruption seems hard to reach; on the other side, such corruption is very strong, and probably no PUF-based RFID scheme may achieve a privacy level higher than (narrow) weak under such corruption. However, special cases may be relevant. One of them is the cold boot attack mentioned above. To defeat it, a PUF double evaluation technique was proposed in [15], which consists of two evaluations in a row of the same PUF. If the attack is applied immediately after the first PUF evaluation, the second PUF evaluation is lost, and vice-versa. This technique was implemented in two RFID schemes [3], [4]. Unfortunately, the authors did not pay much attention to the volatile variables, which made their schemes not achieve even the narrow forward privacy level [2].

Recall that a (narrow) strong adversary may corrupt a tag multiple times. However, working in the first corruption scenario mentioned above (with PUF tags), (narrow) strong adversaries become in fact (narrow) destructive. This is because corruption destroys the PUF tag and, therefore, it cannot be further used. Therefore, Vaudenay's model (with or without temporary state disclosure) for RFID schemes with PUF tags is limited to at most (narrow) destructive privacy.

The PRF-based RFID scheme in [1] achieves mutual authentication and weak privacy in Vaudenay's model with temporary state disclosure. This simply follows from the proof in [1] together with the remark that weak adversaries are not allowed to corrupt tags.

V. DESTRUCTIVE PRIVACY AND READER-FIRST AUTHENTICATION

An interesting question that arises when designing mutual authentication RFID schemes is whether the tag or the reader should be authenticated first. We have thus two approaches: *tag-first* and *reader-first authentication*, respectively [16]. The *tag-first authentication* has some advantages with respect to desynchronization: the tag computes its new state and sends information about it to the reader. However, the tag state is updated only when the reader authenticates the tag and confirms the new state to the tag. The disadvantage of this approach is that the tag should provide some information to the reader before it is confident of the reader's identity.

The *reader-first authentication* might enhance the tag privacy because the tag gives private information to the reader when it is confident of its identity. This also might help prevent adversaries from tracking tags. Another advantage is when the tag is designed only for a limited number of authentications. In such a case, the reader-first approach prevents a form of denial of service attack that would "consume" all the tag's authentication answers.

In [9], a destructive private and mutual authentication RFID scheme in Vaudenay's model with temporary state disclosure was proposed. For mutual authentication it follows the reader-first approach and, according to our discussion in Section 3, all tags are endowed with PUFs.

To describe our scheme, let us assume that λ is a security parameter, $\ell_1(\lambda)$ and $\ell_2(\lambda)$ are two polynomials, and $F = (F_K)_{K \in \mathcal{K}}$ is a pseudo-random function, where $F_K : \{0, 1\}^{2\ell_1(\lambda)+2} \rightarrow \{0, 1\}^{\ell_2(\lambda)}$ for all $K \in \mathcal{K}_\lambda$. Each tag is equipped with a (unique) PUF $P : \{0, 1\}^{p(\lambda)} \rightarrow \mathsf{K}_\lambda$ and has the capacity to compute F, where $p(\lambda)$ is a polynomial. The internal state of the tag consists of a pair (s, x), where $s \in \{0, 1\}^{p(\lambda)}$ is randomly chosen as a seed to evaluate P, and $x \in \{0, 1\}^{\ell_1(\lambda)}$ is a random string used as a "dynamic" identifier of the tag. The reader maintains a database DB with entries for all legitimate tags. Each entry is a vector (ID, K, x), where ID is the tag's identity and $K = P(s)$, where P is the tag's PUF and (s, x) is its state.

The mutual authentication protocol is given in Figure 2. Remark that if the reader does not update x (because it rejects the tag), then it will do so in step 2 of the next protocol session (with the same tag). Therefore, the desynchronization between reader and tag is at most one step.

Theorem 5.1. ([9]) The RFID scheme in Figure 2 is correct ad achieves mutual authentication and destructive privacy in Vaidenay's model with temporary state disclosure, provided that F is a pseudo-random function and the tags are endowed with ideal PUFs.

VI. NARROW DESTRUCTIVE PRIVACY AND READER FIRST AUTHENTICATION

With little effort, the RFID scheme in Figure 2 can be simplified to a narrow destructive private and reader-first authentication RFID scheme in Vaudenay's model with temporary state disclosure. The mutual authentication protocol of this new RFID scheme is presented in Figure 3; all the other elements are as in Section 5, except that F_K is a function from $\{0, 1\}^{\ell_1(\lambda)+2}$ to $\{0, 1\}^{\ell_2(\lambda)}$ and t is polynomial in the security parameter. As one can see, there is no random generator on the tag. Because of this, the synchronization between tag and reader can be lost. The only thing we can do is to check (on the reader side) for a polynomial bounded desynchronization. Due to this, the scheme can be at most narrow destructive private: if an adversary desynchronizes the tag and reader sufficiently enough (for more than t steps), then it will be able to distinguish the real privacy game from the blinded one by means of the *Result* oracle. Roughly speaking, this is because in the real privacy game the *Result* oracle returns 0 (when the tag and reader are desynchronized for more than t steps), while in the blinded privacy game it returns 1.

	Reader (DB, F)		**Tag** (P, s, F, x)
1		$\xleftarrow{u,z}$	$u \leftarrow \{0,1\}^{\ell_1(\lambda)}$, $K = P(s)$ $z = F_K(0,0,u,x)$ erase K, u, z
2	If $\exists(ID, K, x) \in DB$ and $i \in \{0,1\}$ s.t. $z = F_K(0,0,u,x+i)$ then $v \leftarrow \{0,1\}^{\ell_1(\lambda)}$, $x = x+i$ $w = F_K(0,1,v,x)$ else $v \leftarrow \{0,1\}^{\ell_1(\lambda)}$, $w \leftarrow \{0,1\}^{\ell_2(\lambda)}$	$\xrightarrow{v,w}$	
3		$\xleftarrow{w'}$	$K = P(s)$, $w' = F_K(0,1,v,x)$ If $w = w'$ then $x = x+1$, $w' = F_K(1,1,v,x)$ else $w' \leftarrow \{0,1\}^{\ell_2(\lambda)}$ erase K, v, w, w'
4	If $w' = F_K(1,1,v,x+1)$ then output ID, $x = x+1$ else output $\perp$		

Figure 2. Destructive private and reader-first authentication PUF based RFID scheme in Vaudenay's model with temporary state disclosure

Theorem 6.1. ([9]) The RFID scheme in Figure 3 achieves mutual authentication and narrow destructive privacy in Vaudenay's model with temporary state disclosure, provided that F is a PRF and the tags are endowed with ideal PUFs.

It is good to remark that our RFID scheme in Figure 3 also provides an appropriate practical solution to the narrow destructive privacy in the plain Vaudenay's model, where the existing solution is based on random oracles.

A few more words on desynchronization are in order. If we look at the protocol in Figure 3 we remark that the desynchronization is a result of the fact that the tag and reader share a common variable x that is updated by the tag before authenticating the reader. This allows an adversary to query a tag more than t times and, therefore, to desynchronize the tag and the reader.

To prevent desynchronization between reader and tag in reader-first authentication RFID schemes, the tag should update the shared permanent variables after authenticating the reader, and not before.

VII. CONCLUSIONS

Modern applications of RFID systems ask for advanced security and privacy properties. For instance, tag destruction under corruption is an important requirement when the tag is used for access control. Likewise, the disclosure of temporary state under tag corruption is a serious threat in practice. Reader-first authentication [16] assures that the tag will give its private data only when it authenticates the reader. Therefore, tag tracking and data theft are prevented when the reader is fake. All these together mean that we need RFID schemes that provide destructive privacy and reader-first authentication under corruption with temporary state disclosure.

In this paper, we amply discussed how temporary state disclosure affects mutual authentication and privacy of RFID protocols. We argued then in favor of using the PUF technology in order to achieve mutual authentication and a reasonable enough level of privacy under temporary state disclosure. Finally, we presented two RFID schemes that achieve destructive privacy, one of the most important levels of privacy in the context of the physical corruption of tags.

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	Reader (DB, F)		**Tag** (P, s, F, x)
1		$\xleftarrow{z}$	$K = P(s)$ $z = F_K(0, 0, x)$ erase K, z $x = x + 1$
2	If $\exists(ID, K, x) \in DB$ and $0 \leq i < t$ s.t. $z = F_K(0, 0, x + i)$ then $x = x + i$, $w = F_K(0, 1, x + 1)$ else $w \leftarrow \{0, 1\}^{\ell_2(\lambda)}$	$\xrightarrow{w}$	
3		$\xleftarrow{w'}$	$K = P(s)$ If $w \neq F_K(0, 1, x)$ then $w' = F_K(1, 1, x)$ else $w' \leftarrow \{0, 1\}^{\ell_2(\lambda)}$ erase K, w, w'
	If $w' = F_K(1, 1, x + 1)$ then output ID, $x = x + 1$ else output $\perp$		

Figure 3. Narrow destructive private and reader-first authentication PUF based RFID scheme in Vaudenay's model with temporary state disclosure

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Attribute-Based Encryption for Weighted Threshold Access Structures

Alexandra-Ina BUTNARU [1], ORCID: 0000-0001-8180-7727
[1] Faculty of Computer Science, "Alexandru Ioan Cuza" University of Iași, 16 General Henri Mathias Berthelot Street, Iași, alexandraibutnaru@gmail.com

***Abstract*— Access control is a fundamental security component in a system, especially in rapidly developing domains such as the cloud or the Internet of Things. The nature of these domains renders formerly acclaimed access control techniques inefficient in environments that are distributed and need highly scalable solutions. Attribute-based access control offers a multitude of advantages, especially through its cryptographic implementation, attribute-based encryption. Weighted threshold access structures are structures that closely cover real-life scenarios and have high applicability in practice as access control policies.**

Keywords*— *access control; attribute-based access control; attribute-based encryption; weighted threshold access structures

I. INTRODUCTION

Some of the most powerful and fast-paced technologies today, for example the internet of things (IoT) and the cloud, have created a need for stronger, faster, more flexible security solutions than the ones we have employed up until now. It is more common than ever for multiple applications to make use of the same data, a phenomenon which has led to a shift in the industry towards data-centric security and therefore data-centric access control.

The most widely used paradigms in the past, such as mandatory access control (MAC), discretionary access control (DAC) and more recently role-based access control (RBAC), are user-centric and cannot take into consideration contextual information like the time of the day or parameters like the relationship between the user and the resource for which access is requested. Furthermore, they have proven not to be enough when using technologies which employ a large number of devices or users and require speed, strong security and resource efficiency. Even RBAC, the most flexible and expressive out of the access control models mentioned, has been criticized for leading to role explosion and becoming unmanageable in large scale systems [1].

One of the main advantages attribute-based access control has over other access control solutions is the finer granularity it offers due to directly basing authorization on attributes that the requesting party holds.

An additional argument is the overall industry need for better security and the needs that new, distributed, big data technologies (IoT, wireless sensor networks, the cloud) have created, for example when device storage and power is severely limited or the system has highly unsafe components (like public servers and networks). As the number of data breaches and the number of records exposed increases, the money spent by companies to recover data encrypted by ransomware attacks goes well into billions each year.

II. PRELIMINARIES

A. *Attribute-Based Access Control*

One of the core concepts in information security is access control and attribute-based access control is a more powerful and flexible solution than other historically acclaimed techniques specifically because of the use of attributes.

Over time, two major solutions have developed in order to realize the ABAC concept: the first one consists of standardized languages like the eXtensible Access Control Markup Language (XACML) [2] (which is used to define access policies and requests to information), the second one entails using mathematics rather than software for enforcing access control and is called attribute-based encryption [3]. The cryptographic approach has a considerable advantage in flexibility over the other because the encrypted data contains the access control, meaning that it is not reliant on infrastructure and it also can be stored on any, secure or not, public or private servers .

Even though businesses have shied away from using ABAC until recently, the European Telecommunications Standards Institute (ETSI) has released two specifications ([4], [5]) on Attribute-Based Encryption (ABE) for access control and declared it a key enabler technology. By enforcing access control at a mathematical level, ABE is the better solution in terms of security than the ones enforcing it through techniques that rely on software.

The National Institute of Standards and Technology (NIST) has recommended certain key sizes for elliptic curve cryptography (ECC) and showed the cryptographic security each of them offers in comparison to the well-established RSA [6], further reinforcing the superior efficiency of ABE solutions.

B. Attribute-Based Encryption

Sahai and Waters introduced the concept of attribute-based encryption [7] in 2005 as a technique that allows ciphertexts to be encrypted under a collection of attributes and secret keys to contain authorization policies so that a user's private key will only be able to decrypt data that has been encrypted with the attributes that match their policy.

Up until recently attribute-based encryption solutions have mostly been either impractical, not secure or very limited in regards to the policies they can express. Lattice-based solutions, although secure, are infeasible in practice because of the expansion of both the decryption key and the ciphertext. As we do not have at the present time a secure multilinear map candidate, the preferable solution is using just one bilinear map over an elliptic curve in order to construct such schemes [8].

The main advantages of using ABE are inherently the ones offered by ABAC: decreased key size with an increased security and speed of computation, even on smaller, mobile devices with low computational power, and more flexible and expressive access control policies that closely model real-world situations.

Another crucial security aspect of attribute-based encryption is collusion-resistance: an adversary that holds multiple keys should only be able to access data if at least one individual key grants access.

One more advantage ABE has over other cryptographic protocols is its capability to provide data protection (e.g. compliance with General Data Protection Regulation - GDPR) by using attributes that do not disclose sensitive information like a person's name.

A. CP-ABE

Ciphertext-policy attribute-based encryption is the variant of ABE where messages get encrypted with policies under sets of attributes and the central authority distributes decryption keys to which the users' attributes are associated. A user will only be able to decrypt a ciphertext if his attributes satisfy the ciphertext's corresponding policy. The feature is called implicit authorization.

B. KP-ABE

Key-policy attribute-based encryption associates access control policies to the users' private keys, while the ciphertexts are encrypted under finite sets of attributes. A ciphertext's attributes must satisy a user's key's policy in order for the user to have access to the requested resource.

A key-policy attribute based encryption (KP-ABE) scheme consists of four probabilistic polynomial-time (PPT) algorithms [3]:

- Setup(λ): this is a PPT algorithm that takes as input the security parameter λ and outputs a master key MSK and a set of public parameters PP;
- Encrypt(m,A,PP): this is a PPT algorithm that takes as input a message m, the public parameters PP and a non-empty set of attributes A ⊆ U and outputs a ciphertext E;
- KeyGen(□,MSK): this is a PPT algorithm that takes as input the master key MSK and an access structure □ (given as a Boolean circuit) in order to output a decryption key D (for the entire Boolean circuit □);
- Decrypt(E,D): this is a deterministic polynomial-time algorithm that takes as input a ciphertext E and a decryption key D as described above and outputs the decrypted message m or the special symbol ⊥.

C. Access Control Structures

$\mathbb{Z}$ denotes the set of integers. A positive integer a > 1 is a prime number if its only positive divisors are 1 and a. Two integers a and b are called *congruent modulo n* (denoted $a \equiv b$ mod n) if n divides $a–b$ (n is also an integer).

Let $\{P_1, \ldots, P_n\}$ be a set of elements called parties or participants, and $2^{\{P_1,\ldots,P_n\}}$ the set of all subsets of $\{P_1, \ldots, P_n\}$. A collection A is monotone if ∀ □, □: if □ ∈ A and □ ⊆ □ then □ ∈ A. An access structure (respectively, monotonic access structure) is a collection (respectively, monotone collection) A of non-empty subsets of $\{P_1, \ldots, P_n\}$, i.e., $A \subseteq 2^{\{P_1,\ldots,P_n\}} \setminus \{\emptyset\}$. The sets in A are called the authorized sets, and the sets not in A are called the unauthorized sets.

In the following we refer to monotonic access structures whenever access structures are mentioned.

D. Weighted Threshold Access Structures

Weighted threshold access structures are a concept introduced by Shamir [9] that mirror scenarios where an authority wishes to share a secret between multiple parties so that particular subsets of those parties can recover the secret. The fragments of the secret that the aforementioned parties get are called shares. The secret can only be reconstructed if the weights of the parties surpass a threshold established by the authority sharing the secret [10].

Let U be the set of all attributes, a weight function $\omega: U \to N$, a threshold $T \in N$. Define $\omega(A) = \sum_{u \in A} \omega(u)$ and $\Gamma = \{A \subset U: \omega(A) \geq T\}$. Then Γ is called a weighted threshold access structure on U.

E. Bilinear maps

Number.

Let G and G_T be two multiplicative cyclic groups of prime order p. Let g be a generator of G and e be a bilinear map, $e: G \times G \to G_T$. The bilinear map e has the following properties:

1. Bilinearity: for all $u, v \in G$ and $a, b \in Z_p$, we have $e(u^a, v^b) = e(u, v)^{ab}$.
2. Non degeneracy: $e(g, g) \neq 1$.

We say that G is a bilinear group if the group operation in G and the bilinear map $e : G \times G \to G_T$ are both efficiently computable.

III. Our contribution

The number of IoT and cloud applications has skyrocketed over the last years with even more promising (and daunting) predictions. Domains such as these have exhibited a need for faster, more flexible and more scalable security and access control solutions mainly because of their unprecedented size and distributed nature. ABAC, through its cryptographic implementation (ABE), is able to offer finer granularity, more expressive policies and higher security (through its data-centric approach) than previously widely-used solutions like RBAC.

As weighted threshold access structures are structures with many applications in practice, especially in expressing policies in attribute-based access control, finding an efficient solution to implementing them has been imperative.

We can achieve very good security, speed and resource efficiency by using bilinear maps over elliptic curves in order to construct schemes applicable for this type of access structures. In the following we present the cryptographic scheme in its two variants.

F. Scheme WAS_ABE_1

k represents the number of attributes. The compartment gate's threshold is the global threshold t, and q is the sum of all attributes' weights.

In order to share a value , where p is a prime, on a Boolean circuit $\boldsymbol{C}$ we are going to use a secret sharing procedure Share(y,$\boldsymbol{C}$):

- Assign y to the output wire of the circuit (the output wire of the (t,q)-gate);
- Choose uniformly at random and define the polynomial mod p. Then, assign to the input wires of the (t,q)-gate the shares f(1),…,f(q) in this order from left to right.

Now we introduce our scheme as follows:

Setup(λ, n): the algorithm uses the security parameter λ to choose a prime p, two multiplicative groups G and G_T of prime order p, a generator g of G, and a bilinear map $e : G \times G \to G_T$. Then, it chooses $y \in Z_p$ and, for each attribute i.j, chooses $r_{i.j} \leftarrow Z_p$. Finally, the algorithm outputs the public parameters $PP = (p, G, G_T, g, e, n, Y = e(g, g)^y, (T_{i.j} = g^{r_{i.j}} | \, i, j))$ and the master key $MSK = (y, r_{i.j} | i, j)$.

Encrypt(m, A, PP): the encryption algorithm encrypts a message $m \in G_T$ by a non empty set A of attributes as follows:

- $s \leftarrow Z_p$;
- Output $E = (A, E' = mY^s, (E_{i.j} = T_{i.j}^s = g^{r_{i.j}s} | i, j \in A), g^s)$.

KeyGen($\boldsymbol{C}$, MSK): he decryption key generation algorithm generates a decryption key D for the WAS defined by the Boolean circuit $\boldsymbol{C}$ as follows:

- $S \leftarrow Share(y, C)$;
- Output D, where $D(i.j) = g^{S(i.j)/r_{i.j}}, \forall 1 \leq i \leq k, 1 \leq j \leq \omega_i$.

Decrypt(E,D): given E and D as above, the decryption works as follows:

Compute $F_A(i.j)$ for all attributes i.j by
$F_A(i.j) = \{e(g, g)^{S(i.j)s}, \quad if\ i \in A\ \perp, \ otherwise$

and ⊥ means "undefined";

- If the (t,q)-gate is satisfied (i.e., the global threshold is satisfied), then use the Lagrange interpolation formula to derive $O = e(g, g)^{ys}$ from the F_A-values. If the gate is not satisfied, then the value will be ⊥;
- $m = E'/O$.

If we do not multiply the attributes, but distribute multiple decryption keys to each one (as many as the attribute's weight) we can view the resulting scheme as more efficient as it keeps the number of circuit leaves.

G. Scheme ABE_WAS_2

The Setup, Encrypt and KeyGen algorithms perform identically with the ones in the first scheme.

Decrypt(E, D): given E as the result of the Encrypt algorithm and D as the result of the KeyGen algorithm, the decryption works as follows:

- Compute $F_A(i.j)$ for all decryption keys j of all attributes i by
  $F_A(i.j) = \{e(g, g)^{S(i.j)s}, \ if\ i \in A\ \perp, \ otherwise$

and ⊥ means "undefined";

- If the (t,q)-gate is satisfied (i.e., the global threshold is satisfied), then use the Lagrange interpolation formula to derive $O = e(g,g)^{ys}$ from the F_A-values. If the gate is not satisfied, then the value will be $\perp$;
- $m = E'/O$.

H. Security

We prove the security of the second scheme. For the proof is analogous as the two schemes behave similarly.

Theorem 1. In the selective model and under the decisional bilinear Diffie-Hellman assumption the scheme is secure.

Proof. The main proof idea is by contradiction: we defined WAS_ABE_2 by transforming any weighted access structure into a CAS structure. So, if the WAS_ABE_2 scheme is not secure, the CAS_ABE scheme should not be either. Therefore, let us develop this main idea.

Suppose that, in the selective model, the WAS_ABE_2 scheme is not secure. Consider then an adversary **A** which has against this scheme a non-negligible advantage when it is applied to WASs. We define an adversary **A**' against the corresponding CAS_ABE scheme and we show that it has a non-negligible advantage against this scheme, which is a contradiction. If $\boldsymbol{\mathcal{C}}$ stands for a Boolean circuit in the WAS_ABE_2 scheme, then from a technical perspective the CAS_ABE scheme equivalent circuit is identical. To be able to differentiate between the two cases, let $\boldsymbol{\mathcal{C}}'$ denote the CAS_ABE scheme circuit. The adversary **A**' will:

- announce the set **A** of attributes that he wishes to be challenged upon;
- receive the public parameters PP during the Setup phase;
- query the decryption key generation oracle for a Boolean circuit $\boldsymbol{\mathcal{C}}$ representing some CAS. The adversary **A**' is granted access during Phases 1 and 2. The adversary can obtain the decryption key (D',P') as it is described in the CAS_ABE scheme by querying the oracle with $\boldsymbol{\mathcal{C}}$ (**A**) = 0. Consequently **A**' can compute $F_A = e(g,g)^{S(i.j)s}$, for all (i.j). At this point we can notice looking at the WAS_ABE_2 scheme that the F_A-values computed by **A**' are the same F_A-values that would have been computed by **A** if **A** had interrogated the key decryption oracle of the WAS_ABE_2 scheme with the circuit $\boldsymbol{\mathcal{C}}$. Taking note that $\boldsymbol{\mathcal{C}}$(**A**) = 0, the secret sharing would have happened in the same manner at the logic gates;
- submit two messages, m_0 and m_1, of equal length in the Challenge phase and receive **A**'s corresponding ciphertext and one of the two messages, say m_b, where $b \leftarrow \{0,1\}$.

A' can obviously compute in the worst case the same information adversary **A** can. As a consequence, adversary **A**' has a greater probability of correctly guessing b than **A**. We hence arrive at the contradiction that **A**' has a non-negligible advantage against the CAS_ABE scheme.

I. Implementation

The main challenges of implementing schemes like the ones presented above are working with elliptic curves and bilinear maps.

An implementation of the weighted threshold access structure scheme *ABE_WAS_1* has been written using Java 14 and is publicly available at https://github.com/alexandraib/abe-was. For bilinear map support, Ben Lynn's PBC library [11] offers an abstract interface and easy-to-use APIs to a cyclic group with a bilinear pairing. The implementation uses curve $y^2 = x^3 + x$ over the field F_q for some prime q=3 mod 4 and a billinear nondegenerate map $e : G \times G \rightarrow G_T$ where G and G_T are both cyclic groups of prime order r with q+1=rh and h is a multiple of 12 (in order to have $q \equiv -1 \; mod \; 12$).

The implementation uses r on 160 bits and q on 512 bits. It was tested on Windows 10.

IV. Conclusions

Weighted threshold access structures are highly important in practice due to their accuracy in the representation of situations where particular subsets of parties must be authorized and others must not, according to their importance.

These access structures are decidedly important because of the abundance of real-life situations that they can model and the way attribute-based access control can express them in order to regulate access and authorization.

In this paper we propose an attribute-based encryption scheme for weighted threshold access structures. To the best of our knowledge this is the first scheme dealing with this problem.

We have proof that our scheme is secure under the assumption of decisional bilinear Diffie-Hellman.

A remaining issue that requires solving and that would improve the scheme would be finding a procedure that condenses the partial secrets attached into a single attribute.

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An Interface for Phonosemantic Assessment of Russian Words

Tatiana Burlea [1], ORCID: 0000-0001-9454-4313
Victoria Bobicev [1], ORCID: 0000-0003-4450-3964
[1] Technical University of Moldova, bd. Ștefan cel Mare, 168, Chișinău, Republica Moldova, tatiana.burlea@iis.utm.md, http://lilu.fcim.utm.md/, victoria.bobicev@ia.utm.md, http://lilu.fcim.utm.md/

***Abstract*— This paper describes an interface for the phonosemantic evaluation for Russian words. By phonosemantics we mean the subconscious emotional interpretation of the acoustic perception of words independent of their meaning. The given method is based on data about the emotional perception of sounds, obtained from a sample of respondents. The developed program evaluates the emotional characteristics of the words using data about the sounds. The interface allows users to evaluate phonosemantics for a given word as well as to introduce her/his personal perception of phonosemantics for individual sounds of Russian language.**

Keywords—computational linguistics; natural alnguage processing; phonosemantics;web application.

I. Introduction

Sound symbolism or phonosemantics is a branch of linguistics and refers to the idea that vocal sounds have meaning. In particular, sound symbolism is the idea that phonemes carry meaning in and of themselves.

Margaret Magnus, the author of a comprehensive book explaining phonosemantics to the lay reader [1] describes three types of sound symbol (first proposed by [2]):

Onomatopoeia is the imitation of a sound like roar or moo.

Clustering is an effect of the semantic association.

For example: *hacienda, hall, hangar, harem, haunt/s, haven, hearth, hive, hogan, hold, hole, hollow, home, host, hostel, hotel, house, hovel, hut, hutch* – all these words have similar meanings which refer to a concept “home” and begin with /h/. Hence, the first phoneme /h/ is in some way associated with the concept “home”.

Clustering is not entirely blind to reference, and hence has an element of arbitrariness.

True Iconism is the visceral effect of the sound on a person. True Iconism is completely predictable and completely blind to reference. It only directly affects our understanding of what the word’s referent is like, the word’s connotation.

For example:

In the group of words:

flit, flitter, float, flutter, fly

the final /ur/ makes the movement repetitive, the short /i/ makes the movement quick and short.

In the words:

stamp, tramp, tamp, tromp, step, stomp

a pre-final /m/ makes the contact with the ground heavy; a pre-vocalic /r/ makes the motion go forward, and so forth.

Webster's dictionary defines phonosemantics as follows: "The study of the meaning and symbolism of vocal sounds." This assumes that every sound can be perceived as pleasant or unpleasant, rounded or angular, warm or cold. Thus, for example, the English word "*break*" is seen as something sharp, brusque; the Romanian word "*ou*" (egg) as something rounded, "*licurici*" (fireflie) is perceived as something small, pleasant and quick even for those who do not know the Romanian language.

[2] claims that "sound is not simply an imitation, but a sign, which reproduces a common quality of the sound and the object; to mark the object, language chooses the sounds which partly independently, partly in comparison with others produce the impression, which is similar to the listener as that produced by the object on the mind".

In this paper phonosemantics is interpreted as the subconscious emotional perception of the sounds of the word independently of the actual meaning of the word. On the other hand, the meaning of the word is more important for its emotional perception, and the phonosemantic component emerges when the meaning of the word is unknown.

II. Related Work

Phonosemantics is an intersection of phonetics, semantics, lexicology and psychology as theory of perception [3].

While the question of how things are named was studied since Ancient Times, some ancient philosophers thought that things are named by people's agreement and that there is no connection between the meaning and the "sounding" of the word. Plato, however, believed that the names for things were dependent on the features of the thing as well as on the features of the sounds.

The idea that the sounds of the language have their own separate semantics have been developed by Mikhail Lomonosov in its Rhetoric (1748). "According to Lomonosov, each sound has its own meaningful energy. But this energy in itself is not rational, but emotional. Moreover, it carries a clear sign of the irrational" [4]. However, these characteristics of sounds subconsciously affect the receiver emotionally.

[5] created an universal classification of signs that was an important step towards separting phonosemantics as an independent scientific discipline.

Phonosemantics became an independent branch of linguistics only in the middle of the 20th century by [6], the purpose of which is to study the relationship between sound and meaning in a word.

An important contribution to the development of phonosemantics have been made by Alexander Zhuravlev with his works of emotional perception of each sound of the language [7]. He developed a methodology of phonosemantic evaluation of words and entire texts based on this emotional perception of each sound in the word or text.

Online text evaluation system VAAL that used the above mentioned methodology has been developed and used for text content analysis.

[8] described an online interface for phonosemantic evaluation of Romanian words. The created application is mainly based on Zhuravlev methodology [7] and uses phonosemantic assessments of multiple Romanian speaking respondents collected throwgh specific surveys.

Several works studied the similarietes between phonosemantic perceptions in multiple languages.

In [9], the authors, classifying emotional words in Russian and English observed similarities of sounds in words used to convey similar meaning.

[10] by analyzing word lists covering nearly two-thirds of the world's languages, demonstrated that a considerable proportion of 100 basic vocabulary items carry strong associations with specific kinds of human speech sounds, occurring persistently across continents and linguistic lineages.

However, we considered that people speaking different languages associated sounds with slightly different emotions and characteristics. Thus, our aim was to create a similar system for Russian language and to compare its assessments with Romanian application.

III. Methodology

The sound of the letters influences our impression of the sound of the whole word. Thus, we can create the dictionary of sounds, emotionally appreciate each sound and obtain so-called "phonosemantic aura" of the word as a sum of the emotional characteristics of the sounds that the word contains. The "phonosemantic aura" of the word represents the emotional perception of the word. It can be characterized by different methods.

We used the values proposed in (Журавлев & Павлюк, 1989), represented by 20 pairs of adjectives with opposite meanings describing sounds as "good" or "bad", "fast" or "slow", "big" or " small" etc. To check the answers we decided to use all the value variants. If the respondent chose the same values from similar pairs (such as "bad" and "evil") for a sound, then these answers probably reflect people's feelings about the given sound.

The respondents were asked to choose from the proposed values to mark the sounds of the Russian language. For the questionnaire, a web interface has been created with an HTML form and checkboxes (figure 1). Each respondent had to choose features for each sound. Five possibilities were presented for each pair of features: from the most right characteristic to the most left one. For example, for the first pair on Figure 1 (good-bad), the first blue dot indicates that the sound is very good, the second light blue indicates that the sound is somehow good, the middle gray dot indicates that the sound is neutral for this pair of characteristics; not bad, not good. Red dots indicate bad and very bad respectively. This selection is coded with a number from 1 to 5; 1 – very good, 5 – very bad.

Figure 1. Web interface for the questionnaire

IV. The Vocabulary of Russian Sounds

Such interface repeated for each sound of Russian language. It should be mentioned that the number of sounds is much larger than the number of letters.

There are 33 letters in the Russian alphabet. Of these, 10 letters are vowels, 21 are consonants, a hard sign and a soft sign. There are 42 basic sounds in the Russian alphabet. Six of them are vowels, and thirty-six are consonants. The difference in the number of sounds and letters in Russian is due to the fact that some letters include two sounds. The list of letters and corresponding sounds is presented in the tables below.

TABLE I. Russian Letters and Corresponding Sounds

letter	sound	letter	sound	letter	sound
а	а	б	б, б’	п	п, п’
е	йэ	в	в, в’	р	р, р’
ё	йо	г	г, г’	с	с, с’
и	и	д	д, д’	т	т, т’
о	о	ж	ж	ф	ф, ф’
у	у	з	з, з’	х	х, х’
ы	ы	к	к, к’	ц	ц
э	э	л	л, л’	ч	ч
ю	иу	м	м, м’	ш	ш
я	иа	н	н, н’	щ	щ

The Russian alphabet has hard and soft consonants that is reflected in the table. A consonant becomes soft when specific vowel follows it, namely: ***е, ё, и, ю, я***.

For each of these sounds "phonosemantic aura" has been assessed through the interface presented on Figure 1.

V. Metodology of word phonosemantics evaluation

After obtaining the characteristics of the sounds, we can calculate the characteristics of the words by summing all the values for all its sounds. The algorithm used was taken from [7]. Apart from the values given in the algorithm, the so-called information weight of the sounds is used. There are various factors that influence the informational weight of the sounds, among which the accent and the position of the sound in the word are the most influential. Sound frequency is also essential; rarer sounds contain more information. Calculation is made for each pair of the characteristics independently.

$$f_i = \frac{\sum_{j=1,m} n_i^j}{m}, \qquad (1)$$

where f_i is the average value of the phonosemantic evaluation of the sound for a pair of values; n_i^j is the phonosemantic evaluation of sound ***i*** by respondent ***j*** for a pair of values (can be 1, 2, 3, 4, or 5); ***m*** is the number of respondents.
F is the phonosemantic perception of a word for a pair of values.

$$F = \frac{\sum_{i=1,n} f_i k_i}{\sum_{i=1,n} k_i}$$

k_i is the information weight coefficient for each sound in the word:

$$k_i = \frac{1}{P_i}$$

where ***i*** is the position of the sound in the word (***i=1,n***);

P_i is the global frequency of the sound in speech.

The algorithm:
input data:
a word;
calculation:
- the word is divided into letters;
for each letter:
transformation letter → sound i;
for each sound:
for each pair of features:
- the phonosemantic evaluation of the sound is calculated $k_i \cdot f_i$
- the summary F is calculated for the whole word.
F is displayed.

VI. Interface for Data collection and Word Phonosemantic Evaluation

The created application[1] consist of two interfaces: (1) for data collection; (2) for word phonosemantic evaluation.

The data collection interface contains forms presented on Figure 1. There are one form for each sound; each form contains 20 rows with pairs of characteristics. The respondent selects the dot to check on the base of her/his feelings for this particular sound. For example, for the sound ‘r’ one may feel that it is more “frightening” than “safe” or it is more “rough” than “smooth” and so on. The checked forms then are submitted and the introduced results added to the database. In this way opinions were collected from multiple respondents and the average phonosemantic perception of each sound has been calculated.

The word evaluation interface contain a text input element where an user can introduce any word that is

[1] https://phonosemantic-analysis-of-words.000webhostapp.com/

analysed with the above described algorithm and the result is presented for every pair of the characteristics. Figure 2 presents a screenshot of the word evaluation interface with an introduced word. Figure 3 presents an answer of the application, namely, the phonosemantic evaluation of the given word.

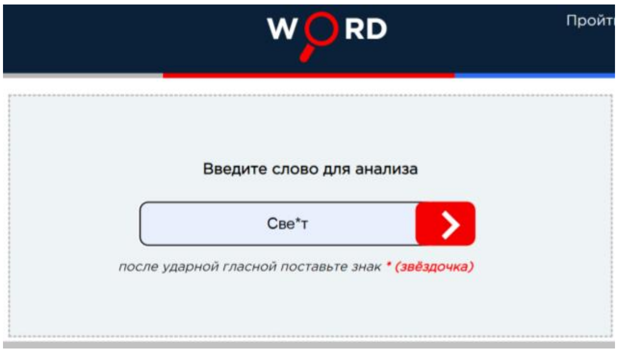

Figure 2. Web interface for the word phonosemantic evaluation

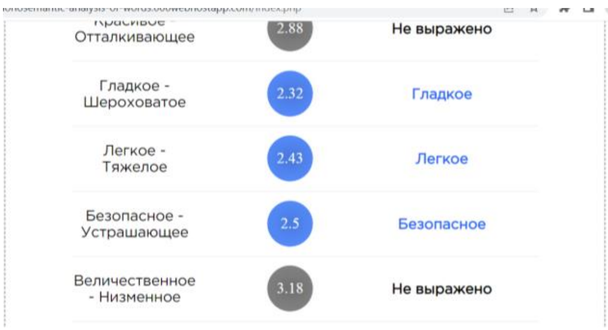

Figure 3. Web interface with a fragment of the the word's phonosemantic evaluation result

If the calculated coefficient for a pair of characteristics is less than 2.5, the first characteristic of the pair is considered important for the evaluated word. If the coefficient is more that 3.5, the second characteristics is considered important. If the coefficient is between 2.5 and 3.5, no one of these two characteristics is important for the given word.

VII. Analysis of the Results

First, we analysed the average characteristics for the individual sounds. Figure 4 presents the results for the sound 'a'. It is seen in the diagram that the most silent features of ths sound are "good", "big" and "strong".

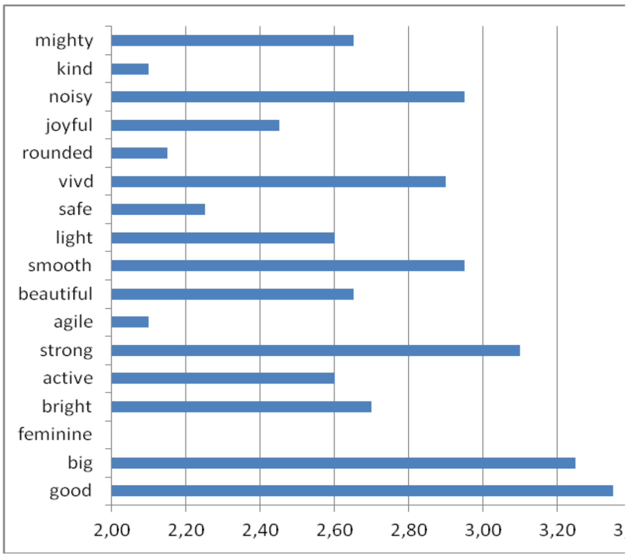

Figure 4. Phonosemantic evaluation result for the sound "a"

Figure 5 presents the results for the sound 'o'. The most silent feature of ths sound is "noisy". Then it is "smooth", "vivid" and "strong". Less silent is the feature "active". There are no any other characteristics that are important for this sound.

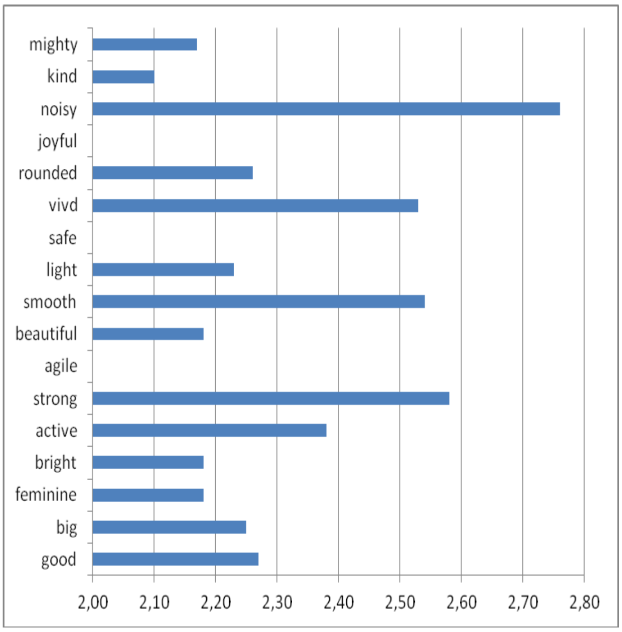

Figure 5. Phonosemantic evaluation result for the sound "o"

Little less silent are features "smooth", "vivid" and "noisy". Even less silent but still important are features "mighty", "beautiful" and "brught". Finally, somehow important are features are "light" and "active". The other features were not selected by respondents as specific for this sound.

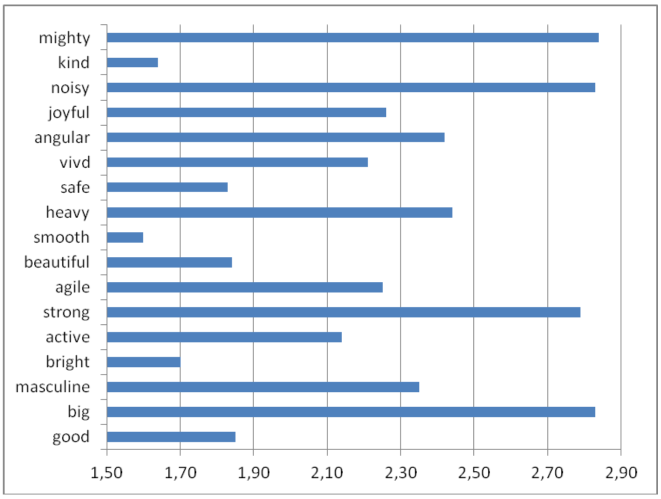

Figure 6. Phonosemantic evaluation result for the sound “r”

The examples on figures 4 and 5 are vowels. Consonants evoke other associations and features.

For example, Fig.6 presents characteristics for the sound ‘r’. In overall, it is perceived as ‘mighty’, ‘noisy’, ‘strong’ and ‘big’ that seems adequate.

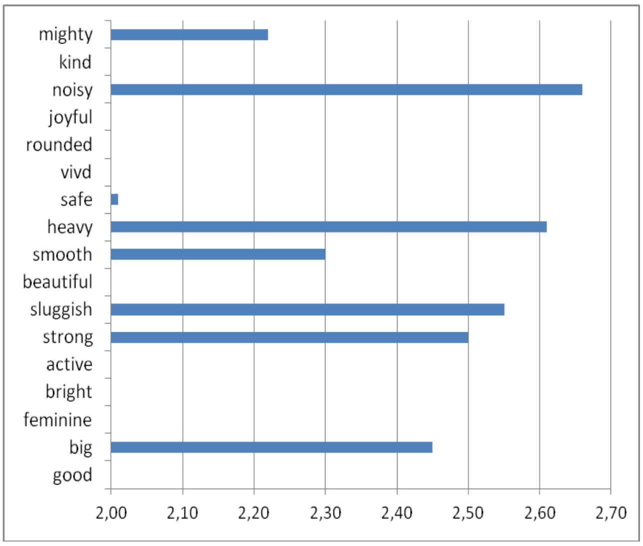

Figure 7. Phonosemantic evaluation result for the word “гром” (thunder)

Overall phonosemantic description of a word is formed as a sum of the characteristics of the sounds of the given word. Figures 7, 8 and 9 presents the examples of phonosemantic evaluation of words “гром” (thunder), “булка” (bun) and “цифра” (number).

Fig. 7 demonstrates the phonosemantic characteristics of the word “гром” (thunder). The most sailent are the characteristics ‘noisy’, ‘heavy’, ‘sluggish’ and ‘strong’. In this case these characteristics correspond to the real word sense; however it is not always the case.

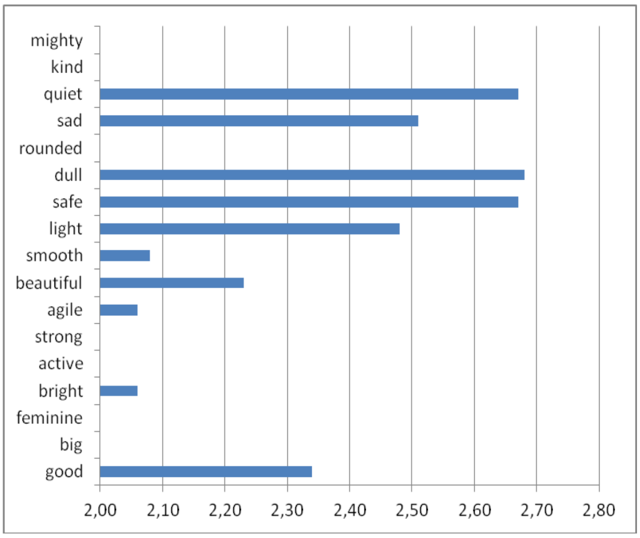

Figure 8. Phonosemantic evaluation result for the word “цифра” (number)

For example, Fig. 8 presents the phonosemantic characteristics ow the word “цифра” (number). The sense in this case is abstract and does not evoke much emotional association. The sound of this word, however, evoke the emotional impression that it is ‘quiet’, ‘dull’, ‘safe’ and ‘sad’.

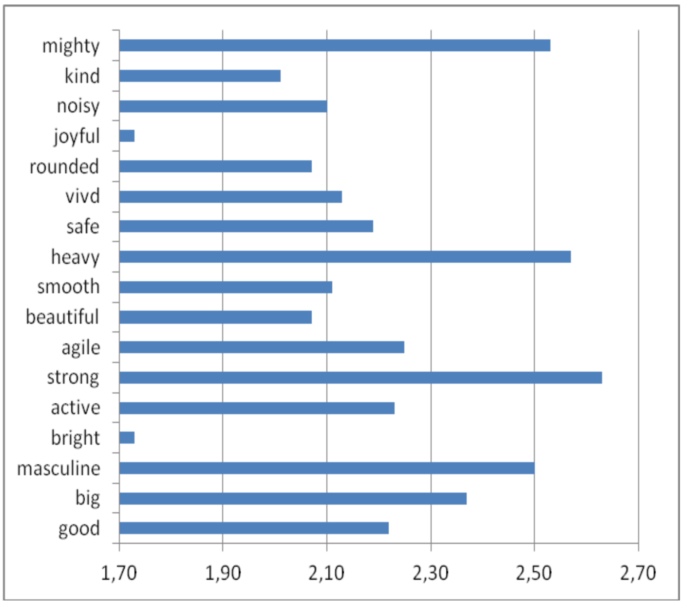

Figure 9. Phonosemantic evaluation result for the word “булка” (bun)

The last example on Fig. 9 is phonosemantic perception of the word “булка” (bun). It is perceived as “heavy”, “strong”, “mighty” and even “masculine”. We can easily notice that in this case, Russian and English words share the combination of sounds ‘b’ and ‘u’ in this word and this combination ‘bu’ makes the word sound “heavy” and “strong”.

VIII. Conclusions

The paper presents an application with a web interface that evaluated phonosemantic perception of Russian words. The application has two interfaces: one is designed to collect users’ perceptions of the individual sounds of Russian language and in the other any user can evaluate phonosemantic perception of a whole word that is calculated as the combination of the phonosemantics of its sounds. In some cases sonund of the word has something in common woth its meaning but in some cases word sounds are perceived differently and and are in contrast with its meaning. Phonosemantic characteristics of words can be used for new names evaluation in advertisement [11].

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Analysis with Unsupervised Learning Based Techniques of Load Factor Profiles and Hyperspectral Images

Ştefan-Gheorghe Pentiuc [1], ORCID: 0000-0002-5239-9493
Elena Crenguţa Bobric [2], ORCID: 0000-0002-6570-3095
Laura-Bianca Bilius [3], ORCID: 0000-0002-6081-3674
[1] MintViz Lab, MANSiD Research Center, Ştefan cel Mare University of Suceava, 13 Universitatii, Suceava 720229, Romania, pentiuc@usm.ro, crengutab@eed.usv.ro, laura.bilius@usm.ro

***Abstract*— The problem of obtaining an optimal partition consistent with a series of partitions resulting from the application of various clustering algorithms is NP complete. A heuristic method based on the concepts of central partition and strong patterns developed by Edwin Diday [3] is proposed. It is presented the experience regarding the use of analysis techniques based on unsupervised learning methods of load factor profiles and hyperspectral images.**

Keywords—machine learning; unsupervised learning; clustering algorithms; load factor profiles; hyperspectral images

I. INTRODUCTION

There are situations in which the data must be divided into disjoint groups that contain elements more similar to each other than to those in other groups. In general, it is required to obtain a partition into equivalence classes of the set of observations. In Machine Learning (ML), the partitioning of a finite set E without having a priori information on how to group its elements into classes corresponds to the context of unsupervised learning. There are several algorithms that achieve this, also called clustering algorithms. These algorithms receive as input the set E and the number M of classes in which the elements of E are to be grouped, and possibly a metric over E or a measure of similarity. Based on these the algorithm will produce at the output a partition P(E,M) into M equivalence classes . But not infrequently the application of several different algorithms or even the same algorithm, but with various input parameters to configure its execution, produce different partitions of E in M classes. The question arises as to which is the best partition among those obtained.

A solution is to obtain a consensus partition that derives from a set of clusters, so that it is better than the other partitions [1] or that fits better according to a certain criterion than any partition from the set of partitions in entry [2].

In the first part of the paper, a heuristic method is presented to find the best partition from the set of partitions provided by several clustering algorithms, starting from the partition of strong patterns, a notion introduced by Edwin Diday [3]. In the second part of the work, the practical validation of the method will be presented in 2 case studies of high current interest (electricity management and remote detection).

II. UNSUPERVISED LEARNING ALGORITHMS

In this paper we use the notion of pattern to represent the entities described by the values of their properties. A similar notion in ML is sample. A pattern is a vector:

$$\mathbf{x} = (x_1, x_2, \ldots, x_p)$$

where x_i are the observed or measured values of the entity's attributes, being called features. If x_i are real, then a pattern is a point in the set R_p.

Let there be a finite set of patterns E and we assume that it is required to find a partition P(E,M) of the set E in M classes. If M is not known, then a series of partitions of E, P(1), P(2), ... , P(n) can be requested, and by analyzing them, it will be decided which is the most suitable partition . A very useful representation of such a series of partitions is the pattern dendrogram which represents an indexed hierarchy of patterns (see Figure 1).

In a dendrogram, by practicing some horizontal cuts for various values of the α index of the hierarchy, successive partitions will be obtained, a class is made up of all the patterns located in the leaf nodes of the respective subtree. For example, in Figure 1, if α=4.5 is considered, then P(1) = { x_1, x_2, ..., x_5} is obtained, if α = 3.5, P(2) = { {x_5} , { x_1, x_3, x_3, x_4} } etc. To choose the most suitable partition from a series of partitions provided by a hierarchical clustering algorithm, the parameters that can guide the user in selecting the most suitable partition can be calculated.

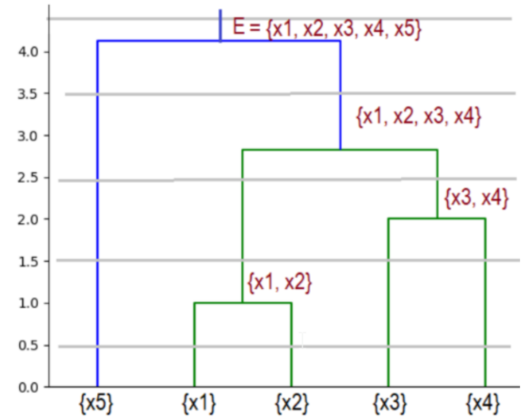

Figure 1. Example of a dendrogram.

However, our method does not refer to this kind of selection.

III. Best Partition

The problem we are addressing is how we choose from several partitions $P_i(E,M)$, with i=1,k, produced by several executions of some clustering algorithms with patterns from the set E. It can be the same algorithm, but executed with different parameters. For example, if we have a hierarchical clustering algorithm and execute it 4 times each time with a different linkage type (Ward, complete, average, or single linkage), it is possible to obtain 4 different partitions. What is the best partition, the one we should choose?

The problem consists in finding an optimal partition of a finite set E of patterns. This problem is NP complete and several heuristics have been proposed to solve it. In general, this problem is known as finding the consensus partition [1, 2] of several partitions.

In the approach we present, we will use the concepts of strong patterns and central partition, concepts defined by Edwin Diday and collaborators [3].

We assume that k clustering algorithms were executed that partitioned the set of patterns into M equivalence classes. All algorithms do not have to be distinct, but even if the same algorithm is executed several times, the executions are with different parameters. As a result of these executions, k partitions P_1 (M), P_2 (M), ... , P_K (M) resulted. Each partition in M equivalence classes, P_i (M), is represented by the equivalence relation $u_i(x,y)$ with x,y patterns in E. It is considered $u_i(x,y)=1$ if patterns x and y are in the same class of the partition P_i (M) and $u_i(x,y)=0$ otherwise.

The central partition is the partition P*(M) which is located at the minimum distance from the partitions P_1 (M), P_2 (M), ... , P_K (M). The distance between 2 partitions $P_i(M)$ and $P_j(M)$ can be calculated [3] like this:

$$\mathrm{d}_C(P^i,P^j)=\frac{1}{2}\sum_{(x,y)\in E\times E}\left|u_i(x,y)-u_j(x,y)\right|$$

To define strong patterns, the following equivalence relation is considered:

$$w^K(x,y)=\begin{cases}1 & \text{if} \quad \sum_{i=1}^{K} u_i(x,y)=K \\ 0 & \text{else}\end{cases}$$

Two patterns will be considered strong if $w^k(x,y) = 1$. We will denote by S the number of strong patterns. The equivalence relation $w^k(x,y)$ determines a partition into S equivalence classes. Π(S) of E, called the partition of hard patterns.

IV. Proposed Method

The whole process is described in the Figure 2 in which each partition $P_i(M)$ was represented by a vector of integers, $\Upsilon_i[n]$ where n is the number of patterns, and $\Upsilon_i[j]$ contains the index of the class to which the pattern j belongs in the partition $P_i(M)$.

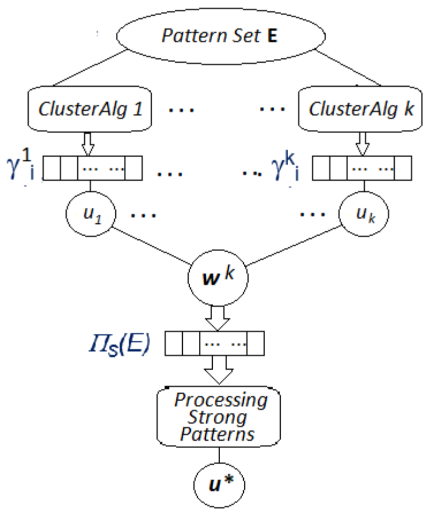

Figure 2. General flowchart of the method.

The partition Π(S) of E, in which the strong patterns are in fact the S equivalence classes, will constitute the input of the most suitable hierarchical ascending classification algorithm in the sense that is the hierarchical ascending classification algorithm that provided the closest partition $P_j(M)$ to the central partition P*(M).

By applying the selected algorithm, the partitions Π(S-1), ..., Π(2) of E will be obtained (see Figure 3).

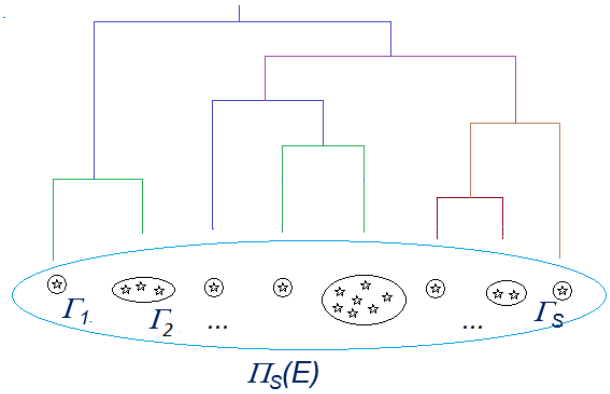

Figure 3. Strong patterns processing.

After applying this method, the user can choose the most suitable partition for the concrete problem to be solved, Π(m), with m in the interval [2, S}, where S is the number of strong patterns obtained after the k applications of some algorithms of clustering on the pattern set E.

V. LOAD PROFILE ANALYSIS

Load Profile represents the electricity consumption graph of a consumer in some period. As a rule, this graph represents the recording of the hourly consumption of electricity in 24 hours. In this case, a load factor will be represented by a pattern xz =(xz1, xz2, ..., xz24) corresponding to day z. The analysis was carried out on the daily Load Profiles from February to April [5] with the aim of determining the significant profiles of energy consumption.

By applying the proposed method, the partition Π(7) was selected, in which class C0 corresponded to some Load Profiles from the days when the substation point was revised, and class C2 contained only one pattern considered outlier. So a partition with 5 classes (Π(7)-{C0, C2}) was retained.

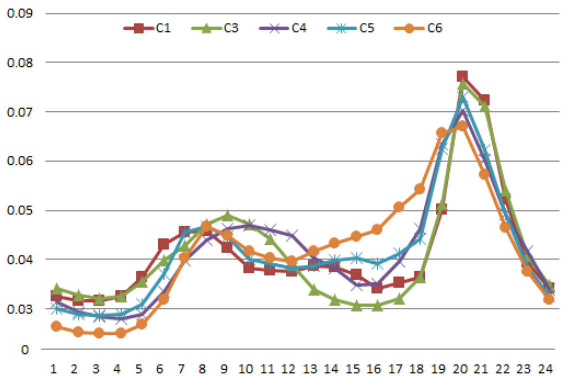

Figure 4. The Load Factor Profiles for the retained classes [6].

The result and the calendar distribution of the retained classes provided significant information [6] for the analysis of the electricity consumption from that substation point (see Figure 4). For example, load profiles from class C1 correspond to working days from the period starting on March 21, and load profiles from class C5 to working days from February to March 21. This fact also confirms the connection between the load profile and the day of the week, but also the atmospheric temperature.

VI. ANALYSIS OF HYPERSPECTRAL IMAGES

Hyperspectral imaging is an analytical technique based on spectroscopy that collects hundreds of images at different wavelengths for the same spatial area in the form of a 3D hypercube, where one dimension contains the spectral information and two dimensions contains the spatial details (see Figure 5 for representation of a Braila hyperspectral image taken from [10]) [11].

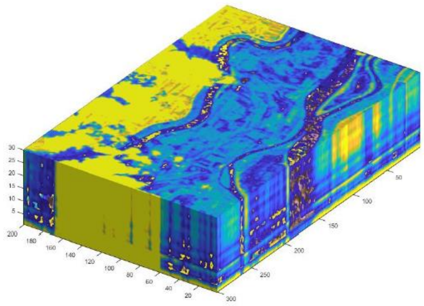
Figure 5. Three-dimensional representation of the hyperspectral image Braila data set.

Spectroscopy involves the study of light emitted or reflected by materials and its variation in energy with wavelength [12]. The property of absorption and emission of electromagnetic radiation varies depending on the material existing on the earth's surface from the visible spectrum to the NearInfraRed and the ShortWave InfraRed [13].

The classification of hyperspectral images involves the grouping of objects according to the characteristics they have by means of automatic learning algorithms, thus allowing the study of hard-to-reach areas, such as rocks, forests, relief, human settlements, roads [11]. The quality of the predictions depends on both the methods used and the spectral and spatial resolution because they are resource consuming. Spectral signatures represent the informational entities or shapes that characterize the pixels and represent the input data for machine learning algorithms. The class a shape belongs to is assigned based on its similarity to other shapes, e.g., the shapes they are most similar to [14].

Regarding the strong patterns, from the hyperspectral images the most representative pixels are chosen. These pixels are grouped using several unsupervised algorithms, such as hierarchical clustering, k-means and mean-shift [15]. We approached unsupervised learning because the absence of groud truth for some hyperspectral images makes it impossible to use supervised learning algorithms. For each pixel, the labels assigned by the unsupervised learning algorithms were concatenated, thus building the multipartition matrix for all pixels. Strong patterns will be searched in the multi-partition matrix.

The goal is to find a consensus partition for the previously obtained multipartition, with the mention that this task is an NP-hard problem. In order to solve this task, the proposed heuristic involves the application of hierarchical grouping for strong patterns extracted from the multipartition matrix. In Figure 6 (right) is the graphical illustration of the extension of the classification to the entire Braila hyperspectral image.

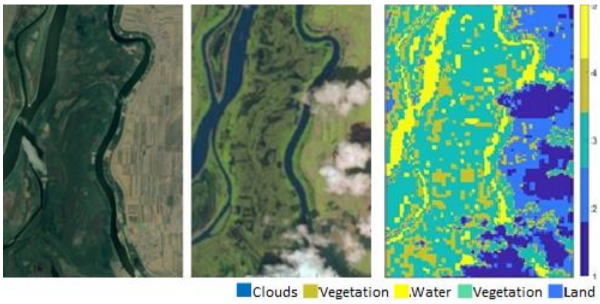

Figure 6. The true color of the Braila zone (an area of Braila's Small Island) in fact a satellite view available from Google Maps (left [1]), the true color provided by the EO-1–Hyperion satellite together (center [2]), and the hyperspectral image colored after clustering (right).

Since there is no general valid algorithm that generates a perfect partition, several partitions were built and the best consensus partition was sought by approaching the heuristic method that is achieved by hierarchical grouping of strong patterns. Strong patterns increased the classification accuracy because the obtained consensus partition is more homogeneous.

VII. Conclusions

The analysis starts from a set of raw data about which we have no a priori information about how it is structured. The analysis techniques are then the ones that take care of the context of unsupervised learning in Machine Learning.

The data set that includes n observations of p characteristics, thus resulting in a matrix of size nxp. These observations can be grouped unsupervised by several clustering algorithms. Of course, different algorithms, or even the same algorithm executed with different input parameters, will provide different partitions of the same data set. The problem arises of finding the best partition. One solution is given.

Two case studies are discussed. The first case study analyzes the outstanding patterns of Load Factor Profiles [3]. In the second case study [4], an attempt is made to classify and color the regions of an hyperspectral image, so that regions of the same nature (soil, water, vegetation etc.) are colored with same color.

Acknowledgment

We acknowledge the financial support provided by the project "Center for knowledge transfer to enterprises in the field of ICT - CENTRIC", Contract no. 5 / AXA 1 / 1.2.3 / G / 2018, Subsidiary contract no. 15.875 / 2021.

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State of water quality in the Prut River for the period of 2019-2021

Nina Sava [1], ORCID: 0000-0001-6827-2721
Galina Marusic [1], ORCID: 0000-0002-2984-2055
[1] Technical University of Moldova, 168, Stefan cel Mare bd., Chisinau, Republic of Moldova, nina.sava@ati.utm.md, galina.marusic@adm.utm.md

***Abstract*— The paper addresses the issue of water quality of the Prut River between 2019 and 2021. The data on pollution of the Prut River and its tributaries are analyzed. The negative influence of detected pollutants on human health is discussed. The statistical analysis of the data is performed through the help of statistical methods using the R language. The obtained results are presented. As a result, it is proposed to develop prediction scenarios exceptional situations of water pollution.**

Keywords*— *prediction scenarios, quality classes, statistical analysis, the Prut river, water pollution, water quality.

I. Introduction

The Prut River has a total area of 27540 km^2, in the Republic of Moldova it covers an area of 8123,35 km^2. The Prut water is also used for irrigation. The river is navigable only on a small portion from the delta to the small town of Leova [1].

The Prut is a transboundary river which begins on the slopes of Mount Goverla, 15 km southwest of the village of Vorhota, on the Carpathian massif with Montenegrin forests (Ukraine). The Prut River is the last important tributary of the Danube river, flowing 174 km from the mouth of the river [2].

In the Republic of Moldova, the waters of the Prut River are mostly used for drinking water supply. It is also worth noting that the results of the water quality check give rise to greater concerns. The Prut River, being also a transboundary waterway, in this case represents a collector that stores polluting substances that contribute to the reduction of water quality [3]. The Prut River is more polluted than the Dniester [4]. Pollutants of organic origin, descended from sewage discharge from urban areas or manure brought into the river by tributaries, predominate in the composition of the water of the Prut River [2].

The main causes of pollution of the river Prut are unpurified or partially purified wastewater from rural or urban locations discharged into the tributaries of the rivers, unpurified meteoric water, inappropriate sanitation of the territories of localities, non-compliance with sanitary protection zones of water basins, arrangement of polluting objects in sanitary protection zones of water basins [5].

II. Problem Formulation

For the Prut River, it is attested a decrease in samples assigned to class I (very good) from 30% in 2018 to 9% in 2019 and an increase in samples assigned to class IV (polluted) from 9% in 2018 to 39 % in 2019 [6]. For bacteriological parameters, the share of samples assigned to class IV (polluted) of quality for the Prut River increased from 8% in 2018 to 12% in 2019 [7].

Classes IV and V (polluted and highly polluted) are attributed to the water samples, which integrate the content of basic pollutants – ammonium, nitrites, nitrates, oxygen content, petroleum products and phenols, in relation to their inadmissible concentrations [5].

The water quality deterioration in terms of sanitary-chemical and mainly microbiological parameters can place the waters of the Prut River in category IV-polluted and V-th - highly polluted, but their use for water supply, recreation and irrigation can constitute a public health problem [6].

The existence of ammonia and nitrites in water is an indirect indicator of bacterial contamination of wastewater. They can have severe toxic effects if humans are exposed to high doses. High concentrations of nitrates cause acute health disorders, determined by the high affinity of these chemical compounds to haemoglobin in the blood. The interaction of nitrates with haemoglobin leads to the formation of methemoglobin, which loses the ability to transport oxygen to the tissues. Especially sensitive to the toxic effects of nitrates are infants who are fed with artificial food prepared on the basis of water with an excess of nitrates [8].

Based on the stated objectives of the work were defined, which consists in analyzing the water quality of the Prut River based on a statistical analysis of data on exceptional situations of water pollution for the period 2019-2021.

III. Solving the Problem

In order to assess the state of water quality in the Prut River, the monthly reports about the quality of the environment on the territory of the Republic of Moldova for the period of 2019-2021 provided by the Environment Agency were analyzed [9].

The subject of the investigation was the quality of water from the Prut River. Eight fixed observation points were analyzed (town Cahul, town Leova, town Lipcani, town Ungheni (upstream), village Braniște, village Giurgiulești, village Pererîta (downstream), village Valea Mare). In order to achieve the objectives presented in the study, statistical investigation methods were used.

The water quality was investigated considering 18 chemical parameters (NO_2, ammonium nitrogen, mineral phosphorus, petroleum products, dissolved O_2, CCO_{Cr}, total phosphorus, magnesium ion, Na^+ + K^+, hardness, nitrate-nitrogen, nitrite-nitrogen, mineralization, orthophosphates, total iron, NH4+, nitrogen of nitrite, substances in suspension).

Figure 1 shows the shares of pollutants in the Prut River by localities in the period 2019-2021.

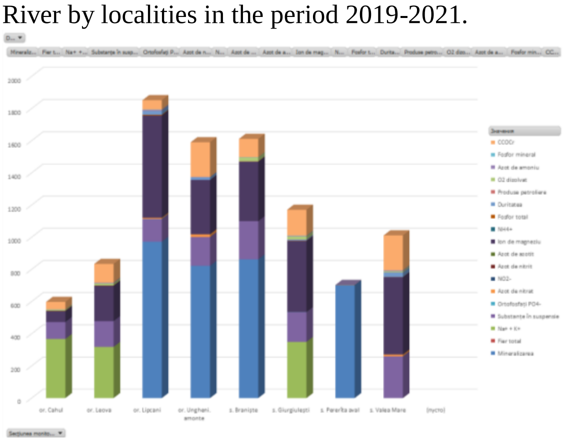


Figure 1. Shares of pollutants in the Prut River by localities in the period 2019-2021

During monitoring the water quality of the Prut River according to the hydrochemical parameters, exceeded values were detected for CCO_{Cr} and total phosphorus.

In the period 2019-2021, the largest number of pollutants was registered in the city of Leova on 19.06.19: ammonium nitrogen (3,85 *mg/l)*, dissolved O_2 (5,8 *mgO₂/l)*, CCO_{Cr} (44,5 *mgO₂/l)*, total phosphorus (0,82 *mg/l)*, magnesium ion (153,2 *mg/l)*, Na^+ + K^+ (317,9 *mg/l)*, substances in suspension (138,4 *mg/l)***.** Figure 2 shows the share of the mentioned pollutants.

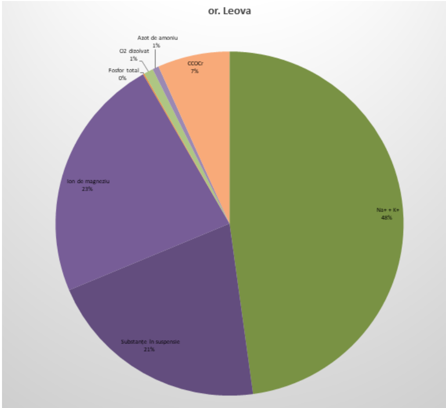


Figure 2. Locality with the maximum number of pollutants between 2019 and 2021

The highest pollution for the period 2019-2021 was detected in the following localities:

1. Lipcani (figure 3)
   - 30.10.19: petroleum products (0,46 *mg/l),* magnesium ion (252,9 *mg/l),* hardness (13,4 *Mmoli/l),* substances in suspension (33 *mg/l).*
   - 06.11.19: mineral phosphorus (0,66 *mg/l),* total phosphorus (0,68 *mg/l),* magnesium ion (209,2 *mg/l),* hardness (10,9 *Mmoli/l).*
   - 12.12.19: mineral phosphorus (0,16 *mg/l),* total phosphorus (0,21 *mg/l),* magnesium ion (64,4 *mg/l),* nitrate-nitrogen (3,17 *mg/l).*
   - 23.03.21: ammonium nitrogen (0,94 *mg/l),* total phosphorus (0,21 *mg/l),* mineralization (972 *mg/*l), orthophosphates (0,13 *mgP/l).*

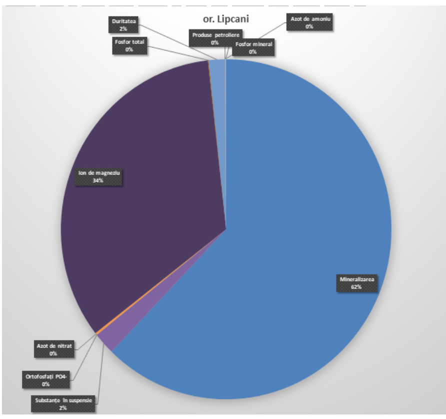


Figure 3. The share of polluting substances in the sector of the Prut river in Lipcani

2. Braniște (figure 4)
   - 07.08.19: dissolved O_2 (6,22 *mgO₂/l),* CCO_{Cr} (18, *mgO₂/l),* magnesium ion (51,07

mg/l), substances in suspension (222,4 *mg/l).*

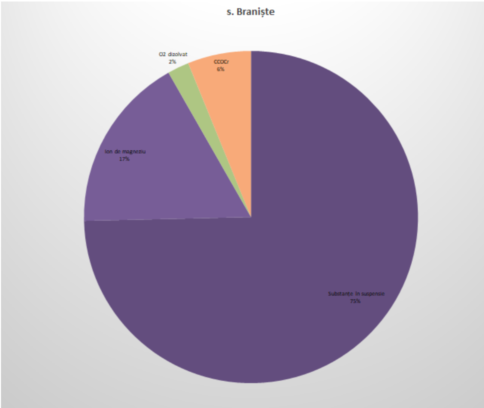


Figure 4. The proportion of polluting substances in the sector of the Prut River in Braniște

3. Valea Mare (figure 5)
   - 15.05.19: ammonium nitrogen (0,5 *mg/l),* mineral phosphorus (0,14 *mg/l),* petroleum products (0,13 *mg/l*), substances in suspension (153,2 *mg/l).*
   - 23.10.19 mineral phosphorus (0,13 *mg/l),* magnesium ion (133,8 *mg/l),* hardness (7,2 *Mmoli/l),* substances in suspension (49,2 *mg/l).*
   - 11.08.21: dissolved O_2 (6,96 mgO_2/l), CCO_{Cr} (34,84 mgO_2/l), total phosphorus (0,5 *mg/l),* orthophosphates (0,16 *mgP/l).*

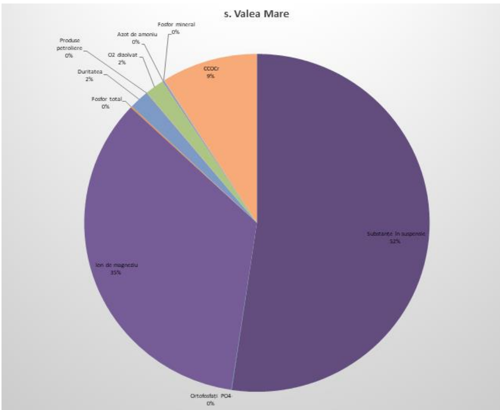


Figure 5. The proportion of polluting substances in the sector of the Prut river in Valea Mare

4. Cahul (figure 6)
   - 20.11.19: mineral phosphorus (0,25 *mg/l),* total phosphorus (0,27 *mg/l),* magnesium ion (68,1 *mg/l),* substances in suspension (20 *mg/l).*

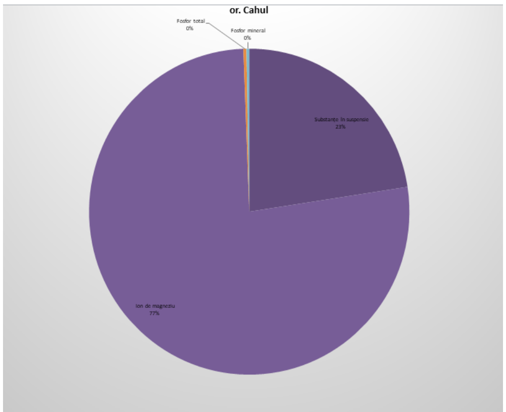


Figure 6. The proportion of polluting substances in the sector of the Prut river in Cahul

5. Leova (figure 7)
   - 21.11.19: mineral phosphorus (0,27 *mg/l),* total phosphorus (0,39 *mg/l),* magnesium ion (66,9 *mg/l),* substances in suspension (22 *mg/l).*
   - 18.08.21: dissolved O_2 (6,92 mgO_2/l), CCO_{Cr} (21,32 mgO_2/l), total phosphorus (0,34 *mg/l),* orthophosphates (0,11 *mgP/l).*

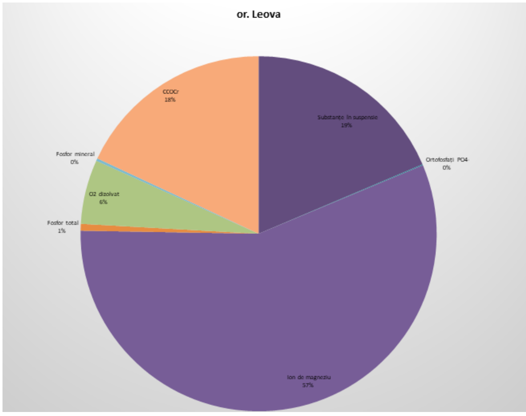


Figure 7. The proportion of polluting substances in the sector of the Prut river in Leova

6. Giurgiulești (figure 8)
   - 19.06.19: dissolved O_2 (6,96 mgO_2/l), magnesium ion (68,1 *mg/l),* $Na^+ + K^+$ (349,1 *mg/l),* substances in suspension (11,6 *mg/l).*
   - 20.11.19: ammonium nitrogen (0,55 *mg/l),* mineral phosphorus (0,2 *mg/l),* total phosphorus (0,25 *mg/l),* magnesium ion (76,6 *mg/l).*
   - 18.08.21: dissolved O_2 (6,23 mgO_2/l), CCO_{Cr} (17,16 mgO_2/l), total phosphorus (0,38 *mg/l),* orthophosphates (0,12 *mgP/l).*

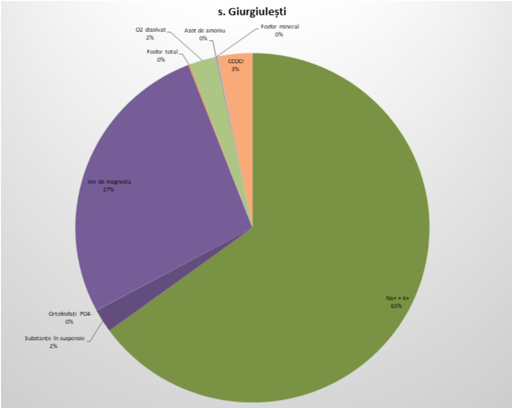


Figure 8. The proportion of polluting substances in the sector of the Prut river in Giurgiulești

7. Pererîta (figure 9)
   - 08.06.21: NO_2 (0,09 *mgN/l)*, total phosphorus (0,32 *mg/l)*, orthophosphates (0,32 *mgP/l)*, NH_4 (0,5 *mgN/l)*.

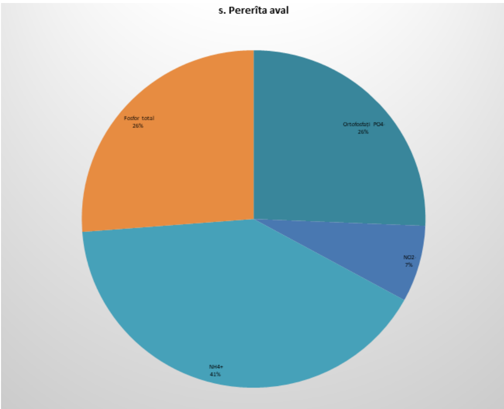


Figure 9. The proportion of polluting substances in the sector of the Prut river in Pererîta

The negative effect of the tributaries of the Prut River is depicted in figure 10 [9]. There were analyzed 6 tributaries of the Prut River: the Lăpușna river left tributary - Sărata Răzeși village, the Camenca river, left tributary - Gvozdovo village, the Gîrla Mare river, left tributary - Sărata Nouă village, the Larga river, left tributary - Chircani village, the Racovăț river, left tributary - Gordinești village, the Sărata river, left tributary - Vîlcele village.

The water quality was investigated for 19 chemical parameters (substances in suspension, dissolved O_2, CBO_5, CCO_{Cr}, ammonium nitrogen, nitrite-nitrogen, total phosphorus, mineral phosphorus, magnesium ion, Na^+ + K^+, hardness, petroleum products, chloride ion, nitrate-nitrogen, sulfate ion, orthophosphates, total iron, nitrogen of nitrite, mineralization).

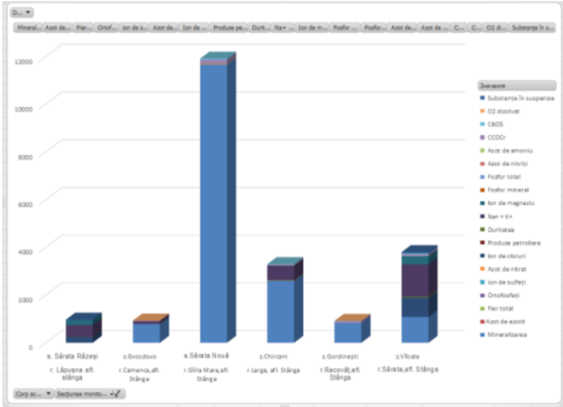


Figure 10. The share of polluting substances in the tributaries of the Prut River by locality in the period 2019-2021

The highest level was recorded for the following pollutants: CBO_5 ammonium nitrogen, total phosphorus.

On 15.09.2021, a maximum volume of pollutants represented in figure 11 was detected in the Gîrla Mare river, Sărata Nouă village: CBO_5 (23,1 *mgO_2/l)*, CCO_{Cr} (140,4 *mgO_2/l)*, ammonium nitrogen (0,47 *mg/l)*, total phosphorus (0,42 *mg/l)*, hardness (9,1 *Mmoli/l)*, orthophosphates (0,3 *mgP/l)*, total iron (0,12 *mg/l)*, nitrogen of nitrite (0,08 *mgN/l*), mineralization (4815,2 *mg/l)*.

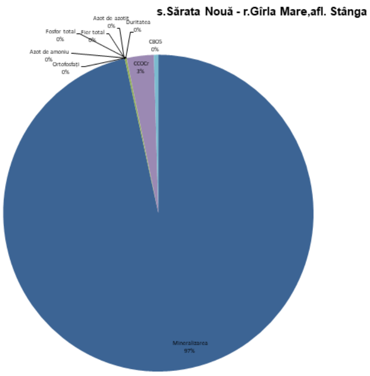


Figure 11. The proportion of polluting substances in the Gîrla Mare river, tributary of the Prut River

In the period 2019-2021, the most polluted tributaries were:

1. Sărata river, Vîlcele village on 19.12.19 (figure 12): CBO_5 (5,36 *mgO_2/l)*, ammonium nitrogen (1,69 *mg/l)*, total phosphorus (0,24 *mg/l)*, magnesium ion (170 *mg/l)*, Na^+ + K^+ (303 *mg/l)*, hardness (9,15 *Mmoli/l)*, chloride ion (437,2 *mg/l)*.

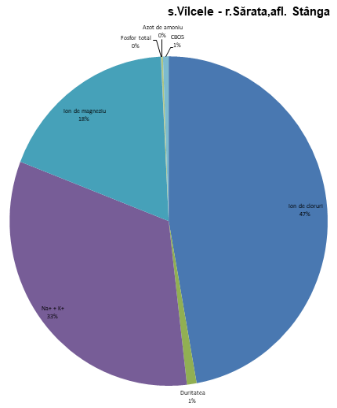


Figure 12. The proportion of polluting substances in the Sărata river, tributary of the Prut River

2. Gîrla Mare river, Sărata Nouă village on 10.03.21 (figure 13): CBO_5 (9,56 *mgO_2/l*), CCO_{Cr} (25,19 *mgO_2/l*), ammonium nitrogen (2,46 *mg/l*), total phosphorus (0,28 *mg/l*), hardness (8,6 *Mmoli/l*), nitrate-nitrogen (14,50 *mg/l*), mineralization (3489,6 *mg/l*)**.**

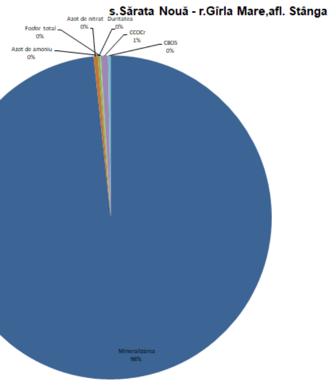


Figure 13. The proportion of polluting substances in the Gîrla Mare river, tributary of the Prut River

3. Racovăț river, Gordinești village on 07.07.21 (figure 14): dissolved O_2 (4,05 *mgO_2/l*), CBO_5 (6,46 *mgO_2/l*), CCO_{Cr} (36,49 *mgO_2/l*), total phosphorus (0,29 *mg/l*), orthophosphates (0,11 *mgP/l*), nitrogen of nitrite (0,19 *mgN/l*), mineralization (825,4 *mg/l*).

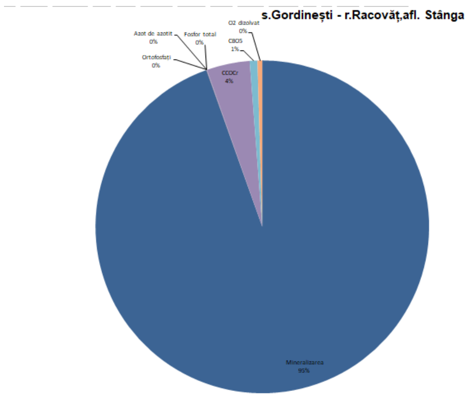


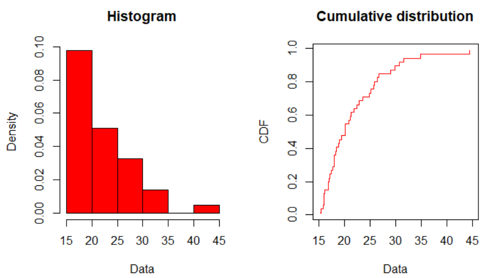
Figure 14. The proportion of polluting substances in the Gîrla Mare river, tributary of the Prut River

Based on the analysis and evaluation of the results obtained for 2019-2021, the Prut River water quality in all the observed sections corresponds to classes III, IV and V, which means medium and high pollution. [9].

Following the analysis of the mentioned data, it was found that the most frequently encountered pollutants were: CCOcr, total phosphorus, ammonium nitrogen, mineral phosphorus, magnesium ion. Thus, the data on the water pollution of the Prut River with the mentioned pollutants were subjected to statistical analysis. The samples with the values of the mentioned pollutants were analyzed and processed with statistical methods from the R language.

The obtained results are presented in figures 15-19. For each pollutant, the histogram of the data, the distribution function, the minimum and maximum values regarding the values of the mentioned pollutant, the first quartile and the 3rd quartile, the average value and the median value of the examined data are observed.

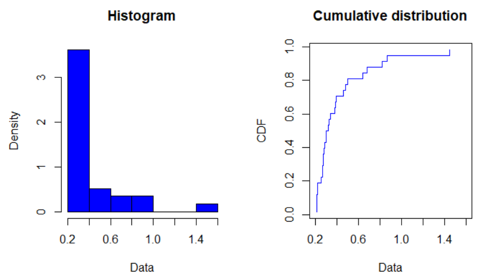
The estimated parameters related to the CCOcr pollutant are presented in figure 15.



Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
15.34	17.29	20.10	21.65	25.05	44.50

Figure 15. CCOcr

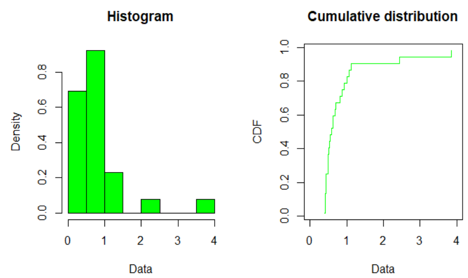
The results of the statistical analysis regarding the total phosphorus pollutant are presented in figure 16.



Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
0.2100	0.2630	0.2980	0.4069	0.4600	1.4480

Figure 16. Total phosphorus

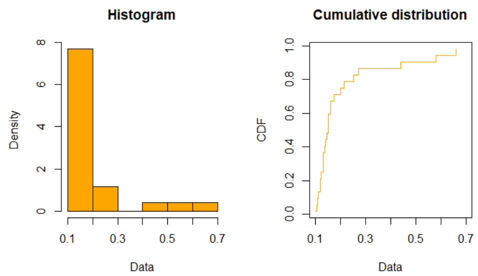
The results of the statistical analysis regarding the ammonium nitrogen pollutant are presented in figure 17.



Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
0.4020	0.4535	0.5670	0.8229	0.8570	3.8500

Figure 17. Ammonium nitrogen

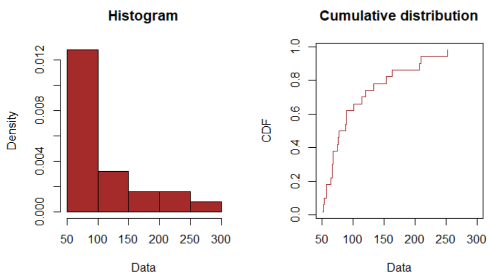
The data on the mineral phosphorus pollutant was also subjected to statistical analysis (figure 18)



Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
0.1000	0.1240	0.1480	0.1984	0.1933	0.6600

Figure 18. Mineral phosphorus

Figure 19 shows the data obtained for magnesium ion.



Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
51.07	66.90	77.82	102.20	120.40	252.90

Figure 19. Magnesium ion

The results allow more detailed analysis of pollutant behavior, including examining the probability with which each value is taken. Knowing how often the relevant values for the pollutant occur under investigation, as well as the cumulative density function and some calculation parameters, we can take measures related to the prevention of water pollution.

CONCLUSIONS

A study of the Prut River water quality was carried out, which revealed a high degree of pollution with various pollutants. Thus, it has been established that the quality of water in the Prut River varies depending on the geographical area of the country.

Statistical analysis of the data was carried out using special software designed for statistical analysis, the R language. The most common pollutants in the Prut River for the period 2019-2021 were subjected to statistical analysis.

The results of the study, including the results of statistical data analysis, allow developing scenarios for predicting water pollution, which will make a significant contribution to reducing water pollution.

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Vulnerabilities of LRSAS Protocol

Denisa-Ionela Țîflea [1], ORCID: 0000-0002-5962-4390
[1] Department of Computer Science, Faculty of Computer Science,
"Alexandru Ioan Cuza" University of Iași, Iași, România, e-mail: tifleadenisa@gmail.com

***Abstract*—The construction of secure and private RFID protocols is necessary with the increasing application of RFID technology in increasingly diverse fields. While security refers to unilateral or mutual authentication depending on the protocol, privacy is a more elaborate concept to which many studies and research have been dedicated. Unfortunately, many RFID protocols are still being developed without consistent security and privacy analysis in well-defined models, such as the Vaudenay model. In this paper, we aim to prove that a recently proposed authentication protocol, LRSAS, does not achieve any form of privacy in Vaudenays model.**

Keywords*—*RFID system, security, privacy

I. Introduction

Radio Frequency Identification (RFID) has its origin when people started to remotely identify objects using radio technology, inventing radar. Nowadays, RFID technology market is increasing, thanks to its multitude of applications, including IoT, tracking and identification. Because its principle of working is based on data transfer, over the last couple of years there was a substantial effort to assure security and privacy over RFID schemes through protocols that can be applied to RFID systems.

A privacy model helps to define the mentioned concepts using different types of adversaries. The model that we follow in this paper is Vaudenay's model [1], being among the most influential and widely accepted security and privacy model.

If we analyze some of the protocols that were proposed in specialized literature we can identify flaws in their design that lead to vulnerabilities. Some of them are a result of not considering privacy models when designing the RFID scheme.

Contribution: In this paper, we develop an analysis of the privacy of the LRSAS protocol [2]. After inspecting the experiments and their probability results we came to the conclusion that the protocol has design flaws and doesn't achieve the class of privacy that the authors mentioned, considering Vaudenay's model.

A discussion on the possibility of fixing the protocol concludes our paper.

Paper structure: This paper is structured in six sections, the first one being the introduction. In Section 2 we present some elementary concepts about RFID schemes and systems. Section 3 consists of presenting the RFID lightweight authentication protocol, LRSAS. The main part of the paper is exposing the vulnerabilities of LRSAS in Section 4, followed by a discussion about the improvements of the protocol in Section 5. We conclude with Section 6.

II. RFID Schemes and Systems

From an informal point of view, an RFID system [3], [4] consists of a *reader*, a set of *tags*, and a *communication protocol* between reader and tags. The reader is a transceiver that has associated a database that stores information about tags. Its task is to identify *legitimate tags* (that is, tags with information stored in its database) and to reject all the other incoming communication. The reader and its database are trusted entities, and the communication between them is secure. A tag is a transponder device with much more limited computation capabilities than the reader. Depending on tag, it can perform simple logic operations, symmetric key, or even public key cryptography. Each tag has a *permanent* (or *internal*) *memory* that stores the state values, and a temporary (or volatile) memory that can be viewed as a set of *volatile variables* used to carry out the necessary computations.

RFID schemes. Let $\mathcal{R}$ be a *reader identifier* and $\mathcal{T}$ be a set of *tag identifiers* whose cardinal is polynomial in some security parameter λ. An RFID *scheme over* ($\mathcal{R}$, $\mathcal{T}$) [1], [5] is a triple $\mathcal{S}$=*(SetupR, SetupT, Ident)* of PPT algorithms, where:

1) SetupR(λ) inputs a security parameter λ and outputs a triple *(pk, sk,DB)* consisting of a key pair *(pk, sk)* and an empty database DB. *pk* is public, while *sk* is kept secret by reader;

2) SetupT (pk, ID) initializes the tag identified by *ID*. It outputs an initial tag state $\mathcal{S}$ and a secret key *K*. A triple *(ID, f(S),K)* is stored in the reader's database *DB*, where *f* is a public function that extracts some information from tag's initial state $\mathcal{S}$;

3) Ident(pk; $\mathcal{R}$*(sk,DB); ID(*$\mathcal{S}$*))* is an interactive protocol between the reader identified by $\mathcal{R}$ (with its private key *sk* and database *DB*) and a tag identified by *ID* (with its state $\mathcal{S}$) in which the reader ends with an output consisting of ID or $\perp$. The tag may end with no output (*unilateral authentication*), or it may end with an output consisting of *OK* or $\perp$ (*mutual authentication*).

4) SetupR(λ*)* creates a reader identified by R and initializes it, *SetupT(pk, ID)* creates a tag $\mathcal{T}_{\mathrm{ID}}$ for each tag identified by *ID*, initializes it with an initial tag state, and also register this tag with the reader by storing some information about it in the reader's database.

The *correctness* of an RFID scheme means that, regardless of how the system is set up, after each complete execution of the interactive protocol between the reader and a legitimate tag, the reader outputs tag's identity with overwhelming probability. For mutual authentication RFID schemes, *correctness* means that the reader outputs tag's identity and the tag outputs *OK* with overwhelming probability.

An RFID *system* is an instantiation of an RFID scheme.

Adversaries. The two most basic security requirements for RFID schemes are *authentication* and *untraceability*. To formalize them, the concept of an *adversary model* is needed. There have been several proposal for this, such as [1], [5], [6], [7], [8], [9], [10], [11]. One of the most influential, which we follow in this paper, is *Vaudenay's model* [1], [5]. We recall below this model as in [12]. Thus, we assume first that some oracles the adversary may query share and manage a common list of tags *ListTags*, which is initially empty. This list includes exactly one entry for each tag created and active in the system. A tag entry consists of several fields with information about the tag, such as: the (permanent) identity of the tag (which is an element from $\mathcal{T}$), the temporary identity of the tag (this field may be empty saying that the tag is *free*), a bit value saying whether the tag is legitimate (the bit is one) or illegitimate (the bit is zero). When the temporary identity field is non-empty, its value uniquely identifies the tag, which is called *drawn* in this case. The adversary may only interact with drawn tags by means of their temporary identities.

The oracles an adversary may query are:

1) CreateTag^b(ID): Creates a free tag $\mathcal{T}_{\mathrm{ID}}$ with the identifier ID by calling the algorithm *SetupT(pk, ID)* to generate a pair *(K, S).* If *b = 1, (ID, f(S),K)* is added to *DB* and the tag is considered *legitimate;* otherwise *(b = 0)*, the tag is considered *illegitimate.* Moreover, a corresponding entry is added to *ListTags;*

2) DrawTag(δ*)*: This oracle chooses a number of free tags according to the distribution δ, let us say *n*, and draws them. That is, *n* temporary identities $vtag_1, \ldots, vtag_n$ are generated and the corresponding tag entries in *ListTags* are filled with them. The oracle outputs $(vtag_1, b_1, \ldots, vtag_n, b_n)$, where b_i specifies whether the tag $vtag_i$ is legitimate or not;

3) Free(vtag): Removes the temporary identity *vtag* in the corresponding entry in *ListTags*, and the tag becomes free. The identifier *vtag* will no longer be used. We assume that when a tag is freed, its temporary state is erased;

4) Launch(): Launches a new protocol instance and assigns a unique identifier to it. The oracle outputs the identifier;

5) SendReader(m, π*):* Outputs the reader's answer when the message *m* is sent to it as part of the protocol instance π. When *m* is the empty message, abusively but suggestively denoted by $\emptyset$, this oracle outputs the first message of the protocol instance π, assuming that the reader does the first step in the protocol;

6) SendTag(m, vtag): Outputs the tag's answer when the message *m* is sent to the tag referred to by *vtag*. When *m* is the empty message, this oracle outputs the first message of the protocol instance π, assuming that the tag does the first step in the protocol;

7) Result(π*):* Outputs $\perp$ if in session π the reader has not yet made a decision on tag authentication (this also includes the case when the session π does not exist), 1 if in session π the reader authenticated the tag, and 0 otherwise (this oracle is both for unilateral and mutual authentication);

8) Corrupt(vtag): Outputs the current permanent (internal) state of the tag referred to by *vtag*, when the tag is not involved in any computation of any protocol step (that is, the permanent state before or after a protocol step).

We emphasize that *Corrupt* does not return snapshots of the tag's memory during its computations. When the *Corrupt* oracle returns the full state, we will refer to this model as being *Vaudenay's model with temporary state disclosure.*

Now, the adversaries are classified into the following classes, according to the access they get to these oracles:

- *Weak adversaries*: they do not have access to the *Corrupt* oracle;
- *Forward adversaries*: once they access the *Corrupt* oracle, they can only acces the *Corrupt* oracle;

- *Destructive adversaries*: after querying *Corrupt(vtag)* and obtaining the corresponding information, the tag identified by *vtag* is destroyed (marked as destroyed in *ListTags*) and the temporary identifier *vtag* will no longer be available. The database *DB* will still keep the record associated to this tag (the reader does not know the tag was destroyed). As a consequence, a new tag with the same identifier cannot be created;
- *Strong adversaries*: there are no restrictions on the use of oracles.

Orthogonal to these classes, there is the class of *narrow* adversaries that do not have access to the *Result* oracle. We may now combine the narrow constraint with any of the previous constraints in order to get another four classes of adversaries, *narrow weak, narrow forward, narrow destructive,* and *narrow strong.*

Security. Now we are ready to introduce the *tag* and *reader authentication* properties as proposed in [1], [5], simply called the security of RFID shemes. First of all, we say that a tag $\mathcal{T}_{\mathrm{ID}}$ and a protocol session π *had a matching conversation* if they exchanged well interleaved and faithfully (but maybe with some time delay) messages according to the protocol, starting with the first protocol message but not necessarily completing the protocol session. If the matching conversation leads to tag authentication, then it will be called a *tag authentication matching conversation*; if it leads to reader authentication, it will be called a *reader authentication matching conversation*.

Tag authentication property is defined by means of an experiment that a challenger sets up for a *strong* adversary $\mathcal{A}$ (after the security parameter λ is fixed). In the experiment the adversary is given the public parameters of the scheme and is allowed to query the oracles. If there has been a session in which the reader has authenticated an uncorrupted tag without a tag authentication matching conversation then the experiment returns 1 (or 0 otherwise).

The advantage of $\mathcal{A}$ in the experiment $RFID_{\mathcal{A},\mathrm{S}}^{t\_auth}(\lambda)$ is defined as

$$Adv_{\mathcal{A},\mathrm{S}}^{t\_auth}(\lambda) = Pr(RFID_{\mathcal{A},\mathrm{S}}^{t\_auth}(\lambda) = 1)$$

An RFID scheme S achieves tag authentication if $Adv_{\mathcal{A},\mathrm{S}}^{t\_auth}(\lambda)$ is negligible, for any strong adversary $\mathcal{A}$.

The experiment for reader authentication, denoted $RFID_{\mathcal{A},\mathrm{S}}^{r\_auth}(\lambda)$, is quite similar to that above. The main difference compared to the previous experiment is that the adversary $\mathcal{A}$ tries to make some legitimate tag to authenticate the reader. As π and $\mathcal{T}_{\mathrm{ID}}$ have no matching conversation, $\mathcal{A}$ computes at least one message that makes the tag to authenticate the reader.

An RFID scheme $\mathcal{S}$ achieves *reader authentication* if the advantage of $\mathcal{A}$, $RFID_{\mathcal{A},\mathrm{S}}^{r\_auth}(\lambda)$, is negligible, for any strong adversary $\mathcal{A}$ ($Adv_{\mathcal{A},\mathrm{S}}^{r\_auth}(\lambda)$ is defined as above, by using $RFID_{\mathcal{A},\mathrm{S}}^{r\_auth}(\lambda)$ instead of $RFID_{\mathcal{A},\mathrm{S}}^{t\_auth}(\lambda)$).

Privacy. Privacy for RFID systems [5] captures anonymity and untraceability. It basically means that an adversary cannot learn anything new from intercepting the communication between a tag and the reader. To model this, the concept of a blinder was introduced in [5].

A *blinder for an adversary* $\mathcal{A}$ that belongs to some class *V* of adversaries is a PPT algorithm $\mathcal{B}$ that simulates the *Launch*, *SendReader*, *SendTag* and *Result* oracles for $\mathcal{A}$, without having access to the corresponding secrets. Moreover, it looks passively at the communication between $\mathcal{A}$ and the other oracles allowed to it by the class *V* (that is, $\mathcal{B}$ gets exactly the same information as $\mathcal{A}$ when querying these oracles).

When the adversary $\mathcal{A}$ interacts with the RFID scheme by means of a blinder $\mathcal{B}$, we say that $\mathcal{A}$ is blinded by $\mathcal{B}$ and denote this by $\mathcal{A}^{\mathcal{B}}$.

Given an adversary $\mathcal{A}$, define the experiment (privacy game):

Experiment RFI$D_{\mathcal{A},\mathrm{S}}^{prv_0}(\lambda)$

1: Set up the reader;
2: $\mathcal{A}$ gets the public key *pk*;
3: $\mathcal{A}$ queries the oracles;
4: $\mathcal{A}$ gets the secret table of the *DrawTag* oracle;
5: $\mathcal{A}$ outputs a bit *b'*;
6: Return *b'*.

In the same way, by replacing "$\mathcal{A}$" with "$\mathcal{A}^{\mathcal{B}}$" we define the experiment $RFID_{\mathcal{A},S,B}^{prv\_1}(\lambda)$. Now, the *advantage* of $\mathcal{A}$ blinded by $\mathcal{B}$ is

$$Adv_{\mathcal{A},\mathrm{S},\mathrm{B}}^{prv}(\lambda) = |P(RFID_{\mathcal{A},\mathrm{S}}^{prv\_0}(\lambda) = 1) - P(RFID_{\mathcal{A},\mathrm{S},\mathrm{B}}^{prv\_1}(\lambda) = 1)|$$

An RFID scheme is private for a class V of adversaries if for any $\mathcal{A} \in V$ there exists a blinder $\mathcal{B}$ such that $Adv_{\mathcal{A},\mathrm{S},\mathrm{B}}^{prv}(\lambda)$ is negligible.

III. LRSAS PROTOCOL

LRSAS [2] is an RFID mutual authentication protocol based on the light-weight block cipher algorithm *SKINNY*.

SKINNY [13] is a tweakable block cipher algorithm that has different block and key sizes depending on the environment of the application, having superior perfomance both in hardware implementations and in adaptability. It has 64-bit and 128-bit version for the block size *n* and *n*, *2n*, and *3n* versions for the key size *t*. The steps required for encryption are the initialization phase and the round function, wich consists of the following operations: SubCells, AddConstants, AddRoundTweakey, ShiftRows and MixColumns. For more information on how the cryptosystem works, the reader is referred to [13].

A lightweight protocol is a category of RFID systems protocols, among mature protocols, simple protocols and ultra-lightweight protocols. Being in a balance of costs and assuring security and privacy, lightweight protocols are usually chosen over other types of protocols. In this setup, a tag has support for simple functions (cyclic redundancy code check) and pseudo-random number generators. Unlike simple and mature protocols, it cannot compute one-way hash functions.

In this protocol, the following version of SKINNY algorithm is adopted: the block has 128 bits, key size is 128 bits and the encryption round is 40 times.

The authors use the following notations to describe the protocol:

- $\mathcal{R}$: reader,
- $\mathcal{T}$: tag,
- *ID*: tag identifier,
- *FID*: encryption of *ID*,
- *K*: key shared by $\mathcal{T}$ and $\mathcal{R}$,
- *r*: random number, generated by $\mathcal{R}$,
- $\oplus$: XOR operation,
- *En(X)*: Encryption using SKINNY.

The protocol is composed of four phases in order to achieve mutual authentication: *initialization* phase, *tag indentification* phase, *mutual authentication* phase and *update* phase.

Before describing the above phases, note that a tag keeps in its permanent memory its *ID* (96 bits), *FID* (96 bits) and the shared key *K* (128 bits), the last two being updated after each authentication, where *FID* is the ciphertext obtained by encrypting *ID* using SKINNY.

Initialization phase: The database *DB* will store two entries for every tag identity *ID*: $\{ID, FID^{old}, K^{old}\}$ and $\{ID, FID^{new}, K^{new}\}$, values that are obtained by reader in the communication with the tag in the previous and current protocol instances.

Tag identification phase: After the reader sends a request, the tag responds with its identifier, FID^{new}. If the reader recognizes the message as the FID^{new} as it is in the database *DB*, the authentication phase starts. If the message received is FID^{old} then the pair (FID^{old}, K^{old}) is used for authentication and the tag may be subjected to desyncronization attack.

Mutual authentication phase: The reader generates *r*, computes M_1 and M_2, then sends $M_1 \| M_2$ to tag.

$$M_1 = FID \oplus r$$

$$M_2 = En(FID \oplus ID \oplus r)$$

The tag computes *r'* and M_2'. If M_2 and M_2' are equal, the reader is authenticated, else, the authentication ends.

$$r' = M_1 \oplus FID$$

$$M_2' = En\,(M_2' \oplus r')$$

After that, the tag calculates M_3' and transmits it to the reader.

$$M_3' = En(M_2' \oplus r')$$

After the reader receives M_3', it will compute M_3. If M_3 and M_3' are the same, the tag is authenticated. Otherwise, the authentication stops.

$$M_3 = En(M_2 \oplus r)$$

Update phase: After the mutual authentication, the update phase starts with two options depending on the pair that the reader is using to authenticate the tag:

- if the reader uses (FID^{old},K^{old}), then the database *DB* will not modify the pseudonym and shared key;
- if the reader uses (FID^{new}, K^{new}), the database *DB* will be updated ($FID^{old} = FID^{new}$, $K^{old} = K^{new}$, $FID^{new} = M_1$), where K^{new} is computed through the key schedule module of SKINNY.

If the tag receives the *OK* message, it will update both its own FID^{new} with M_1, and the K^{new}.

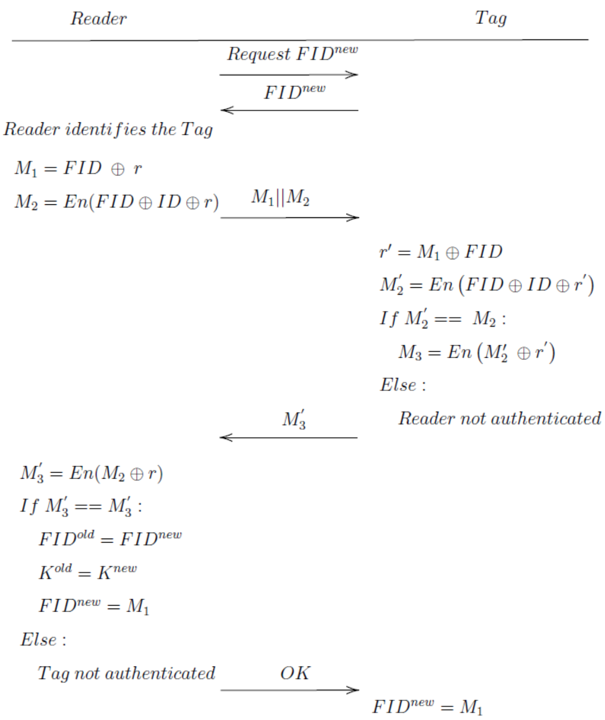

Figure 1. The authentication process of LRSAS

The authors claim that the LRSAS protocol achieves forward security, being protected against impersonation attack, track attack, desyncronization attack and denial of service.

IV. VULNERABILITIES OF LRSAS

In [14] the authors proved that not including a random piece specific to the tag when sending the tag identifier (in our case FID^{new}) to the reader compromises the privacy of the RFID scheme.

Assume that we can determine in polynomial time if two tags contain or not the same tag identifier for the LRSAS RFID scheme.

Consider a narrow weak adversary $\mathcal{A}$ that plays the following privacy game with the LRSAS protocol denoted Σ:

$$\underline{RFID_{\mathcal{A},\Sigma}^{prv\_0}(\lambda)}$$

1) $CreateTag^1(ID_1)$
2) $CreateTag^1(ID_2)$
3) $(vtag_1, 1) \leftarrow DrawTag(uniform\_distribution)$
4) $\pi_1 \leftarrow Launch()$
5) $request \leftarrow SendReader(\emptyset, \pi_1)$
6) $FID_1^{new} \leftarrow SendTag(request, vtag_1)$
7) $Free(vtag_1)$
8) $(vtag_2, 1) \leftarrow DrawTag(uniform\_distribution)$
9) $\pi_2 \leftarrow Launch()$
10) $request' \leftarrow SendReader(\emptyset, \pi_2)$
11) $FID_2^{new} \leftarrow SendTag(request, vtag_2)$
12) $Free(vtag_2)$
13) $\mathcal{A}\ receives\ the\ association\ table\ \Gamma\ of\ DrawTag$
14) $If\ (\Gamma(vtag_1) = \Gamma(vtag_2)\ \wedge$
    $TI(vtag\_1)\ = TI(vtag\_2))$
    $or\big(\Gamma(vtag_1) \neq \Gamma(vtag_2) \wedge TI(vtag_1) \neq$
    $TI(vtag_2)\big)$
    $then\ return\ 0\ else\ return\ 1,$

where *TI(vtag)* represents the *vtag* tag's identifier determined in the present tag's state.

The output of $RFID_{\mathcal{A},\Sigma}^{prv\_0}(\lambda)$ is 0 with overwhelming probability (respectively, 1 with negligible probability) because, given that the adversary $\mathcal{A}$ queries $vtag_1$ and $vtag_2$ on the same request, we have 2 scenarios:

1) If $vtag_1$ and $vtag_2$ refer to the same tag then FID_1^{new} and FID_2^{new} contain the same tag identifier with overwhelming probability;

2) If $vtag_1$ and $vtag_2$ do not refer to the same tag then FID_1^{new} and FID_2^{new} do not contain the same tag id with overwhelming probability.

Now we consider a blinder $\mathcal{B}$ arbitrarily chosen and the blinded privacy game $RFID_{\mathcal{A},\Sigma,\mathrm{B}}^{prv\_1}(\lambda)$ described as $RFID_{\mathcal{A},\Sigma}^{prv\_0}(\lambda)$ but the *Launch, SendReader and SendTag* oracles responses are reproduced by $\mathcal{B}$. Remark that $\Gamma(vtag_1) = \Gamma(vtag_2)$ and $\Gamma(vtag\_1) \neq \Gamma(vtag\_2)$ occur with probability ½.

Next, considering that the blinder $\mathcal{B}$ can output an accurate response to $vtag_1$, it has only ½ chances to give an accurate response $vtag_2$.

Thus, because there is a significant difference between the probability of an accurate response given by the real privacy game, respectively by the blinded privacy game, the adversary $\mathcal{A}$ can determine what game it was playing.

Considering that $\mathcal{A}$ is the most limited type of adversary (narrow weak), we can deduce that the LRSAS protocol does not achieve any type of privacy in Vaudenay's model.

V. IMPROVEMENTS FOR LRSAS

When a protocol presents vulnerabilities, an analysis over the causes may help to determine if we can improve the protocol in order to increase or re-establish the privacy class that it originally claimed to have.

As shown in the previous section, the privacy of the LRSAS protocol is compromised due to non-including a random piece specific to the tag when sending the tag identifier, this step being the first one in the reader-tag communication. Also, this is the only step used for tag identification.

Although some weaknesses can be fixed in faulty protocols, the ones that compromise privacy are difficult to correct, considering that, in our case, LRAS does not achieve any form of privacy.

Because LRSAS doesn't have an omission/oversight/ negligence error, but a design flaw, we cannot improve the protocol. If one would try to increase the privacy of the scheme, it would result in developing another protocol due to LRSAS construction logic.

VI. CONCLUSIONS

With the RFID technology continuously expanding in many fields of our day-to-day life, we need to be sure that our data is protected and existing RFID schemes used for private information have a certain amount of security and privacy.

Some designers of RFID schemes build their privacy analysis without considering well-established models, misclassifying their protocols into another class of security or privacy.

By revealing the vulnerabilities that a protocol has we bring contribution to the scientific community and highlight a design flaw that we should avoid.

In this paper we recalled the concepts that are needed to understand the security and privacy of RFID shemes, then we presented the LRSAS protocol and the cryptosystem that it's using for encrypting the transmitted data and proved that this protocol doesn't achieve any kind of privacy in Vaudenay's model due to a design error that it cannot be fixed.

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A Method for Binary Quadratic Programming with Circulant Matrix

Daniela Istrati [1], ORCID: 0000-0002-1607-9273
Vasile Moraru [1], ORCID: 0000-0002-6400-1374
Sergiu Zaporojan [2], ORCID: 0000-0001-5928-4229
[1] Department of Computer Science and Systems Engineering, Technical University of Moldova, Stefan cel Mare bd., 168, MD2004, Chişinău, Republic of Moldova, www.utm.md, daniela.istrati@ia.utm.md, vasile.moraru@ia.utm.md,
[2] Scientific Research Dept., Technical University of Moldova, 168, bvd. Stefan cel Mare, MD2004, Chişinău, Republic of Moldova, www.utm.md, sergiu.zaporojan@adm.utm.md

Abstract — **Binary quadratic programming is a classical combinatorial optimization problem that has many real-world applications. This paper presents a method for solving the quadratic programming problem with circulant matrix by reformulating and relaxing it into a separable optimization problem. The proposed method determines local suboptimal solutions. To solve the relaxing problem, the DCA algorithm it is proposed to calculate the solutions, in the general case, only local suboptimal.**

Keywords— Binary nonconvex quadratic problems, circulant matrix, Fourier matrix, separable programming, relaxed problem, DC algorithm

I. INTRODUCTION

Consider the following linearly-constrained binary quadratic programming problem:

$$\left.\begin{array}{c} f(x) = x^T Qx \rightarrow max \\ \text{subject to} \\ Ax = b, \\ x \in \{0,1\}^n \end{array}\right\} \qquad (1)$$

where Q is a symmetric $n \times n$ real matrix, A is an $m \times n$ matrix, $rank(A) = m \leq n$, and b is an m real vector.

We will briefly describe the notation used in this paper. All vectors are column vectors. The subscript notation y_k refers to an element of the vector y. A superscript k is used to denote iteration numbers. Superscript "T" denotes transposition.

Over the years, various methods have been developed to solve the problem (1) by:

- linear reformulations [1], [2], [3];
- convex reformulations [4], [5];
- continuous convex programming [6];
- Lagrangian, semidefinite and convex quadratic relaxation, [7], [8], [9], [10].

In this paper we will consider that the Q matrix is a symmetric circulant matrix [11]:

$$Q = \begin{pmatrix} q_0 & q_1 & q_2 & \cdots & q_{n-2} & q_{n-1} \\ q_1 & q_2 & q_3 & \cdots & q_{n-1} & q_0 \\ q_2 & q_3 & q_n & \cdots & q_0 & q_1 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ q_{n-1} & q_0 & q_1 & \cdots & q_{n-3} & q_{n-2} \end{pmatrix}.$$

Circulant matrices appear in a variety of mathematical and engineering applications such as signal processing and error correction of codes [12],[13].

In this context above, we present a method for solving the quadratic programming problem with circulant matrices Q. The problem is converted into a separable programming problem, which consecutively is relaxed to a problem with the objective function represented as the difference of two convex functions, a problem called in the literature DC programming (DC-Difference of Convex functions).

II. EIGENVALUES AND EIGENVECTORS OF CIRCULANT MATRIX

The first row of the circulant matrix Q

$$q_0 \quad q_1 \quad q_2 \cdots q_{n-2} \quad q_{n-1}$$

is called the generator of Q.

The eigenvalues of the symmetric matrix Q are real numbers and are given by

$$\lambda_j = q_0 + q_1\omega_j + q_2\omega_j^2 + \cdots + q_{n-1}\omega_j^{n-1} \quad (2)$$

$j = 1,2,\cdots,n,$

where

$$\omega_j = \exp(\tfrac{2\pi(j-1)}{n}).$$

Note: for n even numbers ($n = 2k$) we have $\lambda_j = \lambda_{n-j}$.

For $j = 1,2,\cdots,n$, the corresponding eigenvectors are given by [11]:

$$p_j = \left(\omega^0, \omega^{j-1}, \omega^{2(j-1)}, \cdots, \omega^{(j-1)(j-1)}\right)^T \quad (3)$$

Here ω is the primitive root of unity :

$$\omega = exp\left(\frac{2\pi i}{n}\right), i = \sqrt{-1}.$$

All circulant matrices can be diagonalized by the same matrix F with the columns $p_j, j = 1,2,\cdots,n$ [11]:

$$F = \frac{1}{\sqrt{n}}(p_1 \quad p_2 \quad \cdots \quad p_n) =$$

$$= \frac{1}{\sqrt{n}}\begin{pmatrix} 1 & 1 & 1 & \cdots & 1 \\ 1 & \omega & \omega^2 & \cdots & \omega^{n-1} \\ 1 & \omega^2 & \omega^4 & \cdots & \omega^{2(n-1)} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & \omega^{n-1} & \omega^{2(n-1)} & \cdots & \omega^{(n-1)(n-1)} \end{pmatrix}.$$

The matrix F is the Fourier matrix (the Discret Fourier Transform DFT) [6].

F is a matrix with the outstanding properties:

- $F^T = F$
- $F^2 = I = \begin{pmatrix} 1 & 0 & \cdots & 0 \\ 0 & 1 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & 1 \end{pmatrix}$
- $\det F = 1,$
- $F^{-1} = F$
- $Sp(F) = \{-1,1\}$

Moreover, the matrix F is a well-conditioned matrix ($cond(F)$=1. This is important from the point of view of numerical calculation: small perturbations in the input data will not produce large variations in the calculations [14].

The circulant matrices are diagonalized by the Fourier matrix F, i.e. we can write

$$Q = F\Lambda F \quad (4)$$

where Λ is the diagonal matrix:

$$\Lambda = Diag\,(\lambda_1, \lambda_2, \cdots, \lambda_n) =$$

$$= \begin{pmatrix} \lambda_1 & 0 & 0 & \cdots & 0 & 0 \\ 0 & \lambda_2 & 0 & \cdots & 0 & 0 \\ 0 & 0 & \lambda_3 & \cdots & 0 & 0 \\ \vdots & \vdots & \vdots & & \vdots & \vdots \\ 0 & 0 & 0 & \cdots & 0 & \lambda_n \end{pmatrix} \quad (5)$$

Thus the symmetric matrix Q is expressed in terms of matrices that contain its eigenvalues (2) and the components of the eigenvectors (3). Using the Fourier matrix F, resulting from (4) and (5), the diagonalization of the circulant matrix can be performed Q: $FQF = \Lambda$.

III. REFORMULATION OF THE QUADRATIC PROBLEM AS A SEPARABLE PROGRAMMING PROBLEM

The objective function *f*(*x*) can be rewritten as:

$$f(x) = x^TQx = x^TF\Lambda Fx = (Fx)^T\Lambda Fx.$$

We note

$$y = Fx = (y_1 \quad y_2 \quad \cdots \quad y_n)^T.$$

As the matrix F is orthogonal ($F^{-1} = F$), we have

$$x = Fy.$$

Then problem (1) becomes a separable programming problem:

$$\left.\begin{array}{c} \varphi(y) = y^T\Lambda y = \sum_{k=1}^{n} \lambda_k y_k^2 \to max \\ \text{subject to} \\ AFy = b, \\ Fy \in \{0,1\}^n \end{array}\right\} \quad (6)$$

Among the eigenvalues of the Q matrix are both positive and negative numbers. The function $\varphi(y)$ can be rewritten as the difference between two convex functions:

$$\varphi(y) = \varphi_1(y) - \varphi_2(y)$$

where

$$\varphi_1 = \sum_{\lambda_k > 0} \lambda_k y_k^2$$

$$\varphi_2 = \sum_{\lambda_k<0} (-\lambda_k) y_k^2$$

The last constraints of problem (6) make it very difficult to solve it. If constraints are not taken into account $(Fy \in \{0\ ,1\}^n)$, then the problem (6) becomes a nonconvex separable quadratic programming problem. A practical approach would be to relax the conditions

$$Fy \in \{0\ ,1\}^n\ ,$$

by replacing them with

$$0 \le Fy \le 1,$$

i.e. with

$$0 \le p_j^T y_j \le 1, j = 1,2, \cdots . n$$

Thus we obtain the relaxed problem

$$\left.\begin{array}{c} \varphi_1(y) - \varphi_2(y) \to max \\ \text{subject to} \\ AFy = b, \\ 0 \le Fy \le 1 \end{array}\right\} \qquad (7)$$

which is a DC programming problem [15].

IV. DC ALGORITHM

As it is mentioned above, to solve the relaxed problem (7) we will use the DCA method [15].

We denote the set of indices i_s for which the eigenvalues $\lambda_{i_s} > 0$:

$$I = \{i|\lambda_i > 0\} = \{i_1, i_2, \cdots, i_s\}.$$

The DCA method is of the primal-dual type and is based on the construction of two strings

$$\{y^{(k)}\}, \{v^{(k)}\}$$

which are calculated at each iteration as follows:

Step 1. $y^{(o)}$ - the initial state approximation, $k = 0$.

Step 2. It is determined

$$u^{(k)} = \nabla\varphi_1(y^{(k)}) = \begin{pmatrix} \dfrac{\partial\varphi_1(y^{(k)})}{\partial y_{i_1}} \\ \dfrac{\partial\varphi_1(y^{(k)})}{\partial y_{i_2}} \\ \vdots \\ \dfrac{\partial\varphi_1(y^{(k)})}{\partial y_{i_s}} \end{pmatrix}$$

Step 3. It is established $y^{(k+1)}$ the solution of the convex separable programming problem:

$$\left.\begin{array}{c} \sum_{\lambda_k<0} (-\lambda_k) y^2 - \sum_{\lambda_k>0} \lambda_k u^{(k)} \to min \\ subject\ to \\ AFy = b, \\ 0 \le p_j^T y_j \le 1, \\ j = 1,2, \cdots . n. \end{array}\right\}$$

Step 4. If the stop criterion is checked, then STOP. Otherwise, $k = k + 1$ will be taken and it is proceed to Step 2.

V. CONCLUSIONS

In this paper, the 0-1 quadratic nonconvex programming problem with circulant matrices was considered. Such problems are NP-hard [16]. The diagonalization of the circulant matrix using the Fourier matrix allows reducing the considered problem to a separable programming problem.

To solve the relaxing problem, the DCA algorithm is proposed to calculate the solutions, in the general case, only local suboptimal. In order to find the optimal global solutions, other methods must be used, such as the branch and bound method [17].

These methods are slow and require many calculations that grow exponentially with the size of the problem. DC Numerical simulations show that in the case of non-convex quadratic programming problems, it is more advantageous to apply the DC Algorithm than the branch and bound method.

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A Brief Overview of Intelligent Interfaces in Production Systems

Daniela Istrati [1], ORCID: 0000-0002-1607-9273
[1] Department of Computer Science and Systems Engineering, Technical University of Moldova, Stefan cel Mare bd., 168, MD2004, Chișinău, Republic of Moldova, www.utm.md, daniela.istrati@ia.utm.md

***Abstract*—This paper presents a state of the art in field of intelligent user interfaces, which are the main elements that make the interaction between humans and machines in the most efficient, natural, effective way. As an interdisciplinary product, the design of user interfaces represents the combination of models from disciplines like software engineering, artificial intelligence, human-computer interaction and other disciplines (sociology, psychology, etc.). In the process of design and operation of production systems, an important factor is its responsiveness and the ability to have integrated the capacity to change over time and functionally. To achieve a high level of structural configuration and feasibility, a production system must have a compatible interface**

***Keywords*—intelligent user interfaces; human-computer interaction, adaptability, intelligent agents, production systems.**

I. Introduction

Communication between humans and computers is a field that has been studied for a considerable period. The subject of interfaces had a progressive change from graphical ones to the most natural, cognitive and adaptive interaction with the user. Thus, the term Intelligent interfaces has been conceived, as a result of a combination of techniques deriving from artificial intelligence and human-computer interaction.

Intelligent interfaces attempt to solve the problems of human-computer interaction by providing new methods of communication and adapting to the user and making the use of the system in the most appropriate, intuitive and intelligent manner [1], [2]. In terms of intelligence, in this case, is the ability to use the information properly and not the cognitive aspect of this definition [2].

In the process of design and operation of production systems, an important factor is its responsiveness and the ability to have integrated the ability to change over time and functionally. To achieve a high level of structural configuration and feasibility, a production system must have a compatible interface [3].

Intelligent user interfaces are part of production systems and socio-technical production systems, which would successfully unite people with the cyber and physical world for mutual understanding [4], [5].

Research into new communication methods focuses on natural language systems, gesture recognition, image recognition, and multimodal interfaces [1], [6], [7], [8]. User adaptation is achieved using artificial intelligence methods to perform reasoning and learning, generate user simulation examples, and recognize plans.

The keyboard of the cell phone, as an amalgam of machine intelligence and human-computer interaction, is an example of an intelligent user interface that attracts researchers' attention. The research on the use of text input, keyboard correction and prevention of errors, is described in papers [9],[10], especially in cell phone use, the behaviour of the users and the learning innovations are the challenges that are encountered when designing or creating intelligent user interfaces.

The cultural aspect of intelligent user interfaces is treated in the paper [11], as an important factor of the end-users ambient due to the boundless acquisition of mobile communication devices.

II. Intelligent User Interfaces

The main objective of intelligent user interfaces to be achieved is the interaction between humans and machines in the most efficient, natural, and affective way [12]. As an interdisciplinary product, the design of user interfaces represents the combination of models from disciplines represented in figure 1.

In [13], it is mentioned the use of intelligent agents in intelligent interfacing that behave like assistants to help the user in the process of interfacing. It could be entities that could perform autonomously, accomplish certain purposes or communicate with other agents or people.

A representation of human-computer interaction in which both the user and the interface are partners and have the same components is shown in the figure (fig. 2):

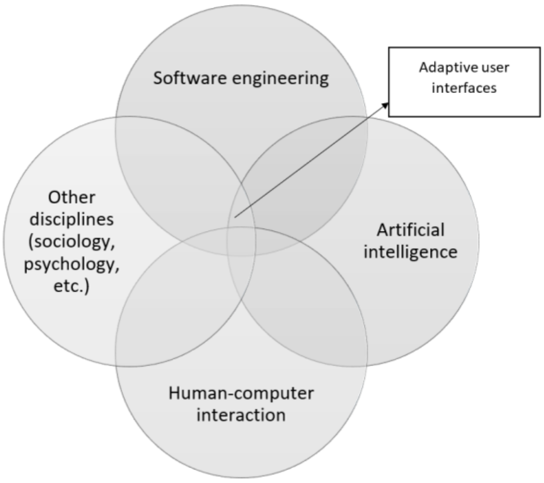

Figure 1. Different fields inter-connection in intelligent user interface creation [12].

As it is represented in the following figure 2, the components of the image can be described as follows:

- An ontology, i. e. a model of the environment in which it acts, which could be used to decide on various courses of action. The environment model can be represented both by artificial neural networks and in symbolic form, by knowledge bases;
- A partner's model, which is often a part of the elaboration of an ontology (for example, in intelligent computer-assisted instruction systems, the student model contains the part of the ontology that the student knows as well as the erroneous knowledge that the student has);
- The goals, beliefs, intentions, and commitments assumed;
- The following plans

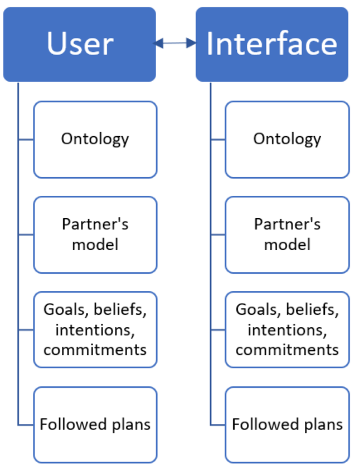

Figure 2. Intelligent interfaces [13]

III. The Functions of Intelligent User Interfaces

The main functions of the intelligent interfaces can be listed as follows [14]:

1. Communication function. It is assumed that a non-programming user will communicate with a computer in a limited natural language that is due to the specific purpose - the formulation of problems that the computer is required to solve. The range of tasks in the mass introduction of computers in various types of human activity can be very wide. With the help of computers, computational problems are being solved, as well as problems related to controlling the logical reasoning, information retrieval, office work and other types of human activity. Therefore, the natural language that is valid at the input of an intelligent interface cannot be too unsatisfactory. Its limitations are manifested not in the volume of the dictionary, but rather in the organization of texts entered by the user into the computer. It is important that the text that is entered be understandable to the computer. The term "understanding" can be perceived at the level of intuition.

When implementing the function of communication, an important role is played by the means of the graphic display of information and the possibility of replacing texts with a set of actions ("objectification" of the text). Therefore, the communication system included in the intelligent interface is not only a system of communication-based on text messages, but also all kinds of input-output systems for voice messages, graphical interaction tools, and cursor-type tools.

2. Function of automatic synthesis. The user's message must be converted into an executable program for the computer. This requires resources for implementing procedures in a computer as part of an intelligent interface that is usually performed by a human programmer. To make this possible, it is necessary to make it possible to translate the user's original message into some precise specification language, and then generate a working program from this record. Such a transformation requires special knowledge that must be available in the computer's memory.

3. Justification function. A user who does not understand or poorly understands how a computer converts his task into a working program and what methods it uses to obtain a solution has the right to demand from the computer to substantiate the solution obtained. He can ask the computer how it converted his problem into a program, what method it used to

find the solution, how this solution was obtained and how it was interpreted at the output. Thus, the justification function includes both the explanation function, which is characteristic of modern expert systems and the trust function, the purpose of which is to increase the degree of user confidence in the computer.

4. Learning function. When a user approaches a computer for the first time, he has the right to expect that he will be able to obtain information about working with it quite easily. For household appliances that he has previously encountered, it is enough to read a simple and small instruction to immediately understand how to handle this appliance. A computer, of course, is more complicated than all those devices that a person has come across in everyday life.

An instruction that would allow the user to master all the capabilities of a computer, to understand the basic principles of working with it, would turn out to be too voluminous and inconvenient for him.

Therefore, computers of new generations are supplied with special tools (tutors), with the help of which the user gradually comprehends how to work with a computer and the subtleties of successful communication with it.

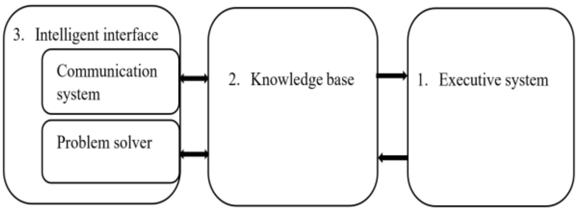

Figure 3. The structure of a modern system for solving applied problems [16]

The structure of the system, as can be seen in figure 3, which satisfies the requirements of the technology for solving problems, consists of three components [15]:

- the executive system, which is a set of tools that ensure the implementation of programs;
- knowledge base containing a system of knowledge about the problem environment;
- an intelligent interface that provides the ability to adapt the computing system to the user.

Thus, the intelligent interface has the structure shown in Figure 3. The central place in this structure is covered by the knowledge base.

IV. The Necessity of Using Intelligent Interfacing

The need for intelligent interfaces and the creation of systems containing intelligent interfaces could be rationalized for following reasons [2]:

- The complexity of applications is rising rapidly along with the necessity of guidance for users on a distinct part of a program, that is rarely used.
- The large amount of information managed by applications. The pertinence of the information that is displayed to the user to not overwhelm the user with data.
- The use of intelligent interfaces as a solution of easing the use of information systems by non-experts in a particular field.
- The use of computers in special or extreme situations or by special users, like military or medical software or high-stress applications. In this case, intelligent interfaces would contribute to the use of multimodal communication and knowledge of the system performance of the user. Intelligent interfaces can induce the accessibility of computers to users, with limited potential for effective use of computers, like people with visual or motor afflictions by using multimodal communication and interface adaptability,

The input of the information could be tactile or visual and the output could be vocal, tactile or typed, depending on the user's model required. Using natural language in the creation of the system, makes it more intuitive for the user, offering a higher degree of independence [2], [14].

To represent intelligent interfaces, we will present the diagram represented in the following figure 4:

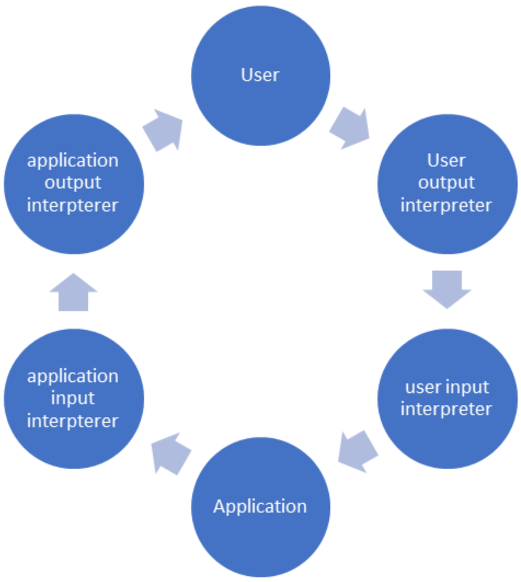

Figure 4. A basic model for intelligent interfaces [2].

As is presented above, the description of the figure could be made as follows:

- User Input Interpreter refers to the part of the system that makes the process of data input more accessible to the user. At this phase, the functions are spell checking, the completion of commands, mouse click detection, etc.
- Application Input Interpreter. At this stage, the interpretation of the user's commands is happening.
- Inside the program. The phase where the inside working on the programs takes place.
- Application Output Interpreter. The part of the program refers to the interpretation of the machine's data into information for the user.
- User Output Interpreter. The stage of displaying the data to the user.

V. CONCLUSIONS

As computer systems become more sophisticated, the use of intelligent interfaces can enhance the use of applications that are continuously improving and making it difficult for users the effectively use the systems.

The main goal of intelligent user interfaces is to achieve the level of usability of the computer systems and simulate the competencies of humans by machines [17].

In the last decades, many techniques from artificial intelligence have been applied in intelligent user interfaces, but still, research continues to finally be able to give to the user the most natural human-computer interaction. The use of computer systems depends on the user's level of comfort during the interaction with the machine. Thus, even though the system will perform the given tasks, the interface that does not achieve a high level of understanding, communication and intelligence with the user will not have a sufficient degree of usability. Research has shown that production and technology development and the production are linked directly to the interfaces, as the decisions made during the process an influence on the result of the product [18]. Thus, the user could even participate virtually a manufacturing process due to an automation tool [19]

The term of the renaissance of production found in [20] shows the meaning of bringing digital innovations to the physical world and intelligent interconnection in production, interacting with the manufacturer, at the same time as the development of Industry 4.0 in the last decades.

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Performability Modeling of Self-Adaptive Systems Based on Extension Neural Rewriting Stochastic Petri Nets

Alexei Sclifos [1], ORCID: 0000-0003-4531-7944
Emilia Sclifos [1], ORCID:0000-0003-1986-7256
Emilian Guțuleac [1], ORCID: 0000-0001-6839-514X
[1] Technical University of Moldova, Bd. Ștefan cel Mare, 168, MD-2004, Chișinău, R. Moldova,
emilian.gutuleac@calc.utm.md, https://utm.md

***Abstract*—Traditional mathematical formalisms are unable to model modern self-adaptive discrete event systems (ADES) because they cannot handle behaviors that change at run-time in response to environmental changes. This paper introduces a new extension of Reconfigurable Stochastic reward Nets (*RSRN*), called Extension Neural Rewriting Petri Nets (ExNRPN), which enables the performability modeling and simulation of modern ADESs. ExNRPNs are obtained by incorporating in some special transitions of *RSRN*s an extension neural network (ENN) algorithm where the run-time calculation and reconfiguration is done in the local components, while the adaptation is performed for the whole system. The application of the proposed ExNRPN is illustrated by performability modeling a particular ADES.**

Keywords—adaptive system; extension neural network; performability modeling; rewriting rule; stochatic Petri net

I. Introduction

Modern dynamic discrete-event systems (DES), such as computing systems and networks; mobile dynamic Ad-hoc computer networks and many technological new solutions, based on cloud computing and Internet of Things applications, etc., must adapt in response to unpredictable changes in their states and environment to remain usefully performing. Traditionally, this adaptation has been handled during system downtime, but currently there is an increased demand to automate this process and perform it while the system is operating [1].

The concept of self-adaptive DES (ADES) was introduced as a realization of continuously adapting systems [1]. ADES are capable of changing their behavior and/or structure at run-time in response to their perception of the environment, the states of the system itself, and its requirements. To achieve this, ideally, systems should have certain adaptive characteristics known as *self -** properties introduced in the autonomic computing paradigm [2].

The focus of this paper is on the dynamic performability modeling of ADES in the context of dynamic self-reconfiguration (SR), a key and essential property. SR of system is the ability to automatically and dynamically reconfigure itself in response to changing of states and/or environment.This may include installing, removing, and composing/decomposing elements of the system [1, 2].

There are many formalisms that can be used for this purpose such as transition systems, finite automata, process algebras [3] and different extensions of Petri nets (*PN*s) [3, 4] such as generalized stochastic *PN* (*GSPN*) and stochastic reward nets (*SRN*) [4, 5]. For example, the paper [6] presents a new learning Petri net based on artificial neural networks (ANN) for modeling adaptive software systems. Nevertheless, run-time reconfigurable *SRN* (*RSRN*) [5] seem a good candidate for performance mo-deling of ADES. However, *RSRN* lack the ability to mo-del learning and adaptation based on environmental changes with incompatible or contradictory parameters.

Next, we present a new extension of matrix hybrid *RSRN* [7], called Extension Neural Rewriting Petri Nets (ExNRPN), with adaption ability to performance modeling of ADES. It contains extension adaption transitions (AT) with learning ability based on extension neural network (ENN) [8] which describes environmental changes.

The application of the proposed ExNRPN is illustrated by performability modeling of a particular system.

II. Extenics Theory Features

Extenics Theory (ET) was proposed by Wen Cai [9] to solve intelligently incompatible or contradictory problems that cannot be solved by given conditions until a proper transformation of the conditions is implemented and reformalizes the concepts to give a solution. There are similarities between Fuzzy Set Theory (FST) and ET. In standard set applications, transfer function shows if an element belongs to a class or not. FST extends this set to [0,1], showing the degree an element belongs to the class. In [9], it is explained that ET extends FST from [0,1] to $[-\infty,\infty]$ and therefore, this situation leads up with an element, belonging to each extension set to a different degree. A comparison of Crips logical, Fuzzy and Extension sets is presented in Table I.

Classical mathematics is familiar with the quantity and shapes of objects. But the *Matter-element* method (MEM) in ET considers both the quality and quantity of an object. In the real world, things, objects are represented by their quantity and quality. Therefore, MEM deals with contradictory issues of quality and quantity. ET considers the transformation of these contradictory problems into MEM models and analyzes them through their qualitative and quantitative modification.

Elements of MEM describing a problem must include the name of the problem (object), its characteristics and the value associated with that characteristic. These three basic elements constitute a problem element R, composed of N (object name), the column vectors: $\mathbf{C}=[c_1, c_2,\ldots,c_n]$ (R features, criteria) and $\mathbf{V}=[v_1, v_2,\ldots,v_n]$ (respective feature values) for any given problem [9]. Thus, the formula for R is: $R=[N,\mathbf{C},\mathbf{V}]$. This triplet represents a fundamental unit to describe a multi-dimensional problem element. In addition, the $\mathbf{V}$ vector can have one or more values. In the multi-valued case, the range covered by the vector $\mathbf{V}$ is called the classical domain. In MEM, two intervals are defined $F_0 =< a, b >$ and $F =< d, e >$ with $F_0 \in F$. The problem element R_0 corresponding to it F_0 is defined as $R_0 = [F_0, \mathbf{C}_j, \mathbf{V}_j]$, where $\mathbf{C}_j = [c_{j,1}, c_{j,2},\ldots,c_{j,n}]$ symbolizes the characteristic of F_0 , and the classic domain $\mathbf{V}_j = [< a_{j,1}, b_{j,1} >, < a_{j,2}, b_{j,2} >,\ldots,< a_{j,n}, b_{j,n} >$ corresponds to the value of $c_{j,i}$, $i=1,2,\ldots,n$.

In the same way, the problem element R_F corresponding to F is expressed as $R_F = [F, \mathbf{C}_k, \mathbf{V}_k]$, where $\mathbf{C}_k = [c_{k,1}, c_{k,2},\ldots,c_{k,n}]$ symbolizes the characteristic of F , and the domain $\mathbf{V}_k = [< d_{k,1}, e_{k,1} >, < d_{k,2}, e_{k,2} >,\ldots,< d_{k,n}, e_{k,n} >]$ corresponds to the value of $c_{k,i}$, $i=1,2,\ldots,n$.

TABLE I THREE DIFFERENT SORTS OF MATHEMATICAL SETS

Compared item	***Crisp set***	***Fuzzy set***	***Extension set***
Research object	Data variables	Linguistic variables	Contradictory issues
Model	Mathematics model	Fuzzy Mathematics model	Matter-element model
Descriptive function	Transfer function	Membership function	Correlation function
Proprety	Precision	Ambiguity	Extension
Range of set	$C_A(x)\in(0,1)$	$\mu_A(x)\in[0,1]$	$K_A(x)\in[-\infty,+\infty]$

The distance between two points in classical mathematics is extended in ET in that to calculate the distance between a point x and an interval correlation function $K(x)$ is constructed. The extension distance (ED) between an arbitrary point x and the interval between $F_0 =< a, b >$ and $F =< d, e >$, $F_0 \subset F$, is expressed as:

$$\rho(x, F_0) = |x-(a+b)/2|-(b-a)/2, \qquad (1)$$
$$\rho(x, F) = |x-(e+d)/2|-(e-d)/2.$$

The membership degree value $D(x, F_0, F)$ between the point x and the intervals F_0 and F and the *extended correlation* function $K(x)$ are defined as:

$$D(x, F_0, F) = \begin{cases} \rho(x, F) - \rho(x, F_0), & x \notin F_0 \\ -1, & x \in F_0 \end{cases}, \qquad (2)$$

$$K(x) = \begin{cases} -\rho(x, F_0), & x \in F_0 \\ \dfrac{\rho(x, F_0)}{D(x, F_0, F)}, & x \notin F \end{cases}. \qquad (3)$$

As illustrated in Fig. 1, the maximum value of $K(x)$ referred to a correlation function occurs for $x\in[a,b]$. The point x is excluded from F if $K(x)<-1$, is contained in F_0 if $K(x)>0$, and is included in the extension field if $-1<K(x)<0$. In addition, x can be brought in F_0 when a transformation condition is met on x in the extension field.

III. EXTENSION NEURAL NETWORK

Extension neural network (ENN) [8,10] is a new neural network type that is a combination of ET and artificial neural network (ANN). While ET makes distance measurement and extended correlation function for classification, ANN is used for its fast and adaptive learning capability.

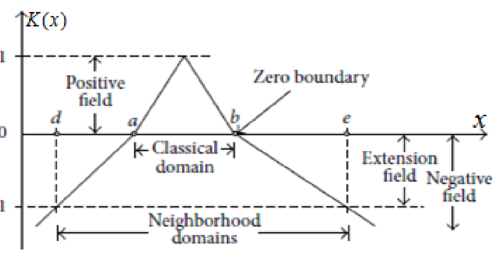

Figure 1. Extension correlation function [9]

ENN was first proposed in 2003 by M. H. Wang [8]. One of important issues in the field of classification and recognition of ENN is how to achieve the best possible classifier with a small number of labeled training data. In [8, 10], it is shown that ENN gives better or equal accuracy and less memory consumption in classification than Multilayer Perceptron ANN, Probabilistic ANN and Counter Propagation ANN.

The structure of an ENN is presented in Fig. 2. Nodes in the output layer of ENN represent the outputs of the nodes in the input layer by a set of weights. The total number of inputs and outputs are n and n_c, respectively, and the total number of instances is N_p. The *data-points* are denoted x_{ij}^{p}, meaning the instance $i=1,2,\dots,N_p$ and the characteristic value $j=1,2,\dots,n$ correspond to the matter-element p. In ENN, x_{ij}^{p} becomes the input and o_{ik} the output of the node k for the instance i. Between the input x_{ij}^{p} and the output o_{ik} there are two sets of weights denoted w_{kj}^{L} and w_{kj}^{U}, respec-tively. These two weights are determined by searching for the lower and upper bounds of the j input of the training data. The upper bound w_{kj}^{U} is found by finding the maximum value for the j input node from all input instances, and the lower bound w_{kj}^{L} is determined inversely. These two weights are adjusted in each iteration to perform more accurate and efficient classification. Nodes o_{ik} in the output layer are the pointers to which an input vector belongs. If i instances inputs correspond to the class k, then the value o_{ik} of the output layer should be smaller than the other output nodes. This situation indicates that the distance between the i instances inputs of the class k is smaller than between the other classes. The transfer function is presented in (4), where the index of the estimated class is k^*. The weights and are the points where the extension distance $ED_{ik}(x)=1$. More details on the ED shown in (4) and the adjustment of the weights are further discussed.

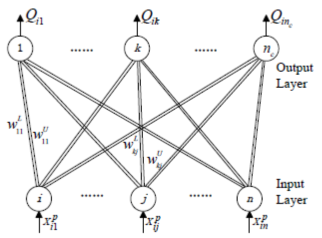

Figure 2. The structure of ENN [8]

$$ED_{ik}(x)=\sum\nolimits_{j=0}^{n}\left(\frac{|x_{ij}^{p}-z_{kj}|-(w_{ij}^{U}-w_{ij}^{L})/2}{|(w_{ij}^{U}-w_{ij}^{L})/2|}+1\right), \qquad (4)$$

$$o_{ik}\equiv ED_{ik}(x),\ \ k=1,2,\dots,n_c.$$

ENN is a supervised learning method which provides an inferring function from supervised training data. Training data is the composition of input and desired output pairs of following *matter-element model* :

$$R_k=[class_k, c_{kj}, V_{kj}],\ k=1,2,\dots,n_c;\ \ j=1,2,\dots,n, \qquad (5)$$

where $class_k$ is the name of the k class. The symbols c_{kj}, $j=1,2,\dots,n$ represent the characteristics and V_{kj} denotes the range for the characteristic c_{kj} of $class_k$. The range value $V_{kj}=[w_{kj}^{L},\ w_{kj}^{U}]$ is determined by w_{kj}^{U} and w_{kj}^{L}. The learning process of ENN is as follows: in the initial step, the weights are determined based on the expression (6), searching among all j instances - the maximum and minimum input of the class k to find the respective weights w_{kj}^{U} and w_{kj}^{L}.

$$w_{kj}^{U}=\max_{\forall i}\{x_{ij}^{k}\};\ \ w_{kj}^{L}=\min_{\forall i}\{x_{ij}^{k}\}, \qquad (6)$$

$$c_{kj},\ i=1,2,\dots,N_p,\ \ k=1,2,\dots,n_c,\ \ j=1,2,\dots,n.$$

After maintaining the matter-element model, the center of the clusters is determined by V_{kj} as shown in (7). We note that the clusters are the representatives of the classes. Each class has the same number of clusters as the number of inputs.

$$Z_k=\{z_{k1}, z_{k2},\dots,z_{kn}\},\ \ z_{kj}=(w_{kj}^{U}+w_{kj}^{L})/2, \qquad (7)$$

$$k=1,2,\dots,n_c,\ \ j=1,2,\dots,n.$$

If these initial values are not sufficient for classification, after performing the initial steps, to obtain a more accurate classification the weights and center of the clusters will be updated. The desired classification accuracy is determined by the learning performance rate $E_\tau=N_m/N_p$, where N_m is the total number of instances misclassified, and where N_p is the total number of instances. The update of the cluster weights and center is continued until the learning performance rate is low enough. All instances must be used during learning. In each iteration, an instance must be randomly chosen from the training data. In (8), for training, the pattern X_i^{p}, whose desired result should be p is randomly chosen:

$$X_i^{p}=\{x_{i1}^{p}, x_{i2}^{p},\dots,x_{in}^{p}\},\quad 1\le p\le n_c. \qquad (8)$$

In the next step, the ED method is used to determine the respective class based on the input vector X_i^{p}, whose elements are the feature values. Then the distance between the training instances X_i^p with data-points x_{ij}^p and each cluster is calculated. According to (4), the distance between the input of the randomly taken instance and the k class is calculated. After the distance of each entry is calculated for a given class, these distances are summed to find the total distance. This procedure must be done for each class. The class that gives the minimum distance is the class that ENN classifies the current instance. However, the desired result is p. If the minimum ED shows that $k^* = p$, then no update is needed. If $k^* \neq p$, then updating is required to make a more accurate classification. If in the training phase $k^* \neq p$, the separator is shifted according to the closeness of the inputs to the cluster centers. The amount of change is directly proportional to the ED. The separator k^* of the misclassified class is displaced from that of the input instances, and the separator p of the desired class is moved next to them as formulated by the expressions (9) and (10).The cluster center and weights are both changed.

$$z_{pj}^{new} = z_{pj}^{old} + \eta \cdot (x_{ij}^p - z_{pj}^{old}), \tag{9}$$
$$z_{k^*j}^{new} = z_{k^*j}^{old} + \eta \cdot (x_{ij}^p - z_{k^*j}^{old}).$$
$$w_{pj}^{Lnew} = w_{pj}^{Lold} + \eta \cdot (x_{ij}^p - z_{pj}^{old}), \tag{10}$$
$$w_{pj}^{Unew} = w_{pj}^{Uold} + \eta \cdot (x_{ij}^p - z_{pj}^{old}),$$
$$w_{k^*j}^{Lnew} = w_{k^*j}^{Lold} + \eta \cdot (x_{ij}^p - z_{k^*j}^{old}),$$
$$w_{k^*j}^{Unew} = w_{k^*j}^{Uold} + \eta \cdot (x_{ij}^p - z_{k^*j}^{old}),$$

where η is the learning rate.

Because the ENN just adjusts the weights of the p-th and the k^*-th class, the learning of ENN has a speed advantage over the other supervised learning algorithms, and can quickly adapt to new and important information.

In ENN only one output neuron node in the n_c output layer remains active (the output value is **1**) and the output values of other neuron nodes are zero to indicate a safety status pattern of the input instance.

The distinctive characteristic of ENN is that the ENN can effectively solve the classification and recognition problems whose features are defined over an interval.

IV. EXTENSION NEURAL REWRITING PETRI NETS

In this section we provide a ExNRPN definition, firing rules of the respective transitions and rewriting rules by the current marking and environmental changes. We assume that the readers are familiar with the basic concepts of *RSRN* and hybrid *SRN*, called *HSRN*, with matrix attributes (*HSRNM*) [5, 7]. Next, due to the space restrictions, we will only give a brief overview to this topic. For more comprehensive details to *RSRN* and *HSRNM* we let the readers refer to [4, 5, 7].

Let IN_+ (resp. IR^+) be the set of natural (resp. positive real) numbers.

The definition of an ExNRPN is derived according to [5, 7] and inherits most of the *RSRN* and *HSRNM* characteristics. Thus, the ExNRPN, denoted $R\Gamma$, is defined as a 17-tuple system such that $R\Gamma = \langle P, T, R, h, A_{rcs}, Pri, G^E, G^R, K^p, \Lambda, \omega, V, \rho, M_0, Lib_R, \phi, Lib_{ENN} \rangle$, where: $P = P^D \cup P^C$ is a finite set of places, where P^D is the set of all discrete places and P^C is the set of continuous places; $T = T^D \cup T^C \cup T^{At}$ is a finite set of transitions, where T^D, T^C and T^{At} are the sets of *discrete, continuous* and *adaptive* transitions, respectively; $h: P \cup T \to \{A, C, D\}$ is a mapping to assign an identifier to each node, where "*A*; *C*; *D* " indicate for every node whether it is adaptive, continuous or discrete; Let $E = T^D \cup R$ be a finite set of events, $T^D \cap R = \varnothing$, $P \cap E = \varnothing$, where R is a finite set of *rewriting rules* about the *run-time structural change* (reconfiguration) of $R\Gamma$. The set E is partitioned into $E = E_0 \cup E_\tau$, $E_0 \cap E_\tau = \varnothing$ so that: E_τ is a set of timed events and E_0 is a set of immediate events; $A_{rcs} = \langle Pre, Post, Inh \rangle$ is a set of *forward, backward* and *inhibition* arcs functions, that describes the respectively arcs with marking-dependent weight cardinalities; *Pri* defines the dynamic marking-dependent priority function for the *firing* of each *enabled* $e \in E$. The firing of an enabled event with higher priority potentially disables all events $e \in E$ with the lower priority. By default, the *Pri*(E_0)>*Pri*(E_τ); $G^E: E \times IN_+^{|P|} \to \{True, False\}$ is the set of *guard function* associated with all event $e \in E$ and $G^R: R \times IN_+^{|P|} \to \{True, False\}$ is the set of *guard function* associated with all *rewriting rule* $r \in R$; $K^p: P \times IN_+^{|P|} \to IN_+ \cup \{\infty\}$ is the capacity bound of each place $p_i \in P$, which can contain an *integer* or real number of *tokens* [5]. By default, K_i^p it is $+\infty$; M_0 is the initial marking; $\tilde{\Lambda}: E_\tau \times IN_+^{|P|} \to IR^+$ is the function that determines the firing rate $0 < \tilde{\lambda}(e, M) < +\infty$ of timed event $e \in E_\tau$, that is *enabled* by current marking M; $\omega: E_0 \times IN_+^{|P|} \to IR^+$ is the weight function $0 \le \omega(e, M) < +\infty$ which determines the firing probability $q(t, M)$ of immediate event $e \in E_0$, therein describes a probabilistic selector; $V: T^C \times IN_+^{|P^A|} \to IR^+$ is the marking dependent fluid rate function of T^C. . If

$u_j \in T^C$ is enabled in *tangible* marking M it fires with rate $V_j(M)$, that continuously changes the fluid level of continuous place $b \in P^C$; $\tilde{\rho}: P \cup E \to IR^+$ is the function that determines the *reward rates* (real numbers) assigned to each current marking M and to each firing event $e \in E$; Lib_R is the set of $R\Gamma_v$, $v = 1, 2, \cdots, n_v$ *subnets* and parameters pattern class library involved in structural reconfiguration of the current $R\Gamma$ configuration by firing of an enabled rewriting rule $r \in R$; $\phi: Lib_{ENN} \to T^{At}$ is a mapping to assign a ENN to each *adaptive transition*, where Lib_{ENN} is the set of all ENNs;

Fig. 3 summarizes the graphical representation *HSRN* primitive elements of $R\Gamma$.

Enabling and firing rules of events $e \in E$ and continuous transitions *by current marking* M in $R\Gamma$ are the same as for RSRN and HSRNM [5, 7].

To develop and present more compact $R\Gamma$ models we will use the approaches presented in [5, 7, 11]. We present here only the most important features of Matrix Transi-tion Net (MTN) [11] wthere *matrices* are used instead of places (transitions) and other attributes as in PNs and SRNs. MTD models are more expressive and compact than PNs and capture a greater amount of information. Removal (placement) of tokens in MTN is a simple sub-traction (addition) of the input (output) matrix from the input (output) function matrix. The result should be the updated input matrix (output) after transition firing, i.e. this is the next marking of that matrix.

Graphically, a matrix attributes of $R\Gamma$ models will be presented in a way that its will contain in square brackets the matrix name [7]. So, for example, a direct arc matrix cardinality, denoted by $[\overset{A}{\longrightarrow}]$, can take values that are contained in a specified matrix **A**.

An adaptive transition, called **At** - transition, is a transition associated with a respective learned ENN.

Fig. 4 shows an **At** – transition, At_j, that corresponds to the ENN in Fig. 2. The inputs of an At - transition are presented by Matrix C-place $[\mathbf{B}_j]_{n\times 1}$ that determine the respective inputs of the ENN, while the marking of the output D – place p_k represent the order number of the k^*-th class selected by the ENN function .

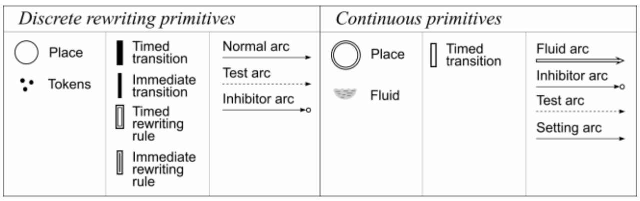

Figure 3. The graphical primitive of the *HSRN*

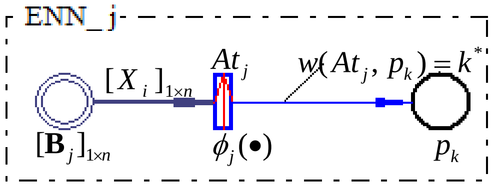

Figure 4. An **At**-transition representing the ENN in figure 2

If the outputs of two or more **At**-transitions can eventually access the same place, they operate independently. This structure can be used to model two components that separately and independently complete adaptation. But since their outputs eventually reach the same D-transition, they are dependent on each other. This structure is used to model that several components are combined together to complete the adaptation. **At** -transitions have lower priorities than C-transitions and D-transitions in a conflict.

V. Performability Modeling Case Study

In this section, we will illustrate the application of the ExNRPN to performability modeling of a particular DES, for exemple, steam turbine generator [12], manufacturing system [6]. The concept of performability emerged from a need to assess a system's ability to perform when performance degrades as a consequence of faults.

In Fig. 5 is presented the FMSRN1 model, denoted $R\Gamma 1$, which describes the behavior, on-line ENN fault diagnosis [6, 10] and recovery of a particular ADES. *The meanings of places and transitions in* $R\Gamma 1$ *model*:

- **Places.** $p1$ - initiation of the maintenance period; $p2$ - operation of the system during the diagnosis; $p3$ - reliable operation of the system; $p4$ - setting the generation of the current values of the environment pa-

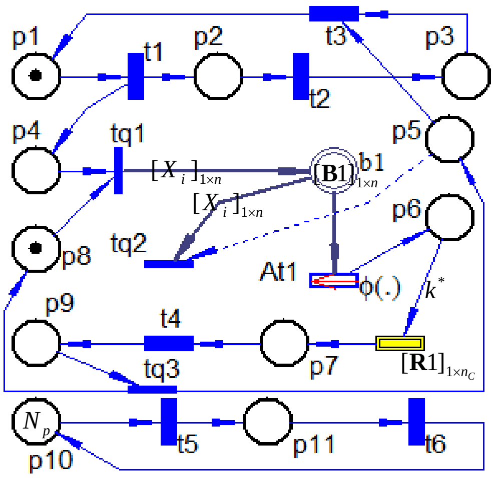

Figure 5. $R\Gamma 1$ performability model of steam turbine generator

rameters; $p5, p9$ - the end of the diagnosed fault recovery; $p6$ - indicator of the k^* type of diagnosed fault; $p7$ - initiating the recovery of the system in reliable state; $p8$ - ENN is ready to diagnose the system; $p10$ - indicate the total number $M_0(p10) = N_p$ of instances environment space parameters; $p11$ - control place that generates the current environment instance.

- **Timed transitions.** $t1$ - system maintenance time period; $t2$ - the duration of the system's operation during the diagnostics; $t3$ - reliable system operation time; $t4$ - system recovery time; $t5$ - generation time of a new environment parameter instance; $t6$ - the current instance time of the environment.
- **Immediate transitions.** $tq1$ - generation of the environment current instance; $tq2$ - elimination of the markings in matrix C-place $b1$; $tq3$ - reseting of ENN.

There are N_p environmental instances X_i that are represented in a matrix $\mathbf{X}$. Each instance is an line - vector $X_i = (x_{i,1}, x_{i,2}, \ldots, x_{i,n})$ and it can be randomly chosen from the matrix $\mathbf{X}$ using the control place $p11$, such that $i = M(p11)$ specify the index row of $\mathbf{X}$.

The line-vector $\mathbf{R}1 = (r_1, r_2, \ldots, r_{n_C})$ describes all the rewriting rules for on-line reconfiguration of $R\Gamma1$ model. With each rewriting rule $r_j \in \mathbf{R}1$ is associated the respective type of diagnosed fault F_j, i.e. F_j involves enabling an firing of r_j. Thus, the selection of r_j to be enabled and fired depends on the current marking of the *control place* $p6$, i.e. $j = M(p6) > 0$ specify the index of r_j.

The guard functions of rewriting rule r_j in $R\Gamma1$ are:

$g^E(r_j) := (M(p6 > 0); \; g^R(r_j) := "True", \; j = 1, 2, \ldots, n_c$.

Generation of environment parameters: if transition $tq1$ is enabled, its firing generates a line-vector quantity, written as $X_i = (x_{i,1}, x_{i,1}, \ldots, x_{i,1})$, where each component is a positive real number. The reason is that if the system captures the change of the environment, that is reflected in the line-vector cardinalite of directed arc $(tq1, b1)$. The weights can be adjusted during the training process of a ENN1, which adds the adaptation ability to the $R\Gamma1$.

A dynamic reconfiguration of $R\Gamma1$ by the firing of enabled $r_j \in R$ is a map $r_j : R\Gamma_L \rhd R\Gamma^w_j$, The operator $\rhd$ represents a binary rewriting operation which produces a *structural change* in $R\Gamma1$ by *replacing* the current subnet $R\Gamma_L \subseteq R\Gamma1$ ($R\Gamma_L$ is dissolved) and a new $R\Gamma^w_j \in Lib_R$ subnet is *added* and belongs to the new modified resulting underlying net $R\Gamma1' = (R\Gamma1 \setminus RN_L) \cup R\Gamma^w_j$, where the meaning of \ (and $\cup$) is operation of removing (adding) RN_L from ($R\Gamma^w_j$ to) $R\Gamma1$. As exemple, in our case $R\Gamma_L := t_4$. For more detail to using of the $\rhd$ see [5].

Performability analysis of $R\Gamma1$ model can be performed following the approach described in [5, 7].

In a future work, we will focus on developing a visual simulator software system incorporate into VRPN ToolBox [13] with a friendly interface for checking behavioral properties and performability analysis of $R\Gamma$ models that involve other kinds of law time distributions fuzzy parameters of transition and firing rewriting rules.

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Graphical methods as a complements of analytical methods used in the research of dynamic models for networks reliability

Alexei Leahu [1], ORCID: 0000-0002-1670-0111
Veronica Bagrin-Andrievschi [1], ORCID: 0000-0001-8364-9873
Maria Rotaru [1], ORCID: 0000-0002-3198-0297
[1] Technical University of Moldova, Technical University of Moldova, 168, Stefan cel Mare av., Chisinau, MD-2004, Republic of MOLDOVA, alexei.leahu@ati.utm.md, veronica.bagrin@ati.utm.md, maria.gorban@isa.utm.md

***Abstract*—Our work deals with a typical problem of comparing the reliability of a serial-parallel type network vs the reliability of a parallel-serial type network. Using graphic methods on elementary models, we show how they lead to the formulation of mathematically argued conclusions. These conclusions are then extended to whole families of probabilistic dynamic models related to the initial models.**

Keywords—lifetime distribution, survivival / reliability function, serial-parallel and parallel-serial networks

I. INTRODUCTION

Our problem appears in the context of studying dynamic probabilistic models, looking at identifying the conditions in which a serial-parallel network is always more reliable than a parallel-serial network. We will rely, essentially, on the fact that for networks of this type in which the number of subnets, but also the number of elements are not random variables, in the paper [1] the analytical formulas for calculating the corresponding survival/reliability functions were deduced.

We remind you that, according to the generally accepted definition in the specialized literature, by the survival / reliability function of a system (or networks) we will understand the function $R(x)$ which coincides with the probability that the lifetime of this system will exceed the time threshold x, i.e., $R(x)=1-F(x)$, where $F(x)$ is lifetime cummulative distribution function (c.d.f.) of the sistem.

Thus, in the papers [1]-[2], thanks to the calculation formulas, the sufficient condition was found that a network of type ***A***, i.e. of serial-parallel type, is always more reliable than a network of type ***B***, i.e. of parallel-serial type. We specify that the nominated networks have the same number of subnets equal to M, $M\in\{2,3,\ldots\}$, the number of elements in each subnet being equal to N_i, $i=1,M$, and the lifetimes of all elements are nonnegative independent, identically distributed random variables, (i.i.d.r.v.). We notice that the case $M=1$ was omitted, because the network of type ***A*** becomes, in this way, the network of parallel type, and the network of type ***B*** becomes the network of serial type, of which it is well known that the first network is, always, more reliable than the second one.

The formulas derived in the paper [1] allowed us to extend to the case of dynamic modeling the conclusion made in [3]-[4] for the static modeling regarding the reliability of the ***C***-type parallel-serial network in which the number of subnets is equal to N, $N\geq 2$ and the number of elements in the each subnet is the same and equal to M versus the reliability of the ***D***-type network in which the number of subnets, on the contrary, is equal to M, $M\geq 2$, the number of elements in each subnet being equal to N , and the lifetimes of all elements being v.a.i.i.d. More precisely, in paper [1] it was demonstrated that in the dynamic case, like in the static case, the ***C***-type network is always more reliable than the ***D***-type network, regardless of the values of M and N and regardless of lifetime c.d.f. $F(x)$ of each element. The question arises, but what will happens if the number of elements in each of the N subnets of the ***C***-type network can be different from M, and the number of elements in each of the M subnets of the ***D***-type network can, analogously, be different from N. Next, the duestion arises: will you still have Type ***C*** network (series-parallel) more reliable than type ***D*** network (parallel-series) or not? If yes, under what conditions? These are the questions we aim to answer.

II. RELIABILITY OF MODIFIED *C* NETWORK VS MODIFIED *D* NETWORK RELIABILITY

We will call, in the following, the models described above the modified ***C*** and ***D*** networks.

If we denote by $R_{s-p}(x)$ and by $R_{p-s}(x)$, respectively, the reliability functions of the modified networks of type ***C*** and ***D***, then, according to the formulas derived in [1], we will have that

$$R_{s-p}(x) = \prod_{k=1}^{N}\left[\left(1-(F(x))^{M_k}\right]\right. \quad \textbf{(1)}$$

$$R_{p-s}(x) = 1-\prod_{k=1}^{M}\left[1-\left(1-(F(x))\right)^{N_k}\right] \quad \textbf{(2).}$$

Question: what can we say, based on these analytical formulas, about the reliability of one network vs the reliability of the other? If, in particular case, $M_1 = M_2 = \ldots = M_N = M$ *and* $N_1 = N_2 = \ldots = N_M = N$, then we know, due to the paper [1], that the reliability of the modified Type ***C*** network is always higher than the reliability of the modified Type ***D*** network, otherwise the answer is not clear. In order to identify a more general rule, we will first use the method of graphical representation of the reliability of both networks according to particular cases. But we mention that, as was shown in the paper [1], this positioning does not depend on the lifetime c.d.f. of each element of the network. So, Therefore, in all the following examples, we can consider that the lifetime X of each unit has uniform c.d.f. , i.e. $F(x)=x$, for $x\in[0,1]$, otherwise $F(x)=0$, if $x<0$ and $F(x)=1$, if $x>1$, shortly $X\sim U[0,1]$. The case M = N being analyzed in the same paper [1], we will analyze separately the cases $M > N$ and $M < N$ under what conditions $M_1 = M_2 = \ldots = M_N = M$ *and* $N_1 = N_2 = \ldots = N_M = N$ are not fulfilled. Reliability function $R_{s-p}(x)$ will be represented graphically with a ***continuous line*** and the reliability function $R_{p-s}(x)$ will be represented with a ***broken line***.

Example 1. a) $X\sim U[0,1]$, $M>N$; $M=3$, $N=2$; $M_1 = M_2 = 3$; $N_1 = 1$, $N_2 = 3$, $N_3 = 2$; $R_{s-p}(x)= (1-x^3)^2$, $R_{p-s}(x)= 1-(1-(1-x))\,(1-(1-x)^3)\,(1-(1-x)^2)$ (see Fig.1.a);

b) $X\sim U[0,1]$, $M>N$; $M=3$, $N=2$; $M_1 =2$ $M_2 = 4$; $N_1 = 1$, $N_2 = 1$, $N_3 = 4$; $R_{s-p}(x)= (1-x^2)\,(1-x^4)$, $R_{p-s}(x)= 1-(1-(1-x))^2\,(1-(1-x)^4)$ (see Fig.1.b);

c) $X\sim U[0,1]$, $M>N$; $M=3$, $N=2$; $M_1 =1$ $M_2 = 5$; $N_1 = N_2 = N_3 = 2$; $R_{s-p}(x)= (1-x)\,(1-x^5)$, $R_{p-s}(x)= 1-(1-(1-x)^2)^3$ (see Fig.1.c);

d) $X\sim U[0,1]$, $M>N$; $M=3$, $N=2$; $M_1 =1$ $M_2 = 5$; $N_1 = 1$, $N_2 = 3$, $N_3 = 2$; $R_{s-p}(x)= (1-x)\,(1-x^5)$, $R_{p-s}(x)= 1-(1-(1-x))\,(1-(1-x)^3)\,(1-(1-x)^2)$ (see Fig.1.d);

e) $X\sim U[0,1]$, $M>N$; $M=3$, $N=2$; $M_1 = M_2 = 3$; $N_1 = N_2 = N_3 = 2$; $R_{s-p}(x)= (1-x^3)^2$, $R_{p-s}(x)= 1-(1-(1-x)^2)^3$ (see Fig.1.e);

f) $X\sim U[0,1]$, $M>N$; $M=3$, $N=2$; $M_1 =3$ $M_2 = 5$; $N_1 = 2$, $N_2 = 3$, $N_3 = 4$; $R_{s-p}(x)= (1-x^3)\,(1-x^5)$, $R_{p-s}(x)= 1-(1-(1-x)^2)\,(1-(1-x)^3)\,(1-(1-x)^4)$ (see Fig.1.f).

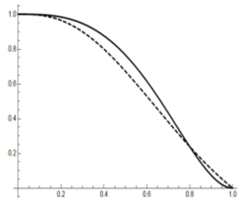
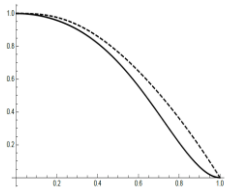

Fig. 1.a. Unclair situation. Fig. 1.b $R_{s-p}(x)\le R_{p-s}(x)$.

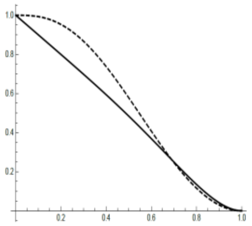
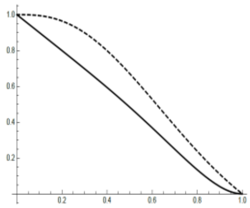

Fig. 1.c. Unclair situation. Fig. 1.d. $R_{s-p}(x)\le R_{p-s}(x)$.

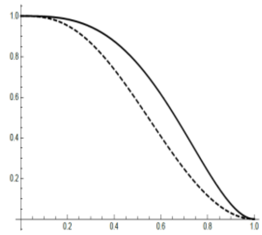
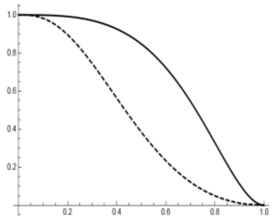

Fig. 1.e. $R_{s-p}(x)\ge R_{p-s}(x)$. Fig. 1.f. $R_{s-p}(x)\ge R_{p-s}(x)$.

Now we will give a similar example for the case M<N.

Example 2. a) $X\sim U[0,1]$, $M<N$; $M=2$, $N=3$; $M_1 = M_2 = M_3 = 2$; $N_1 = 1$, $N_2 = 5$; $R_{s-p}(x)= (1-x^2)^3$, $R_{p-s}(x)= 1-(1-(1-x))\,(1-(1-x)^5)$ (see Fig.2.a);

b) $X\sim U[0,1]$, $M<N$; $M = 2$, $N=3$; $M_1 =1$, $M_2 =3$, $M_3 =2$; $N_1 = 1$, $N_2 = 5$; $R_{s-p}(x)= (1-x)(1-x^3)\,(1-x^2)$, $R_{p-s}(x)= 1-(1-(1-x))\,(1-(1-x)^5)$ (see Fig.2.b);

c) $X \sim U[0,1]$, $M<N$; $M=2$, $N=3$; $M_1=1$, $M_2=1$, $M_3=4$; $N_1=N_2=3$; $R_{s\text{-}p}(x)=(1-x)^2(1-x^4)$, $R_{p\text{-}s}(x)=1-(1-(1-x)^3)^2$ (see Fig.2.c);

d) $X \sim U[0,1]$, $M<N$; $M=2$, $N=3$; $M_1=1$, $M_2=1$, $M_3=4$; $N_1=1$, $N_2=5$; $R_{s\text{-}p}(x)=(1-x)^2(1-x^4)$, $R_{p\text{-}s}(x)=1-(1-(1-x))(1-(1-x)^5$ (see Fig.2.d);

e) $X \sim U[0,1]$, $M<N$; $M=2$, $N=3$; $M_1=M_2=M_3=2$; $N_1=N_2=3$; $R_{s\text{-}p}(x)=(1-x^2)^3$, $R_{p\text{-}s}(x)=1-(1-(1-x)^3)^2$ (see Fig.2.e);

f) $X \sim U[0,1]$, $M<N$; $M=2$, $N=3$; $M_1=3$ $M_2=5$, $M_3=2$; $N_1=3$, $N_2=4$; $R_{s\text{-}p}(x)=(1-x^2)(1-x^3)(1-x^5)$, $R_{p\text{-}s}(x)=1-(1-(1-x)^3)(1-(1-x)^4)$ (see Fig.2.f).

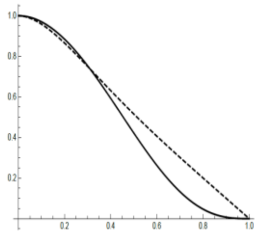
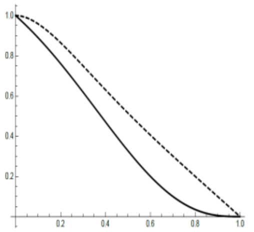

Fig. 2.a. Unclair situation. Fiig. 2.b. $R_{s\text{-}p}(x) \leq R_{p\text{-}s}(x)$.

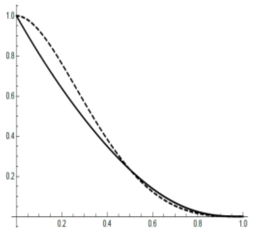
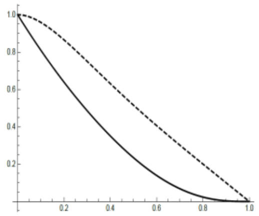

Fig. 2.c. Unclair situation. Fig. 2.d. $R_{s\text{-}p}(x) \leq R_{p\text{-}s}(x)$.

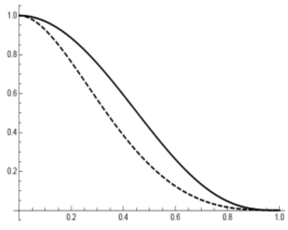
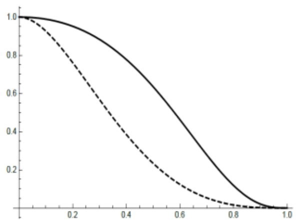

Fig. 2.e. $R_{s\text{-}p}(x) \geq R_{p\text{-}s}(x)$. Fig. 2.f. $R_{s\text{-}p}(x) \geq R_{p\text{-}s}(x)$.

Next we will consider that lifetime X of each units is no longer uniform distributed r.v. as in examples 1-2. So, let us consider, as another example, that c.d.f. of r.v. X coincides with exponential distribution with parameter $\lambda=1$, i.e., $F(x)=1-exp\{-x\}$, for $x\geq 0$ and $F(x)=0$, for $x<0$, shortly $X \sim exp\{1\}$.

Example 3. a) $X \sim exp\{1\}$, $M>N$; $M=3$, $N=2$; $M_1=M_2=3$; $N_1=1$, $N_2=3$, $N_3=2$; $R_{s\text{-}p}(x)=(1-(1-e^{-x})^3)^2$, $R_{p\text{-}s}(x)=1-(1-(1-(1-e^{-x})))(1-(1-(1-e^{-x}))^3)(1-(1-(1-e^{-x}))^2)$ (see Fig.3.a);

b) $X \sim exp\{1\}$, $M>N$; $M=3$, $N=2$; $M_1=M_2=3$; $N_1=N_2=N_3=2$; $R_{s\text{-}p}(x)=(1-(1-e^{-x})^3)^2$, $R_{p\text{-}s}(x)=1-(1-(1-(1-e^{-x}))^2)^3$ (see Fig.3.b);

c) $X \sim exp\{1\}$, $M>N$; $M=3$, $N=2$; $M_1=1$ $M_2=5$; $N_1=1$, $N_2=3$, $N_3=2$; $R_{s\text{-}p}(x)=(1-(1-e^{-x}))(1-(1-e^{-x})^5)$, $R_{p\text{-}s}(x)=1-(1-(1-(1-e^{-x})))(1-(1-(1-e^{-x}))^3)(1-(1-(1-e^{-x}))^2)$ (see Fig.3.c);

d) $X \sim exp\{1\}$, $M<N$; $M=2$, $N=3$; $M_1=3$ $M_2=5$, $M_3=2$; $N_1=3$, $N_2=4$; $R_{s\text{-}p}(x)=(1-x^2)(1-x^3)(1-x^5)$, $R_{p\text{-}s}(x)=1-(1-(1-x)^3)(1-(1-x)^4)$ (see Fig.3.d).

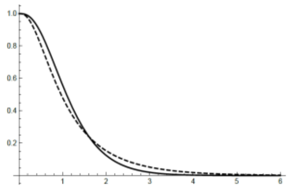
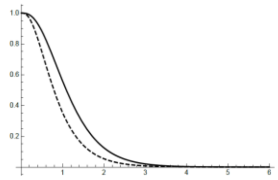

Fig. 3.a. Unclair situation. Fig. 3.b. $R_{s\text{-}p}(x) \geq R_{p\text{-}s}(x)$.

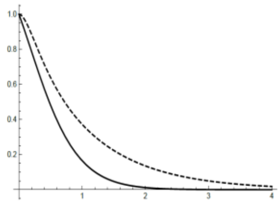
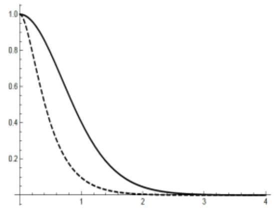

Fig. 3.c. $R_{s\text{-}p}(x) \leq R_{p\text{-}s}(x)$. Fig. 3.d. $R_{s\text{-}p}(x) \geq R_{p\text{-}s}(x)$.

III. CONCLUSIONS BASED ON THE GRAPHIC EXAMPLES

From examples 1.a) - 1.d) and 2.a) - 2.d) given previously we can draw the following empirical conclusions: a) Regardless of the fact that $M<N$ or $M>N$, when $min(M_1, M_2, \ldots, M_N)<M$ or $min(N_1, N_2, \ldots, N_M)<N$, we cannot say anything with certainty about the reliability of Type ***C*** network (serial-parallel) vs the reliability of Type ***D*** network (parallel-serial). On the contrary, the situation changes radically in examples 1.e) - 1.f) and 2.e - 2f, regardless of the fact that $M<N$ or $M>N$, in the sense that, when the conditions $min(M_1, M_2, \ldots, M_N)\geq M$ and $min(N_1, N_2, \ldots, N_M)\geq N$ are satisfied, we can say with certainty that networks of type ***C*** (serial-parallel) will be more reliable than networks of type ***D*** (parallel-serial).

Example 3 graphically show us that conclusions made above a valid regardless of lifetime c.d.f. $F(x)$.

The result of these graphic experiments suggests, in fact, that the following statement becomes plausible, but which must be proved mathematically.

Propozition. *If the numbers $M_1, M_2,..., M_N$ of the units included in each of the N subnets of the modified **C**-type network and the numbers $N_1, N_2,..., N_M$ of the units included in each of the M subnets of the modified **D**-type network (simultaneously) satisfy the conditions $min(M_1, M_2,...., M_N)\geq M$ and $min(N_1, N_2,...,N_M)\geq N$, then, regardless of lifetime c.d.f. F(x) of each units, the **C**-type network is more reliable than the **D**-type network.*

Prove. In fact, to prove our statement it is enough to show, according to formulas (1) and (2), that, regardless of lifetime c.d.f. F(x) of each units,

$$R_{s-p}(x) = \prod_{k=1}^{N}\left[\left(1-(F(x))^{M_k}\right] \geq\right.$$

$$\geq R_{p-s}(x) = 1 - \prod_{k=1}^{M}\left[\left(1-(1-F(x))^{N_k}\right].\right.$$

But in the paper *[1]* it was shown that, due to the characteristic properties of the c.d.f., this kind of inequalities, if they occur, they are valid for any lifetime c.d.f. *F(x)*. Therefore, if we want to prove this inequality, it is enough to show that it is valid for the case when F(x) coincides with the uniform distribution on the interval *[0,1]*. So, we have to prove that

$$\prod_{k=1}^{N}[1-x^{M_k}] \leq 1 - \prod_{k=1}^{M}[(1-(1-x)^{N_k}].$$

Another words, we have to prove that

$$\prod_{k=1}^{N}[1-x^{M_k}] + \prod_{k=1}^{M}[(1-(1-x)^{N_k}] \geq 1$$

for every $x\in[0,1]$. On the other hand, due to the conditions $min(M_1, M_2,...., M_N)\geq M$ and $min(N_1, N_2, ..., N_M)\geq N$, we have that for every $x\in[0,1]$

$$\prod_{k=1}^{N}[1-x^{M_k}] + \prod_{k=1}^{M}[(1-(1-x)^{N_k}] \geq$$

$$\geq (1-x^M)^N + (1-x^N)^M.$$

Because, from paper [1] , we know that

$(1-x^M)^N + (1-x^N)^M \geq 1$, for each $M,N\in\{1, 2, 3, ...\}$ this fact completes the proof of the statement from our Proposition.

The final conclusion resides in the folowing: the graphic method applied in Network's reliability is thery useful not only for visualizing reliabilty of the ghiven system, but also for identifying some mathematical laws regarding the reliability of one network vs another Network.

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Evaluation of the Multi-Algorithms Targets Recognition Systems

Veaceslav Perju [1], ORCID: 0000-0002-7755-4277
Dorian Saranciuc [2], ORCID: 0000-0003-0551-8215

[1]Agency for Military Science and Memory, 47, Tighina Str., Chisinau, MD2001, Republic of Moldova
vlperju@yahoo.com
[2]Technical University of Moldova, 168, Stefan cel Mare Bld, Chisinau, MD2004, Republic of Moldova
dorian.saranciuc@ati.utm.md

Abstract **— This paper presents the evaluation's results of the new classes of the target recognition systems – multi-algorithms unimodal systems and multi-algorithms multimodal systems. The structures and the graphs of the systems are described. The mathematical descriptions and the formulas for evaluation of the system's costs depending on the algorithm's recognition probability and the relation between the costs of the algorithm's software and the system's hardware are presented. The approach to determine the cost of a system for an established threshold level of the system's recognition probability is proposed. The relation of the system's cost to the system's recognition probability for different values of the algorithm's recognition probability is evaluated as well as the rating of the target recognition systems based on their recognition probabilities and costs.**

Keywords — algorithm, cost, evaluation, probability, recognition, system, target

I. INTRODUCTION

At present, the different kinds of target recognition systems exist, which are characterized by corresponding classification algorithms, technical realization, and applications. The systems for objects and image recognition using computer neural networks are described in [1, 2]. The architectures for automatic target detection on satellite images and military objects classification based on deep transfer learning are presented in [3, 4]. The target tracking and detection systems based on sensor scheduling and resource allocation in distributed and multi-static radars are described in [5, 6, 7]. The systems based on multi-core and multimodal computation are described in [8].

The new classes of systems – multi-algorithms unimodal and multimodal architectures are proposed in [9], where the investigation's results of the systems regarding their recognition probability are presented.

In this paper, there are presented the results of the general evaluation of the multi-algorithms unimodal and multimodal systems. The structure and graphical models of the target recognition systems (TRS) - unimodal, multimodal, multi-algorithms unimodal and multi-algorithms multimodal systems are described in section II.

The evaluation results of the system's costs depending on the relation between the costs of the system's hardware and the algorithm's software, and the algorithm's recognition probability are presented in section III.

The results of the comparative analysis of the recognition probability and costs of different TRS are described in section IV. The approach to determine the cost of a TRS for an established threshold level of the system's recognition probability is proposed. The relation of the system's cost to the system's recognition probability for different values of the algorithm's recognition probability is evaluated. The rating of the different TRS based on their recognition probabilities and costs is evaluated in section V.

II. THE GRAPH PRESENTATION OF THE TARGET RECOGNITION SYSTEM

In the article [9] the general structure of the target recognition system (TRS) is presented (Figure 1), for which there were developed the graph models of the different kinds of the TRS – unimodal and multimodal systems, multi-algorithms unimodal and multimodal systems (Figure 2). These systems are characterized by a different number of sensors S, processing algorithms A and output decision-making modules D.

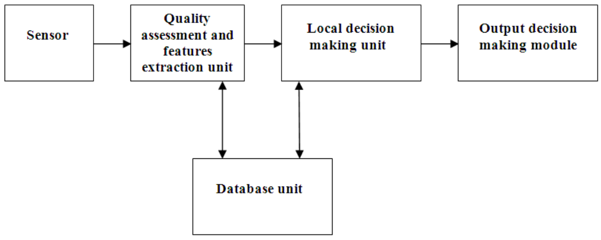
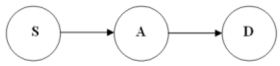
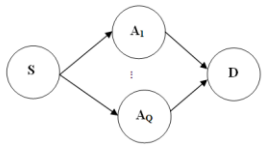


Figure 1. The general structure of the target recognition system

The target recognition processes consist of the following [9]. At the initial stage, the input target's function T(x,y) is generated using the sensor S. At the next stage, the features $F_A=\{f_{Ai}\}$, i=1÷I are extracted from the function T(x,y) following algorithm A. Later, the matrix $D_A=\min\{W[F_A,F_{Aj}]\}$ is determined, where $F_{Aj}=\{f_{Aj}\}$ – features of the reference targets, j=1÷J. And finally, the target is identified in module D.



a)



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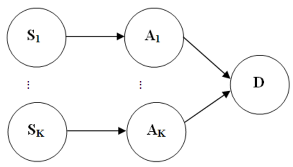

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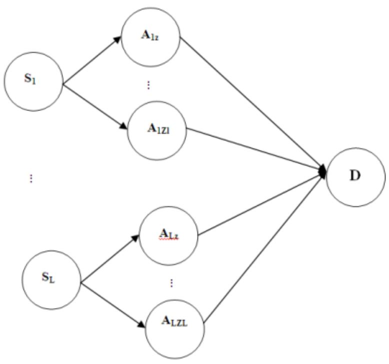

d)

Figure 2. The graph presentation of the target recognition systems:
a) - unimodal system; b) - multimodal system;
c) - multi-algorithms unimodal system;
d) - multi-algorithms multimodal system.

III. Evaluation of The System's Cost

Let's estimate the system's cost considering the components of the system – the Sensor and Algorithm, where the costs of the Sensor and Algorithm are C_S and C_A respectively, with relation $C_A = zC_S$, and $1 \geq z > 1$.

In this case, the cost of the unimodal system (UMS) can be estimated in the next mode:

$$C_{UMS}=C_S+C_A=(1+z)C_S \tag{1}$$

The cost of the multimodal system (MMS) can be estimated as:

$$C_{MMS}=\sum_{k=1}^{K}(C_{Sk}+C_{Ak})=\sum_{k=1}^{K}(C_{Sk}+z_kC_{Sk})=\sum_{k=1}^{K}(1+z_k)C_{Sk}, \tag{2}$$

where K is the number of the sensors equal to the number of the algorithms.

The cost of the multi-algorithms unimodal system (MAUMS) will be:

$$C_{MAUMS}=C_S+\sum_{q=1}^{Q}C_{Aq}=C_S+\sum_{q=1}^{Q}(z_qC_S), \tag{3}$$

where Q is the number of the algorithms.

The cost of the multi-algorithms multimodal system (MAMMS) can be evaluated as:

$$C_{MAMMS}=\sum_{l=1}^{L}\{C_{Sl}+\sum_{z=1}^{Zl}(z_{lz}C_{Sl})\}, \tag{4}$$

where L is the number of the sensors; Zl is the number of the algorithms referring to the sensor.

The cost evaluation of the TRS is carried out according to the formulas (1) - (4). The results are presented in Table 1 and in Figure 3, where z is the ratio of the cost of the algorithm's software C_A to the cost of the system's hardware C_S: $z = C_A/C_S$.

TABLE 1. The Costs Of The Systems, Units

z	UMS-1A1S	MMS-1A2S	MMS-1A3S	MAUMS-2A1S	MAUMS-3A1S	MAMMS-2A2S	MAMMS-3A2S	MAMMS-2A3S	MAMMS-3A3S
0.50	1.50	3.00	4.50	2.00	2.50	4.00	5.00	6.00	7.50
0.75	1.75	3.50	5.25	2.50	3.25	5.00	6.50	7.50	9.75
1.00	2.00	4.00	6.00	3.00	4.00	6.00	8.00	9.00	12.00
1.25	2.25	4.50	6.75	3.50	4.75	7.00	9.50	10.50	14.25
1.50	2.50	5.00	7.50	4.00	5.50	8.00	11.00	12.00	16.50
1.75	2.75	5.50	8.25	4.50	6.25	9.00	12.50	13.50	18.75
2.00	3.00	6.00	9.00	5.00	7.00	10.00	14.00	15.00	21.00

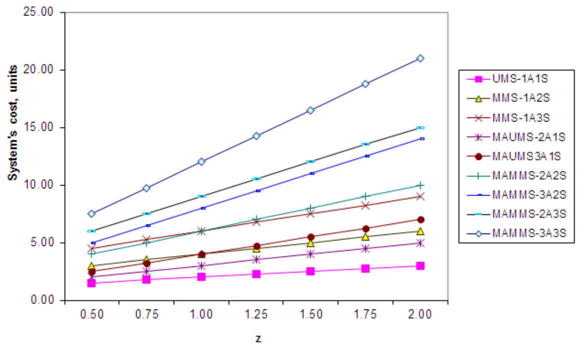

Figure 3. The cost of the systems depending on z – the ratio of the costs of the algorithm's software to the system's hardware

The results show that the cheapest is the system UMS. The most expensive are the systems MAMMS-3A3S, MAMMS-2A3S, and MAMMS-3A2S. For z >1.0 the system MAMMS-2A2S is more expensive than system MMS-1A3S and the system MAUMS-3A1S is more expensive than system MMS-1A2S. The systems MAUMS-2A1S and MAUMS-3A1S (for z<1.0) are cheaper in comparison with systems of classes MMS and MAMMS.

IV. Systems' Costs Evaluation Depending on the Algorithm's Recognition Probability

In many cases it is important to evaluate the cost of the system C_S depending on the algorithm's recognition probability p_A. Let the parameters z and p_A are changing in the diapasons $\{z_{min} \div z_{max}\}$ and $\{p_{Amin} \div p_{Amax}\}$, respectively. In this case, parameter z can be calculated via p_A in the next mode:

$$z = (p_A - p_{Amin})w + z_{min}, \tag{5}$$

where $w = (z_{max} - z_{min})/(p_{Amax} - p_{Amin})$.

After the substitution of the value of z from formula (9) in the formulas (1) - (4), will be obtained:

$$C_{UMS}=[1+(p_A-p_{Amin})w+z_{min}]C_S \tag{6}$$

$$C_{MMS}=\sum_{k=1}^{K}\{[1+(p_{Ak}-p_{Akmin})w_k+z_{kmin}]C_{Sk}\} \tag{7}$$

$$C_{MAUMS}=C_S+\sum_{q=1}^{Q}[(p_{Aq}-p_{Aqmin})w_q+z_{qmin}C_S] \tag{8}$$

$$C_{MAMMS}=\sum_{l=1}^{L}\{C_S+\sum_{z=1}^{Zl}[(p_{Alz}-p_{Alzmin})w_{lz}+z_{lzmin}C_{Sl}]\} \tag{9}$$

Table 2 and Figure 4 consist of the data regarding the costs of the systems depending on the algorithm's recognition probability.

TABLE 2. The Costs Of The Systems Depending On The Algorithm's Recognition Probability

p_A	UMS-1A1S	MMS-1A2S	MMS-1A3S	MAUMS-2A1S	MAUMS-3A1S	MAMMS-2A2S	MAMMS-3A2S	MAMMS-2A3S	MAMMS-3A3S
0.50	1.50	3.00	4.50	2.00	2.50	4.00	5.00	6.00	7.50
0.55	1.67	3.33	5.00	2.33	3.00	4.67	6.00	7.00	9.00
0.60	1.83	3.67	5.50	2.67	3.50	5.33	7.00	8.00	10.50
0.65	2.00	4.00	6.00	3.00	4.00	6.00	8.00	9.00	12.00
0.70	2.17	4.33	6.50	3.33	4.50	6.67	9.00	10.00	13.50
0.75	2.33	4.67	7.00	3.67	5.00	7.33	10.00	11.00	15.00
0.80	2.50	5.00	7.50	4.00	5.50	8.00	11.00	12.00	16.50
0.85	2.67	5.33	8.00	4.33	6.00	8.67	12.00	13.00	18.00
0.90	2.83	5.67	8.50	4.67	6.50	9.33	13.00	14.00	19.50
0.95	3.00	6.00	9.00	5.00	7.00	10.00	14.00	15.00	21.00

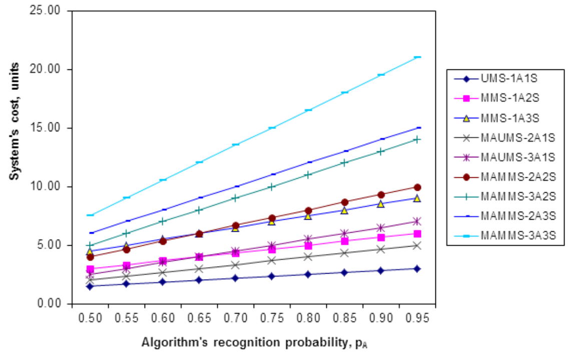

Figure 4. The costs of the systems depending on the algorithm's recognition probability

The analysis shows that system UMS-1A1S is of the lowest cost. The system MAUMS-2A1S is cheaper than MAUMS-3A1S and other systems of classes MMS and MAMMS. For p_A<0.65 the system MAMMS-2A2S is cheaper than the system MMS-1A3S, and the system MAUMS-3A1S is cheaper than the system MMS-1A2S.

In some cases, there appears the necessity to determine the cost C_S of a TRS for an established threshold level of the system's recognition probability P_{ST}. The proposed approach includes the next stages. At the first stage, for the established value of P_{ST} the maximum value of the algorithm's recognition probability p_{AM} is determined, as is demonstrated in [9]. In the next stage, using the formulas (6)÷(9) the costs of the systems are estimated.

Table 3 consists of the data regarding the values of p_{AM}, z, and costs of the different systems for P_{ST} = 0.99.

TABLE 3. The Costs Of The Systems At The Threshold Level Of The Systems Recognition Probability PST=0.99

	UMS	MMS-1A2S	MMS-1A3S	MAUMS-2A1S	MAUMS-3A1S	MAMMS-2A2S	MAMMS-3A2S	MAMMS-2A3S	MAMMS-3A3S
p_{AM}	-	0.9	0.8	0.9	0.8	0.7	0.55	0.55	0.5
z	-	1.83	1.5	1.83	1.5	1.17	0.67	0.67	0.5
C_S	-	5.67	7.50	4.67	5.50	6.67	6.00	7.00	7.50

One of the important parameters of the TRS is the relation of the system's cost to the system's recognition probability $E_{CP}=C_S/P_S$ for different values of p_A. Table 4 and Figure 5 consist of the data regarding the values of E_{CP}.

TABLE 4. THE RELATION OF THE SYSTEM'S COST TO THE SYSTEM'S RECOGNITION PROBABILITY

p_A	UMS-1A1S	MMS-1A2S	MMS-1A3S	MAUMS-2A1S	MAUMS-3A1S	MAMMS-2A2S	MAMMS-3A2S	MAMMS-2A3S	MAMMS-3A3S
0.50	3.00	4.00	5.14	2.67	2.86	4.27	5.08	6.10	7.51
0.55	3.04	4.18	5.50	2.92	3.30	4.87	6.05	7.06	9.01
0.60	3.05	4.37	5.88	3.18	3.74	5.47	7.03	8.03	10.50
0.65	3.08	4.56	6.27	3.42	4.18	6.09	8.01	9.02	12.00
0.70	3.10	4.76	6.68	3.66	4.62	6.72	9.01	10.01	13.50
0.75	3.11	4.98	7.11	3.91	5.08	7.36	10.00	11.00	15.00
0.80	3.13	5.21	7.56	4.17	5.54	8.01	11.00	12.00	16.50
0.85	3.14	5.45	8.03	4.43	6.02	8.67	12.00	13.00	18.00
0.90	3.14	5.73	8.51	4.72	6.51	9.33	13.00	14.00	19.50
0.95	3.16	6.02	9.00	5.01	7.00	10.00	14.00	15.00	21.00

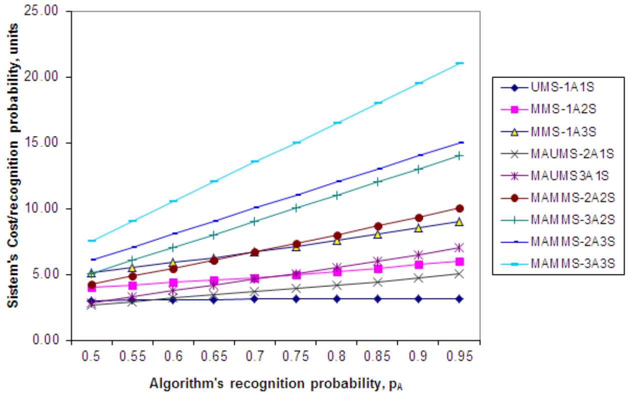

Figure 5. The relation of the system's cost to the system's recognition probability depending on algorithm's recognition probability

The results show that for $p_A<0.55$ the system MAUMS-2A1S is more efficient than other systems. For $p_A>0.7$ the system MAUMS-3A1S is more efficient than the system MMS-1A2S and the system MAMMS-2A2S is more efficient than the system MMS-3S. The system MAMMS-3A2S is more efficient in comparison with the system MAMMS-2A3S.

V. RATING OF THE TARGET RECOGNITION SYSTEMS

On the bases of the data from Tables 1, 4 was determined the rating of the systems based on their recognition probabilities P_S, costs C_S, and relation C_S/P_S. The results are presented in Table 5 and Figure 6.

TABLE 5. THE RATING OF THE SYSTEMS

	UMS-1A1S	MMS-1A2S	MMS-1A3S	MAUMS-2A1S	MAUMS-3A1S	MAMMS-2A2S	MAMMS-3A2S	MAMMS-2A3S	MAMMS-3A3S
Systems' recognition probability P_S	6	5	4	5	4	3	2	2	1
Systems' cost C_S	1	4 for $p_A>0.7$	6 for $p_A>0.7$	2	3 for $p_A<0.7$	5 for $p_A<0.7$	7	8	9
Relation C_S/P_S	2 for $p_A>0.55$	4 for $p_A>0.7$	6 for $p_A>0.7$	1 for $p_A<0.55$	3 for $p_A<0.7$	5 for $p_A<0.7$	7	8	9
Total nr of points, S	9	13	16	8	10	13	16	18	19
General rating	2	4	5	1	3	4	5	6	7
Total nr of points for P_S and C_S	7	9	10	7	7	8	9	10	10
General rating for P_S and C_S	2	4	5	1	3	4	5	6	7

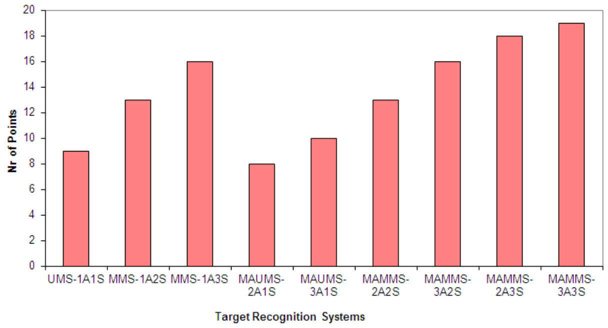

Figure 6. General rating of the systems

The data show that the highest general rating has the system MAUMS-2A1S – multi-algorithms unimodal system regarding system's recognition probability P_S, system's cost C_S and relation C_S/P_S. The same rating is observed if are taken into account only the parameters P_S and C_S (Table 5, last 2 rows).

CONCLUSIONS

As a result of the research, the mathematical models there were obtained for estimation of the system's cost according to the relation between the costs of the algorithm's software and system hardware and the algorithm's recognition probability.

The approach to determine the cost of a target recognition system for an established threshold level of the system's recognition probability is proposed.

The evaluation of the relation of the system's cost to the system's recognition probability for different values of the algorithm's recognition probability is made, where the effectiveness of different systems is determined.

The rating of the different target recognition systems based on their recognition probabilities and costs is evaluated. It is established that the highest general rating has the system MAUMS-2A1S – multi algorithms unimodal system, in which are realized 2 recognition algorithms.

The proposed theory allows the design of new target recognition systems according to the predetermined recognition probability and cost.

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Comparing two security models for RFID

Rareș-Aurelian Radu [1], ORCID: 0000-0002-3168-6047
[1] Alexandru Ioan Cuza University of Iași, Faculty of Computer Science, supervisor Prof. Dr. Țiplea Ferucio-Laurențiu
radu.rares.a@gmail.com, https://ro.linkedin.com/in/rares-aurelian-radu-18400b223

Abstract — **Radio Frequency Identification Technology became more and more involved in authentication processes over the years and is still rising. Security in this context needs to be strongly ensured, hence security models have a crucial role motivated by the fact that any entity with the right tools can interfere or eavesdrop in the communication process between a tag and a reader. The two most relevant, complete and worth mentioning models at this hour are Serge Vaudenay's model based on the introduced 'blinder' notion and the HPVP model of J. Hermans, R. Peeters and B. Preenel's based on the left-or-right indistinguishability notion. We provide a comparison between these two models that highlights not only the differences and the similarities, but also the elements that make each model unique along with the tag corruption aspects and the different privacy levels achieved by each model regarding both symmetric and asymmetric cryptography.**

I. INTRODUCTION

In recent years, Radio Frequency Identification technology has become more and more involved and relevant in authentication processes and it is still rising. Security in this context needs to be strongly ensured. Tags' and readers' communication has to resist attacks such as impersonation attacks or eavesdropping. Several security models have been designed and suggested to tackle the security and privacy issues. Two of these models we consider to be the most relevant, complete and worth mentioning at this time are Vaudenay's model based on the introduced *blinder* notion [1] and the HPVP model of J. Hermans, R. Peeters and B. Preneel's based on the *left-or-right* indistinguishability notion [2]. In this paper we come up with the detailed comparison of these two models, which we believe has not been provided strictly on these two models side by side. We believe this papers' approach highlights the important differences between two highly used security models, points out the stronger notions of privacy that can be achieved in similar contexts and, lastly, presents an invitation to anyone interested in the subject and to anyone willing to contribute on the open issue of achieving higher notions of privacy with symmetric key encryption along with extending the HPVP model and refining the *blinder* of Vaudenay's model.

II. BASIC NOTATIONS AND NOTIONS

The notations and definitions are similar to the ones provided in [2,1,3,4].

A. RFID System

Incorporates a set of tags □, a set of readers $\mathcal{R}$ and a communication protocol between them. Each tag T_i has an identifier ID, a memory (temporary memory and persistent memory) that contains a volatile state □ that may change during the course of life of the tag and that can store the ID. Each tag is a transponder that has finite internal memory and limited computable capacity. Reader's database holds the ID of the tag paired with a secret, $K_{Rj,\ Ti}$ for each tag T_i in □. The role of readers consists in identifying and recovering IDs of authorized tags and, on the other hand, to repudiate all other trials of communication. The authentication process of a tag is successful if the reader's database holds an entry for that specific tag. Such a system needs algorithms and protocols to setup tags, readers and to bind tags that already are or not in a readers' database in an online or offline manner.

B. RFID Scheme

Contains three important items:

1. **SetupReader(1^s)** - algorithm that initializes readers' database and generates the input that is composed of a public-key K_p and a private key K_s
2. **SetupTag$_{K_p}$(ID)** - algorithm that generates the tag's secret K and the initial state of the tag S. If one tag is *authorized*, the pair (ID, K) is kept in readers' database
3. **protocol between a reader and a tag** - that outputs $\perp$ if the tag's identification fails, or an ID if the tag's identification succeeds

C. Public-key encryption

A public-key encryption scheme over the triple *(K, P, E)* is a system S which includes three algorithms: 1) a PPT algorithm used for generating a pair of keys (*pk*, sk) denoting the public-key and the secret-key, 2) an encryption algorithm that outputs a ciphertext computed from the encryption of a plaintext with the *pk* and 3) a decryption polynomial-time algorithm which outputs the decrypted message computed from the ciphertext with the *sk* taken as input or ⊥ (denotes failure).

D. Symmetric encryption

A symmetric encryption scheme over the triple *(K, P, E)* is a system *S* which includes three algorithms: 1) a PPT algorithm used for generating a key *k*, 2) an encryption algorithm which outputs a ciphertext computed from the encryption of a plaintext with the *k* and 3) a decryption PT algorithm which outputs the decrypted message computed from the ciphertext with the *k* taken as input or ⊥ (denotes failure).

E. Pseudo-random function

A pseudo-random function (PRF) is a family of functions that if a function from this family is randomly chosen, then its input and output are indistinguishable from a computational point of view compared to a random function. Considering two polynomials, γ and δ, a set of keys □ and a security parameter $\lambda \in \mathbb{N}$, $□_\lambda = \{K \in □ \setminus |K| = \lambda\}$. A family of functions indexed by □ is denoted by $F = F_{\lambda, K\ \{K \in □\}}$ where $F_{\lambda, K}$ is a function from $\{0, 1\}^{\gamma(\lambda)}$ to $\{0, 1\}^{\delta(\lambda)}$. If γ and δ are polynomially bounded, if $2^{-\gamma(\lambda)}$ and $2^{-\delta(\lambda)}$ are negligible and if an adversary has negligible advantage in distinguishing an oracle simulating $F_{\lambda, K}$ with K random from an oracle initialized with a random function, we say that $F_{\lambda, K}$ is a PRF. The following security game proves that $F_{\lambda, K}$ is a PRF: a) a challenger chooses a random bit from {0, 1} b) if $b == 1$ then the challenger picks K from $□_\lambda$ and sets $f = F_K$, otherwise the challenger picks a random function and sets *f* to that function and gives oracles access to *f* for the adversary c) the adversary outputs a bit *d*. The adversary wins if $d = b$.

F. Physically unclonable function

A physically unclonable function or PUF can be identified as a physical object that, when it is queried with some challenge, generates a response that depends on the object's particular properties and on the challenge. PUFs are assumed to be hard to clone, unpredictable in response given a stray challenge and tamper-evident regarding attacks or unauthorized physical access to them that result in changing the behavior of the challenges and responses relevant to them.

G. Basic notations

1. $t \in_R □$ means that *t* is uniformly chosen from the set □
2. |□| denotes the cardinal of □
3. □ is an *algorithm*, □ is an *oracle*, $□^{□}$ hints that □ has access to *oracle* □
4. *vtag* denotes a virtual reference for a tag
5. □ refers to an instance of a protocol
6. *m, m'* represent the message that is sent and the answer that is sent back
7. ⊥ represents the failure of an operation
8. λ represents a security parameter denoting the probability of an adversary breaking the cryptographic scheme

III. Philosophy of the Models

The HPVP model's philosophy is heavily based on the notion of left or right indistinguishability, whereas Vaudenay's model is based on simulations of interactions with a RFID system by the means of a *blinder*. The HPVP model, by design, does not suffer from the concept of *blinder* introduced in Vaudenay's model, the privacy games played are based on guessing with which tag an adversary has interacted with and, moreover, tackles important aspects such as *tag tampering*, *privacy leakage* or *tag corruption limitations* that in Vaudenay's model are present. In Vaudenay's model, a *blinder* simulates the operations of an adversary and the goal is to arrive at the conclusion, based on the simulations of a real adversary or a *blinded* adversary, regarding the output of the simulations.

IV. Adversarial Models

The definitions of readers and tags remain the same between both models. In regards to HPVP, the first difference occurred is that the set of readers $\mathcal{R}$ and the set of tags □ are initially empty and are being dynamically populated with readers and tags by the adversary. Another difference that appears in HPVP is that, as we will see below when we will talk about the oracle's differences between the two, the adversary is allowed to draw pairs of tags and is allowed to interact with only one of them, the *left tag* or the *right tag*. The goal of the adversary is to guess if the tag that he ended up interacting with is a *left tag* or a *right tag*.

Next, we are going to underline the similarities and differences between the definitions of the oracles given and present in both models. Firstly, we will touch on the oracles' definitions that they have in common:

- **CreateTag** oracle creates a free tag in both models, the differences that appear in HPVP model are that all the tags created are registered in reader's database, hence all the tags are legitimate tags, the oracle does not fail on duplicate IDs and returns a reference to the new tag created; in Vaudenay's model, if the tag is not legitimate, the reader's database is not updated, otherwise it is updated and the oracle does not return anything.
- **Launch** oracle has the same outcome in both (resp. launches a new instance of a reader's protocol) with the difference that in the HPVP

model the reader can be chosen and given as input.

- **DrawTag** oracle, from the beginning, is quite different from both sides of the model; in HPVP, the oracle takes two real tag (free) references as input, T_i and T_j, generates a *vtag* for one of the tags, depending on *b*'s value and stores the triple *(vtag,* T_i*,* T_j*)* in □' (the hidden table from Vaudenay's model); in Vaudenay's model, the oracle takes an algorithm, as input, to draw a number of tags and generates a vector of *vtags* for the tags, generates a vector of bit values (1 for legitimate tags, 0 for the others) for the drawn tags and returns a combined vector of the two ($vtag_1$, b_1, $vtag_2$, b_2, ...).
- **Free** oracle presents the same input and output with the difference that in the HPVP model the *vtag* is no longer accessible because of the deletion of the triple *(vtag,* T_i*,* T_j*)* from the □', the tag's temporary memory is erased, but its state is maintained.
- **SendReader** and **SendTag** oracles both send a message; in Vaudenay's model the message is sent to a reader's protocol instance or to a *drawn* tag which is identified by the *vtag* taken as input for the **SendTag** oracle and returns a list of successive protocol messages; in HPVP model the message is sent to a tag according to the *vtag* and *b* value given as input (for **SendTag** oracle), or to the reader identified by its reference R_j given as input (for **SendReader** oracle) and returns a reply message for the tag, if the triple corresponding to □' is found or ⊥ otherwise (for **SendTag** oracle), and from the reader R_j if the reader sends a reply otherwise it does not return anything (no reply given from the reader).
- **Result** oracle in both models takes as input an instance of a session □ and may output a bit value; in Vaudenay's model it returns 1 if the session is complete, or 0 otherwise; in HPVP model a reader R_j is also given as parameter for which the session instance □ is bound to and returns a bit value if the reader acknowledged the session and authenticated a tag successfully and the session is finished, otherwise it returns ⊥.
- **Corrupt** oracle, in Vaudenay's model, takes as input a *vtag* to a tag, the tag is destroyed if the tag is never used again and returns the current state of the tag; in HPVP model, the oracle takes as input a real reference to a tag, no control over the tag is given to the adversary and returns both the temporary and permanent state of the tag.

Secondly, we will touch on the newly-introduced oracles in the HPVP model that in Vaudenay's model do not appear:

- **CreateReader** creates a new reader and returns a reference R_j for the reader created.
- **RegisterTag** takes as input a tag T_i and a reader R_j, then bounds the tag with the reader R_j.
- **CreateInsider** takes as input an ID of a tag, calls **CreateTag** to create a new tag, corrupts it for it to become an *insider tag*, introduces it in a list of *insider tags* and returns the insider tag and its state; the oracle is used for exploiting the privacy of other tags using the state of a corrupted tag.
- **CorruptReader** oracle takes as input a reader R_j, corrupts it by leaking the reader's DB and returns that DB along with all the secrets; when a reader is corrupted, only a tag should authenticate to other readers it is bound to and its identity must be concealed for those readers.

V. SECURITY AND PRIVACY

Both models present the same definitions in regards to security. Both models articulate that for achieving security, *tag authentication* and *reader authentication* have to be provided.

Tag authentication is achieved if, for any **STRONG** adversary, the probability of retrieving an uncorrupted tag ID along with not having a matching conversation with any tag ID in that protocol instance has to be negligible.

Reader authentication is achieved if, for any **STRONG** adversary, the probability of authenticating the reader with an uncorrupted legitimate tag ID along with not having a matching conversation is negligible.

Regarding privacy of the models, the restrictions on the adversary in the HPVP model are the same as in Vaudenay's model. We will now talk about the adversary classes which are, or not, present in both models.

In both Vaudenay and HPVP models the following classes are present are remain the same:

- **STRONG**: no restrictions on any oracle usage.
- **DESTRUCTIVE**: **Corrupt** oracle destroys the tag.
- **FORWARD**: only corruptions allowed after the first **Corrupt** oracle usage.
- **WEAK**: not allowed to call the **Corrupt** oracle.
- **NARROW**: cannot use the **Result** oracle.

The following adversary classes do not appear in Vaudenay's model but have been introduced in the HPVP model:

- **WIDE**: no restrictions on the usage of the **Result** oracle.
- **INSIDER**: allowed to call the **CreateInsider** oracle.

- **FORWARD-INSIDER**: allowed to call **CreateInsider** oracle, but only allowed corruptions after the first **Corrupt** call.
- **WEAK-INSIDER**: allowed to call **CreateInsider** oracle, but not allowed to call the **Corrupt** oracle.

In Vaudenay's model, privacy of a given class is achieved if, with the help of the *blinder* notion, the probability of receiving different output given the communication between a reader and a tag from both a real adversary and a *blinded adversary* simulation is negligible, then privacy is achieved.

In HPVP model, privacy is denoted by the probability of an adversary to guess correctly with which tag he interacted, either a *left tag* or a *right tag*, based on the guess bit outputted. If this probability is negligible then privacy is achieved.

VI. TAG CORRUPTION ASPECTS

In regards to Vaudenay's model, if an adversary corrupts a tag, then both the *temporary* and *persistent* part of the tags are revealed, hence no notion of privacy is possible to be achieved. However, if the tag cleans its *temporary* part each time the adversary loses the tag from its range, then the corruption problem vanishes. On the other hand, if the tag is in the adversary's range, corruption can be made before the cleaning of the *temporary* part of the tag, hence *reader authentication* is not possible. With *temporary state disclosure* only **WEAK** and **NARROW-WEAK** privacy might be achieved [5]. Without *temporary state disclosure*, only the *persistent* part is revealed, but the possibility of learning the *temporary state of the tag* can be exploited during the protocol execution, hence an adversary can distinguish between a *blinded adversary* or a *real adversary* simulation in regards to *reader authentication* [5]. On the other hand, by not being able to interact with the *temporary state of the tag*, an adversary cannot make any verification between the responses of the simulations of a *blinded adversary* and a *real adversary*, hence **NARROW-FORWARD** privacy is not reachable. On the other hand, with PUFs added to the PRF based scheme which ensures **WEAK** privacy in [1], the problem of achieving **DESTRUCTIVE** privacy is resolved if the call on the **Corrupt** oracle on a tag destroys the PUF and the **Corrupt** oracle provides the state of the tag between protocol steps. *Mutual authentication* is also ensured with the addition of a seed to a PUF for extending the domain of the PRF function.

In regards to the HPVP model, some restrictions on tag corruption are imposed. **Corrupt** oracle reveals both the *persistent* and *temporary* parts of a tag, hence privacy notions that are stronger can be achieved. Corruptions can occur only if physical access is possible. Another restriction is that an adversary is forbidden to corrupt tags that are in the course of being drawn for him to learn if that tag is an active tag because, otherwise, it would contradict the physical access assumption and also, he would be able identify that tag. Hence, corruptions by any adversary are allowed to be made only on inactive tags, those drawn in the *left* or *right* privacy games.[2]

VII. WEAK PRIVACY IN HPVP

As another common element between the two models, the RFID scheme based on PRF, found in [1], achieves **WEAK** privacy in both models. We saw that in section 4.1 in [1], **WEAK** privacy has been proved for Vaudenay's model, based on **Lemma 8** [1], by proving **NARROW-WEAK** privacy. The usage of the *blinder*, which simulates the privacy game without knowing the secrets of the tag or the reader and simulates the **Launch**, **SendReader**, **SendTag** and **Result** oracles, is similar with the indistinguishability game. If there is no way to distinguish between the output of a *blinded adversary* and the output of the *real adversary* then privacy is achieved. If a **NARROW-WEAK** adversary has no significant advantage over a *blinded adversary*, meaning that if the output of the protocol is not different between the two, with negligible probability, then in the privacy game played by both, when the reader never picks duplicate *a*'s, the tag never picks duplicate *b*'s and i does not present an advantage to any because of the PRF properties, then a **NARROW-WEAK** adversary does not win more than a *blinded adversary* and vice-versa.

Given the HPVP model, by using the same PRF-based RFID scheme, by design **WEAK** privacy is achieved in this context. As mentioned above, a *blinder* for an adversary simulates the operations of that adversary. If there is no way to distinguish between a *blinded adversary* and a *real adversary* then privacy is achieved. In the privacy game in the context of PRF, we first play with the PRF function and then play with a random function which outputs only random elements - this represents the way of distinguishing the PRF function from the random function. HPVP model is based on the *left-or-right* indistinguishability which fits the PRF game, hence fits to achieve **WEAK** privacy. The blinder simulates a random game which is complementary at its core with the random game simulated in the PRF game.

VIII. FORWARD PRIVACY USING SKC

In Vaudenay's model, the impossibility result of **NARROW-FORWARD** privacy in [1] denotes the fact that with temporary state disclosure we cannot both achieve **NARROW-FORWARD** privacy and *mutual authentication*. Thus, **NARROW-FORWARD** privacy can be brought up only if the corruption does not disclose the temporary state of the tag or the authentication is not mutual. In [6] the author clarifies that **FORWARD** privacy cannot be achieved in Vaudenay's model. Desynchronization is heavily involved in the proof of the last affirmation. Desynchronization implies that one tag can be desynchronized with the reader if, when the communication between the tag and the reader starts, the tag secret is updated but the reader's database fails to update its database due to a protocol shutdown. Unbounded desynchronization means that there are no boundaries given the number of times one is allowed to desynchronize a tag and a reader. Bounded desynchronization means that after a certain predefined number of steps the tag and the reader synchronize back. The proof of the impossibility of achieving **FORWARD** privacy in Vaudenay's model is by contradiction. It is assumed that there exists such a scheme and there is an adversary that creates two authorized tags, draws one tag, launches an instance of a protocol, receives the reader's message, the tag sends back a reply message, the adversary frees the tag drawn and draws another one. Then, the adversary queries the tag on the first message but in another protocol step, the tag answers with a different message then the first reply, the adversary corrupts the messages, retrieves the table which links temporary tags with real tags. Using a SKC, the adversary which now has the link table and knows what the database states, can check if the reader's and tags' answer and reply are valid. By using the *blinder* notion, it is shown that a blinder can give a valid answer to a *vtag* with 1/2 probability, hence, an adversary can distinguish between a real or blinded privacy game and no **FORWARD** privacy can be achieved.

In [7], as briefly talked about also in [6], four classes of RFID schemes are introduced when talking about symmetric key protocols:

- Type 0: no tag state updates in the reader's database
- Type 1: tag state is updated at each protocol execution
- Type 2a: tag state is updated after a reader authentication
- Type 2b: tag state is updated before a reader authentication

In [7], Type 0 was demonstrated to not provide **FORWARD** privacy due to the fact that corruption discloses the key tag and provides only **WEAK** privacy given the PRF used. Type 1 was demonstrated to not provide any notion of privacy that is not **NARROW** due to the fact that Type 1 protocols are Type 0 protocols with key update and synchronization. Due to desynchronization only **NARROW-FORWARD** can be achieved. Type 2a is proved to be reduced to Type 0 protocols, hence **WEAK** privacy is achieved and Type 2b can be reduced to Type 2a or Type1.

Now, having given the information above, regarding HPVP, can we assume that the higher notion on privacy achieved is **WEAK** privacy?

If there is a Type 0 SKC protocol for the HPVP model, it is safe to assume that at least **WEAK** privacy is achieved. The authors of HPVP refer to [7] and assume that the examples of protocols based on SKC given are expected to achieve the same privacy notions since no protocols given as examples achieves **WIDE-FORWARD** privacy. The question remains open still.

IX. FORWARD PKC-BASED SCHEME IN VAUDENAY'S MODEL IS STRONG IN HPVP MODEL

In this section we highlight the differences between the proposed HPVP model and Vaudenay's model in regards to the Vaudenay's PKC-based protocol which is **NARROW-STRONG** private given the encryption is IND-CPA and **FORWARD** private given the encryption is IND-CCA which in HPVP model the protocol achieves higher notions of privacy.

We reiterate below the experiment which follows Vaudenay's model on the PKC-based protocol proposed.

1. reader picks a random $a \in \{0, 1\}^{\alpha}$
2. sends a to the tag
3. the tag computes a challenge c by encrypting the concatenation of the tag ID, the shared secret K between the tag and the reader and the received a from the reader with the K_p of the reader and sends the challenge c to the reader
4. reader decrypts the challenge c with its K_s, retrieves the shared secret K, identifies the tag ID and the given a from the tag
5. if the value of a sent by the tag is equal with the a sent by the reader to the tag in the first step and if the shared secret K is located in the reader's database, then the system outputs the tag ID, otherwise outputs $\perp$, meaning failure

By relying on the IND-CPA encryption, the protocol achieves **STRONG**} privacy given **NARROW** adversaries in Vaudenay's model and **FORAWRD** privacy by relying on the IND-CCA encryption.

In HPVP model [8], the same protocol achieves **NARROW-STRONG** privacy if the encryption is IND-CPA and **WIDE-STRONG** if the encryption is IND-CCA. For the proof of **NARROW-STRONG**, assume an adversary that wins the privacy game with high probability and construct an adversary that wins the IND-CPA game with high probability. The adversary that is constructed communicates to the adversary that wins the privacy game by simulating the system where the reader's K_p is the public key for the IND-CPA game and the **SendTag** oracle retrieves two references of two distinct tags using their *vtag*, generates the corresponding c from step three of the above experiment for each tag with the encryption oracle of the IND-CPA game which returns only one of the two challenges and then the newly constructed adversary outputs the guess of the given adversary. If the given adversary can distinguish between the left or the right world, then the constructed adversary conquers the IND-CPA game. Based on the security of the models (which is common between the two as presented in the section 6.1.3) and the correctness of the scheme, **Lemma 8** in [1] helps in defining the **WIDE-FORWARD** privacy. To achieve **WIDE-STRONG** privacy, IND-CCA encryption must be used. Following the proof for **NARROW-STRONG** privacy, when getting the output of the **Result** oracle, the adversary compares *c* with a list of encrypted ciphertexts provided by the encryption oracle of the IND-CPA game when **SendTag** oracle calls were made. If any matches then *true* is returned. If there are no matches, then the **Result** oracle hands the ciphertext to the IND-CCA decryption oracle and receives the plaintext which is later verified. This game has the exact outcome as the IND-CPA game.

X. CONCLUSION

Which model is better? There is no simple answer to this question. Both models provide different levels of privacy. If we need strong privacy with a reasonable demonstration, we can choose the HPVP model. However, this strong privacy is just forward privacy in Vaudenay's model. We can switch our approach, pick Vaudenay's model and try to achieve destructive privacy with special elements like PUFs. What if we need more than destructive privacy? We may reach a complicated situation due to the fact that Vaudenay's model cannot achieve strong privacy. If the blinder's definitions and restrictions can be tweaked, we may reach strong privacy, but that means we are no longer in Vaudenay's mode, hence the highest privacy class achieved is destructive, which essentially is forward privacy enriched with vast corruption capabilities. Can we approach a blinder-less scenario? What has been underlined is that the demonstrations based on the blinder are hard from a theoretical point of view. It would be useful if there was a simplified privacy-based model with the same levels of privacy as Vaudenay's model. Can the HPVP model be a better alternative for demonstrations? We believe that it is a relevant approach due to the fact that it inherits the properties and definitions of the indistinguishability-based cryptosystem models. However, is it natural for RFID schemes to distinguish between two privacy games? Certainly, the use of the blinder for proving privacy seems more natural and firmer than distinguishing between two privacy games. We open the discussion for extending the HPVP model and also, for refining Vaudenay's model by refining the blinder.

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Pseudo Genetic Algorithm of Clustering For Linear and Ellipsoidal Clusters

Valerii Fratavchan [1], ORCID: 0000-0001-9347-9855
Tonia Fratavchan [1], ORCID: 0000-0003-1076-0794
Victor Ababii [2], ORCID: 0000-0002-0769-8144
[1] Yuriy Fedkovych Chernivtsi National University, Chernivtsi, Ukraine, v.fratavchan@chnu.edu.ua
[2] Technical University of Moldova, Chisinau, Republic of Moldova

***Abstract*—this article considers the method of clustering in the problems of pattern recognition when studying with a teacher in the case of n-dimensional numerical features. Clusters of linear and ellipsoidal forms that are optimal in the number of errors are created by the method of pseudo genetic algorithm. The pseudo genetic algorithm has a simplified procedure for performing mutation and crossover operations.**

Keywords – cluster; clustering; linear cluster; ellipsoidal cluster; genetic algorithm; mutation; crossover; discriminant function.

I. INTRODUCTION

Let's define a set of objects belonging to K classes. Each object is described by an n-dimensional vector of numerical features $X = (x_0, x_1, ..., x_{n-1})$. Each feature is a random variable. Objects of the same class are distributed in the feature space according to the near normal law. Each class in the feature space takes a particular area. Moreover, class areas can intersect. The problem is that it is necessary to divide the feature space for each class into areas that do not intersect (clusters) in such a way that the number of objects, which are not localized in the cluster of "their" class, is minimal [1]. The clustering process takes place according to the method of "learning with the teacher". Also, a learning sequence of images, which consists of representative sets of samples of each class $T = \left(T^{(1)}, T^{(2)}, ..., T^{(K)}\right)$, has been created. What is created in the feature space is an object area that consists of clusters $C = \left(C^{(1)}, C^{(2)}, ..., C^{(K)}\right)$. Consequently, each item of the training sequence must belong to only one cluster $X^{(i)} \in C^{(j)}, (X^{(i)} \notin C^{(k)}, j \notin k)$. Considering everything said above, it is desirable that the clusters in the feature space have a convex shape. As well as that, the classification procedure has to be quite simple. Such requirements are met by clusters of linear and ellipsoidal configurations [2].

II. CONSTRUCTION OF LINEAR CLUSTERS

Linear clusters have a convex polygonal shape. There is a hyperplane that optimally separates one cluster from another in an n-dimensional space for any two non-matching clusters (Figure 1).

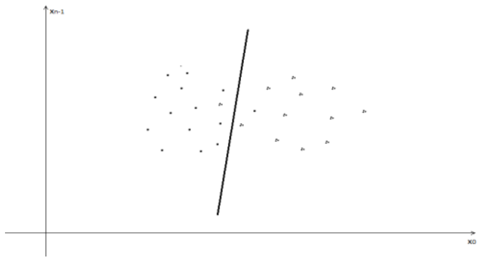

Figure 1. Hyperplane between clusters.

In the case of K classes, it is necessary to find $K-1$ such hyperplanes for each cluster, in the total of $K(K-1)/2$, since for each pair the hyperplanes coincide (Figure 2). Polygonal clusters can have an open or closed shape.

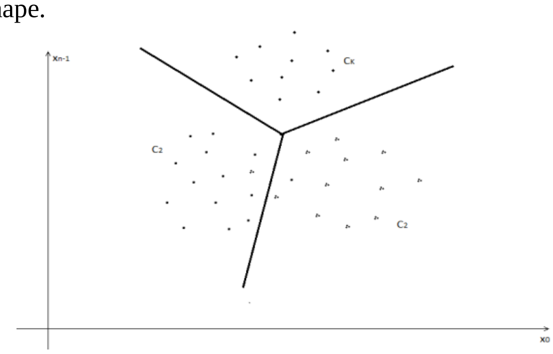

Figure 2. Polygonal clusters.

Mathematically, each cluster is defined by a system of inequalities:

$$\begin{cases} a_{1,0}^{(k)}x_0 + a_{1,1}^{(k)}x_1 + \ldots + a_{1,n-1}^{(k)}x_{n-1} + b_1^{(k)} \le 0 \\ a_{2,0}^{(k)}x_0 + a_{1,1}^{(k)}x_1 + \ldots + a_{2,n-1}^{(k)}x_{n-1} + b_2^{(k)} \le 0 \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ a_{K-1,0}^{(k)}x_0 + a_{1,1}^{(k)}x_1 + \ldots + a_{K-1,n-1}^{(k)}x_{n-1} + b_{K-1}^{(k)} \le 0 \\ k = 1,\ldots,K. \end{cases}$$

Thus, the set of clusters is determined by the set of weighting coefficients:

$$W = \begin{Bmatrix} a_{j,i}^{(k)}, (k = 1..K,\ j = 1..K-1, i = 0..n-1) \\ b_j^{(k)}, (k = 1..K,\ j = 1..K-1) \end{Bmatrix} \quad (1)$$

III. Construction of Ellipsoidal Clusters

Among the pattern recognition methods, there is a quite popular method of discriminant functions [4] such as

$$g_k(X) = \begin{cases} v \ge 0,\ X \in C^{(k)} \\ v < 0,\ X \notin C^{(k)} \\ k = 1..K \end{cases}.$$

In order to construct ellipsoidal clusters, it is suggested to use a discriminant function of the quadratic (parabolic) type (Figure 3).

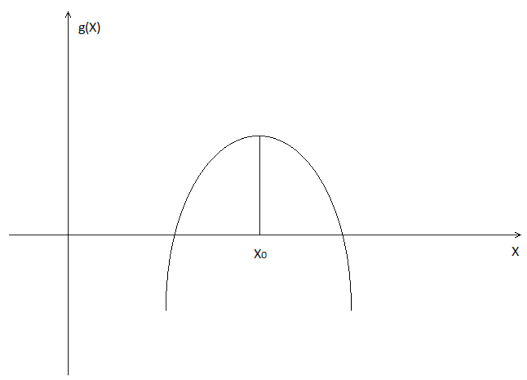

Figure 3. Parabolic discriminant function.

For the n-dimensional case, such a function will be set by the formula below:

$$g_k(X) = -a_0^{(k)}(x_0 - c_0^{(k)})^2 - a_1^{(k)}(x_1 - c_1^{(k)})^2 - \ldots \\ - a_{n-1}^{(k)}(x_{n-1} - c_{n-1}^{(k)})^2 + b_k$$

In n+1-dimensional space, these functions form paraboloids, which form ellipsoids in the n-dimensional feature space (Figure 4).

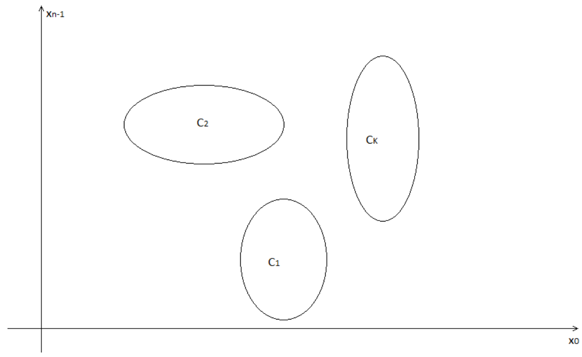

Figure 4. Ellipsoidal clusters.

Similarly to the case of linear clusters, elliptical clusters are determined by the set of coefficients of the discriminant functions and by the coordinates of the ellipsoid centers:

$$W = \begin{Bmatrix} a_i^{(k)}, k = 1..K, i = 0..n-1; \\ b_k, k = 1..K; \\ c_i^{(k)}, k = 1..K, i = 0..n-1 \end{Bmatrix}. \quad (2)$$

It can be noted that for each elliptic cluster it is necessary to define a $2n+1$ parameter that in case of dealing with numerous classes requires significantly less computing resources than for linear clusters. However, at the same time, the efficiency of clustering with ellipsoidal shapes can be inferior to linear clusters.

IV. Applications of Pseudo Genetic Algorithm for Building Optimal Clusters

Cluster construction procedures are the same for linear and elliptical clusters and are implemented as optimization problems [3]:

$$\begin{aligned} &E(W) \to \min, \\ &W \in D. \end{aligned} \quad (3)$$

Where: $E(W)$ – is the function that estimates the number of errors for the training set;

W – aggregate vector of cluster parameters according to formulas (1) or (2);

D – a domain of definition of cluster parameters.

The optimization problem is solved by a pseudo genetic algorithm. It has a simplified system of mutation and crossover genetic operations. In the classical genetic algorithm, these operations are performed on the binary code of "chromosomes", thus the values of specific bits change. In the pseudo genetic version, operations are performed on the components of the parameter vector.

For **mutation**, we randomly select a specimen of the current population and the index of some component of the vector of cluster parameters, after this the component is given a new random value from the domain of definition:

$$\{w_1,..., w_m,..., w_s\} \to \{w_1,..., u_m,..., w_s\},$$

Where: $m -$ is the index of the component selected for mutation:

s - the size of the parameter vector;

$u_m = random(d, d \in D)$.

For the **crossover** operation, we randomly select two "parent" instances of parameter vectors from the current population and the crossover point index. Eventually, the information is being exchanged relative to this point:

$$\begin{pmatrix} \{w_1,..., w_m, w_{m+1},..., w_s\}, \\ \{u_1,..., u_m, u_{m+1},..., u_s\} \end{pmatrix} \to \begin{pmatrix} \{w_1,..., w_m, u_{m+1},..., u_s\}, \\ \{u_1,..., u_m, w_{m+1},..., w_s\} \end{pmatrix}.$$

The general procedure of the genetic algorithm corresponds to the classical scheme and consists of the formation of the initial population of various cluster system configurations, and the population regeneration process with the usage of mutation, crossover and selection operations. The stages of regeneration continue until the value of the evaluation function is stable or until the desired qualitative assessment of the classification is achieved when processing the training set samples.

CONCLUSIONS

The purpose of the paper is to suggest algorithms for clustering a multidimensional feature space in pattern recognition tasks in the learning mode with a teacher. Summing up the results, it can be concluded that algorithms are built on relatively simple mathematical models and do not require powerful system resources. This paper has clearly shown that algorithms are quite effective if the selected features allow localizing clusters in the feature space with areas of convex shape. However, the algorithms are not effective in large estimates of the mutual intersection of the internal parts of the cluster linear shells. To implement clustering procedures, it is necessary to a priori create representative training sequences, in which the normal laws of image distribution in the cluster become sufficiently noticeable. These features require preliminary statistical analysis of training sets.

The obtained data indicate that these algorithms are recommended for use in cybernetic stand-alone systems, where the application of highly effective library intellectual tools is obstructed.

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Application of the Schwinger's oscillator model of angular momentum to quantum computing

Ion I. Geru ORCID: 0000-0003-1320-3889
Academy of Sciences of Moldova, Department of Exact and Engineering Sciences, 1 Stefan cel Mare av., Chisinau, MD-2001 Republic of Moldova, iongeru11@gmail.com

Abstract— **The Schwinger's oscillator model of angular momentum is applied to define quantum logical elements in quantum circuits by means of wave functions of two independent harmonic oscillators. It is shown how four EPR entangled states can be determined based on this model.**

Keywords—qubit; quantum computing; logical elements; quantum circuit

I. Introduction

Unlike calculations in classical computer science, based on the concept of a bit, quantum computer science uses the concept of a quantum bit (qubit). A qubit is a quantum system that can be in two states |0⟩ and |1⟩ (the Dirac notations [1] are used). An example of such systems is an electron with two spin orientations or a photon with two possible polarizations. In the general case, the state of a qubit is given by a superposition of basis vectors |0⟩ and |1⟩ with coefficients α and β satisfying the condition $|\alpha|^2+|\beta|^2 = 1$, which follows from the normalization condition for the qubit wave function. The fundamental difference between a qubit and a bit is that a qubit can be simultaneously in states |0⟩ and |1⟩ (the coefficients α and β are simultaneously different from zero). This actually determines the difference in the ways of constructing classical and quantum computers. We note that at present quantum computers are not yet mass-produced, but experimental samples have already been built (see, for example, the results of calculations carried out on one of them [2]).

To describe multi-qubit systems, it is convenient to introduce the effective spin $S = 2^{(N-1)}-1/2$ [3], where N is the number of qubits. The N-qubit system is characterized by 2S+1 states |S, S⟩, |S, S-1⟩, |S, S-2⟩, …, |S, 2-S⟩, |S, 1-S⟩, |S, -S⟩. Any N-qubit system can be in any of these states, as well as in any state of their superposition.

The Schwinger oscillator model of angular momentum [4] can be used to conduct quantum computing [3]. In this case, it is necessary to convert single- and multi-qubit logical elements from the spinor representation to the two-boson one. This article discusses some of the features of applying the two-boson Schwinger representation of the effective spin to quantum computing

II. On two-bosonic Schwinger representation of angular momentum

The two-boson Schwinger representation for the effective spin is realized using two types of independent harmonic oscillators. We denote by A_1^+, A_1 and A_2^+, A_2 the Bose operators of creation and annihilation corresponding to these harmonic oscillators. Then, in the system of units in which Planck's constant ħ=1, the spin projection operators S_x, S_y, and S_z are defined by the expressions [4]

$$S_x = \frac{1}{2}\left(A_1^+A_2 + A_2^+A_1\right), S_y = \frac{1}{2i}\left(A_1^+A_2 - A_2^+A_1\right),\\ S_z = \frac{1}{2}\left(A_1^+A_1 - A_2^+A_2\right) \tag{1}$$

The spin wave function in the two-boson Schwinger representation of the angular momentum has the form

$$|S,M\rangle = \frac{1}{\left[(S+M)!(S-M)!\right]^{1/2}}\left(A_1^+\right)^{S+M}\left(A_2^+\right)^{S-M}|0\rangle \tag{2}$$

where |0⟩ denotes the vacuum state $|0\rangle = |0\rangle_1|0\rangle_2$.

III. Logical elements of a one-qubit system in a two-boson representation of the effective spin S=1/2

A. *Logical element NOT (or Pauli-X)*

In the two-boson representation of the effective spin S = 1/2, the Pauli-X logical element of the one-qubit system has the form

$$X = \left(A_1^+ A_2^+\right)\begin{pmatrix}0 & 1\\ 1 & 0\end{pmatrix}\begin{pmatrix}A_1\\ A_2\end{pmatrix} = A_1^+A_2 + A_2^+A_1. \tag{3}$$

Let us act by operator *X* on the wave function of the qubit $|\psi\rangle = \alpha|1\rangle_1|0\rangle_2 + \beta|0\rangle_1|1\rangle_2$:

$$X|\psi\rangle=\left(A_1^+A_2+A_2^+A_1\right)(\alpha|1\rangle_1|0\rangle_2+ \beta|0\rangle_1|1\rangle_2)=\beta|1\rangle_1|0\rangle_2+\alpha|0\rangle_1|1\rangle_2 \quad (4)$$

It can be seen that as a result of such an action, the coefficients α and β in the original qubit are reversed (that is, $\alpha\rightarrow\beta$ and $\beta\rightarrow\alpha$).

The normalized eigenvectors of operator X in the representation of paired bosons have the form

$$|\psi\rangle_{1,2}=\frac{1}{\sqrt{2}}\left(|1\rangle_1|0\rangle_2\pm|0\rangle_1|1\rangle_2\right). \quad (5)$$

B. Logical element Z (or Pauli-Z)

In the two-boson representation of the effective spin S = 1/2, the Pauli-X logical element of the one-qubit system has the form

$$Z=\left(A_1^+A_2^+\right)\begin{pmatrix}1 & 0\\ 0 & -1\end{pmatrix}\begin{pmatrix}A_1\\ A_2\end{pmatrix}=\left(A_1^+A_1-A_2^+A_2\right). \quad (6)$$

Under action of operator Z on the wave function of a qubit $|\psi\rangle=\alpha|1\rangle_1|0\rangle_2+\beta|0\rangle_1|1\rangle_2$, we obtain

$$Z|\Psi\rangle=\left(A_1^+A_1-A_2^+A_2\right)(\alpha|1\rangle_1|0\rangle_2+ \beta|0\rangle_1|1\rangle_2)=(\alpha|1\rangle_1|0\rangle_2-\beta|0\rangle_1|1\rangle_2). \quad (7)$$

As can be seen from (7), the operator Z does not change the coefficient at the basis vector $|1\rangle_1|0\rangle_2$ and changes the sign of the coefficient at the basis vector $|0\rangle_1|1\rangle_2$ .The eigenvectors of the operator Z coincide with the eigenvectors $|1\rangle_1|0\rangle_2$ and $|0\rangle_1|1\rangle_2$.

C. Hadamard gate H

In the spinor basis, the Hadamard logical element is given by the matrix [3]

$$H=\frac{1}{\sqrt{2}}\begin{pmatrix}1 & 1\\ 1 & -1\end{pmatrix}. \quad (8)$$

In the two-boson representation, the operator H has the form

$$H=\frac{1}{\sqrt{2}}(X+Z)= \frac{1}{\sqrt{2}}\left[A_1^+(A_1+A_2)+A_2^+(A_1-A_2)\right], \quad (9)$$

where X and Z are real Pauli matrices.

The action of the operator H on the wave function of the qubit $|\Psi\rangle$ leads to the following result:

$$\frac{1}{\sqrt{2}}\left[A_1^+(A_1+A_2)+A_2^+(A_1-A_2)\right](\alpha|1\rangle_1|0\rangle_2+\beta|0\rangle_1|1\rangle_2)= \frac{1}{\sqrt{2}}\left[(\alpha+\beta)|1\rangle_1|0\rangle_2+(\alpha-b)|0\rangle_1|1\rangle_2\right]. \quad (10)$$

The normalized eigenvectors of the Hadamard operator H have the form

$$|\Psi\rangle_{1,2}=\frac{1}{4\mp2\sqrt{2}}\left[|1\rangle_1|0\rangle_2\pm(\sqrt{2}\mp1)|0\rangle_1|1\rangle_2\right] \quad (11)$$

which agrees with the results for $|\Psi\rangle_1$ and $|\Psi\rangle_2$ in the spin representation.

D. Logical element Y

The logical element Y in the two-boson representation has the form

$$Y=\left(A_1^+A_2^+\right)\begin{pmatrix}0 & -i\\ i & 0\end{pmatrix}\begin{pmatrix}A_1\\ A_2\end{pmatrix}=i\left(A_2^+A_1-A_1^+A_2\right). \quad (12)$$

Under the action of the oparator Y, the wave function of the qubit $|\Psi\rangle$ transforms to the form

$$i\left(A_2^+A_1-A_1^+A_2\right)\left(\alpha|1\rangle_1|0\rangle_2+\beta|0\rangle_1|1\rangle_2\right)= i\left(\alpha|0\rangle_1|1\rangle_2-\beta|1\rangle_1|0\rangle_2\right). \quad (13)$$

It can be seen that the coefficient α at the basis vector $|1\rangle_1|0\rangle_2$ goes into $-i\beta$ and the coefficient β at the basis vector $|0\rangle_1|1\rangle_2$ goes into $i\alpha$. The normalized eigenvectors of the operator Ψ have the form

$$|\Psi\rangle_{1,2}=\frac{1}{\sqrt{2}}\left(|1\rangle_1|0\rangle_2\pm i|0\rangle_1|1\rangle_2\right) \quad (14)$$

E. Logical phase element T

The complex logical phase element T (which is also denoted by π/8) in the spinor representation is given by the matrix

$$T=\begin{pmatrix}1 & 0\\ 0 & \exp(i\pi/8)\end{pmatrix}. \quad (15)$$

In the two-boson representation, the logical element T is determined by the expression

$$T=\left(A_1^+A_2^+\right)\begin{pmatrix}1 & 0\\ 0 & \exp(i\pi/8)\end{pmatrix}\begin{pmatrix}A_1\\ A_2\end{pmatrix}= A_1^+A_1+\exp(i\pi/8)A_2^+A_2 \quad (16)$$

The operator T acts on the qubit wave function according to the rule:

$$T|\Psi\rangle=\left[A_1^+A_1+\exp\left(i\pi/8\right)A_2^+A_2\right](\alpha|1\rangle_1|0\rangle_2+\beta|0\rangle_1|1\rangle_2)= \alpha|1\rangle_1|0\rangle_2+\beta\exp\left(i\pi/8\right)|0\rangle_1|1\rangle_2. \quad (17)$$

Thus, the operator T does not change the coefficient at the basic vector $|1\rangle_1|0\rangle_2$ and changes the phase of the coefficient at the basis vector $|0\rangle_1|1\rangle_2$. It can be shown that the eigenvectors of the operator T coincide with the basic vectors $|1\rangle_1|0\rangle_2$ and $|0\rangle_1|1\rangle_2$.

F. *Logical phase element S*

In the two-bosonic representation, the logical phase element S (not to be confused with the spin operator) is defined by the expression

$$S=\left(A_1^+A_2^+\right)\begin{pmatrix}1 & 0\\ 0 & i\end{pmatrix}\begin{pmatrix}A_1\\ A_2\end{pmatrix}=A_1^+A_1+iA_2^+A_2. \quad (18)$$

Under the action of the operator S, the wave function of the qubit is transformed as follows

$$\begin{aligned}&(A_1^+A_1+iA_2^+A_2)(\alpha|1\rangle_1|0\rangle_2+\beta|0\rangle_1|1\rangle_2)=\\&\alpha|1\rangle_1|0\rangle_2+i\beta|0\rangle_1|1\rangle_2\end{aligned} \quad (19)$$

Transformation (19) does not change the coefficient α at the basis vector $|1\rangle_1|0\rangle_2$, but multiplies by *i* the coefficient β which is at the basis vector $|0\rangle_1|1\rangle_2$. The eigenvectors of the operator S coincide with the basic eigenvectors $|1\rangle_1|0\rangle_2$ and $|0\rangle_1|1\rangle_2$.

G. *Logical phase element Φ*

By definition, the logical phase element Φ is given in the two-bosonic representation by the operator

$$\begin{aligned}&\Phi=\left(A_1^+A_2^+\right)\begin{pmatrix}1 & 0\\ 0 & \exp(i\varphi)\end{pmatrix}\begin{pmatrix}A_1\\ A_2\end{pmatrix}=\\&A_1^+A_1+\exp(i\varphi)A_2^+A_2.\end{aligned} \quad (20)$$

where φ is the angle of rotation of the state vector of the qubit $|\Psi\rangle$, starting at the center of the Bloch sphere and ending at the surface of the sphere. Rotation is around the z-axis. The basis vector $|1\rangle_1|0\rangle_2$ is oriented along this axis, and the basis vector $|0\rangle_1|1\rangle_2$ is oriented in the opposite direction. The action of the operator Φ on the qubit state vector is determined by the expression

$$\begin{aligned}&\Phi|\Psi\rangle=\\&\left[A_1^+A_1+\exp(i\varphi)A_2^+A_2\right](\alpha|1\rangle_1|0\rangle_2+\beta|0\rangle_1|1\rangle_2)\\&=\alpha|1\rangle_1|0\rangle_2+\beta\exp(i\varphi)|0\rangle_1|1\rangle_2.\end{aligned} \quad (21)$$

According to (21), the action of the operator Φ on the state vector |Ψ⟩ of the qubit does not change the coefficient α at the basis vector $|1\rangle_1|0\rangle_2$ and multiplies the coefficient β at the basis vector $|0\rangle_1|1\rangle_2$ by the factor $\exp(i\varphi)$. The eigenvectors of the operator Φ coincide with the basis vectors $|1\rangle_1|0\rangle_2$ and $|0\rangle_1|1\rangle_2$.

IV. EPR STATES IN TWO-BOSON REPRESENTATION OF THE EFFECTIVE SPIN

Let a quantum circuit contains the quantum logic element CNOT (I is the unitary operator):

$$CNOT=\begin{pmatrix}I & 0\\ 0 & A_1^+A_2+A_2^+A_1\end{pmatrix}, \quad (22)$$

in the control input of which the Hadamard element H is included. If two base vectors $|1\rangle_1|0\rangle_2$ are applied to both inputs of the circuit, then one of them will go immediately to the controlled input of element CNOT, while the second will go to the control input of the CNOT after passing the element H (Fig. 1).

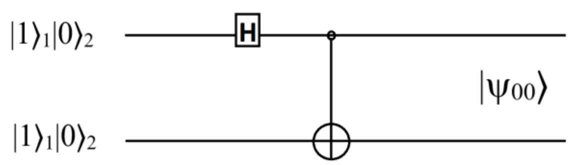

Figure 1. Quantum scheme for creating the EPR [5] or Bell [6] states.

The gate H transforms the basis vector $|1\rangle_1|0\rangle_2$ as follows:

$$\begin{aligned}&H|1\rangle_1|0\rangle_2=\frac{1}{\sqrt{2}}[A_1^+\left(A_1+A_2\right)+\\&A_2^+\left(A_1-A_2\right)]|1\rangle_1|0\rangle_2=\frac{1}{\sqrt{2}}\left(|1\rangle_1|0\rangle_2+|0\rangle_1|1\rangle_2\right)\end{aligned} \quad (23)$$

It can be shown that in this case, the input of logical element CNOT is the vector $\frac{1}{\sqrt{2}}\left(|3\rangle_1|1\rangle_2+|1\rangle_1|2\rangle_2\right)$ which, after passing the element CNOT, is converted to the Bell state

$$|\psi_{00}\rangle=\frac{1}{\sqrt{2}}\left(|3\rangle_1|0\rangle_2+|0\rangle_1|3\rangle_2\right) \quad (24)$$

The other three Bell states are found similarly in the two-boson representation:

$$\begin{aligned}
|\psi_{01}\rangle &= \frac{1}{\sqrt{2}}\left(|2\rangle_1|1\rangle_2 + |1\rangle_1|2\rangle_2\right) \\
|\psi_{10}\rangle &= \frac{1}{\sqrt{2}}\left(|3\rangle_1|0\rangle_2 - |0\rangle_1|3\rangle_2\right) \qquad (25) \\
|\psi_{11}\rangle &= \frac{1}{\sqrt{2}}\left(|2\rangle_1|1\rangle_2 - |1\rangle_1|2\rangle_2\right)
\end{aligned}$$

DISCUSSION AND CONCLUSIONS

In the two-boson representation of an effective spin S, a one-to-one correspondence between the discrete energy spectrum of a spin system with a finite number of degrees of freedom and the energy spectrum of two harmonic oscillators with an infinite number of degrees of freedom is possible only in one case.

To do this, it is necessary to introduce a limit on the number of oscillatory states. Namely, to depict spin states using the states of two harmonic oscillators, only those bosonic states must be involved that satisfy the condition $n_1 + n_2 \leq 2S$, where n_1 and n_2 are the occupation numbers of the bosonic states related to oscillators 1 and 2. Taking into account (2), the 2S + 1 spin states acquire in the two-boson representation the form
$|2S\rangle_1|0\rangle_2, |2S-1\rangle_1|1\rangle_2, ..., |S+M\rangle_1|S-M\rangle_2, ...,$
$|1\rangle_1|2S-1\rangle_2, |0\rangle_1|2S\rangle_2$.

Based on the above, the following conclusions can be drawn:

1. The Schwinger's oscillator model of angular momentum can be used to determine logical quantum elements, as well as logical quantum circuits of single- and multi-qubit systems in quantum computing.

2. The application of the two-boson representation of angular momentum to quantum computing may be useful due to the peculiarities of this representation for one- and multi-qubit systems

3. In the case of N-qubit systems, the form of spin operators in the two-boson representation does not depend on the value of N that can lead to simplifications in quantum calculations in some particular cases.

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An Inverse Stochastic Optimal Control Problem

Mario Lefebvre [1], ORCID: 0000-0002-9451-543X
[1] Polytechnique Montréal, 2900 boul. Édouard-Montpetit, Montréal, Canada, mlefebvre@polymtl.ca,
https://www.polymtl.ca/expertises/en/lefebvre-mario

***Abstract*—The problem of controlling a compound Poisson process until it leaves an interval is considered. In this paper, instead of choosing the density function of the jumps and trying to find the corresponding value function, from which the optimal control follows at once, we consider the inverse problem: we fix the value of the value function and we look for admissible density functions for the jumps.**

Keywords*—*homing problem; Poisson random jumps; first-passage time; integro-differential equation; dynamic programming

I. Introduction

In [1], the author considered the controlled jump-diffusion process $\{X_u(t), t \geq 0\}$ defined by

$$X_u(t) = X_u(0) + \mu t + \int_0^t b[X_u(s)]\, u[X_u(s)]\, \mathrm{d}s + \sigma B(t) + \sum_{i=1}^{N(t)} Y_i, \qquad (1)$$

where $\mu \in$ | and $\sigma > 0$ are constants, $b(\cdot) \neq 0$, $u(\cdot)$ is the control variable, $\{B(t), t \geq 0\}$ is a standard Brownian motion and $\{N(t), t \geq 0\}$ is a Poisson process with rate λ. Moreover, $\{B(t), t \geq 0\}$ and $\{N(t), t \geq 0\}$ are independent, and the random variables Y_1, Y_2, ... are independent and identically distributed. The aim was to find the control that minimizes the expected value of the cost criterion

$$J(x) := \int_0^{T(x)} \left\{ \frac{1}{2} q[X_u(t)]\, u^2[X_u(t)] + \theta \right\} \mathrm{d}t + K[X_u(T(x))], \qquad (2)$$

where θ is a real constant, $q(\cdot) > 0$, $K(\cdot)$ is a general termination cost function and the final time $T(x)$ is a random variable (known as a *first-passage time* in probability theory) defined by

$T(x) = \inf\{t \geq 0 : X_u(t)$ ⌠ $(a, b) \mid X_u(0) = x\}$, (3)

where $x \in [a, b]$. Explicit solutions to particular problems were obtained when Y_1, Y_2, ... are exponentially distributed, which implies that the random jumps are always positive, and we assume that the ratio $b^2(x)/q(x)$ is a (positive) constant:

$$\kappa := \frac{b^2(x)}{2q(x)} \qquad (4)$$

This type of stochastic control problem, in which the final time is a first-passage time, is called a *homing problem*; see Whittle [2] and/or Whittle [3]. In the case when the parameter θ is positive (respectively, negative), the optimizer must try to minimize (respectively, maximize) the time spent by the controlled process in the continuation region (a, b), taking the quadratic control costs $q[X_u(t)]\, u^2[X_u(t)]/2$ and the termination cost $K[X_u(T(x))]$ into account.

In this paper, we set $\sigma = 0$. It follows that $\{X_u(t), t \geq 0\}$ becomes a controlled compound Poisson process (with drift μ); see, for example, Ross [4]. Moreover, we define

$$T(x) = \inf\{t \geq 0 : X_u(t) \geq 1 \mid X_u(0) = x \leq 1\}. \qquad (5)$$

That is, the continuation region is the interval $(-\infty, 1)$.

II. Optimal Control

Let $f_Y(y)$ be the common density function of the random variables $Y_1, Y_2, \ldots$ The following result is an extension of Proposition 2.1 in [1].

Remark. The function $f_Y(y)$ can involve the Dirac delta function. That is, Y can be a discrete or a mixed type random variable.

Proposition 2.1. *The value function*

$$V(x) := \inf_{\substack{u[X_u(t)]\\ 0 \le t \le T(x)}} E[J(x)] \tag{6}$$

satisfies the first-order, non-linear integro-differential equation

$$0 = \theta + \mu V'(x) - \frac{1}{2}\frac{b^2(x)}{q(x)}\left[V'(x)\right]^2 + \lambda \int_0^\infty \left[V(x+y) - V(x)\right] f_Y(y)\,\mathrm{d}y \tag{7}$$

for $x < 1$. *Moreover, this equation is subject to the boundary condition*

$$V(x) = K(x) \quad \text{if } x \ge 1. \tag{8}$$

$$\begin{aligned} V(x) &= \inf_{\substack{u[X_u(t)]\\ 0\le t\le \Delta t}} E\Bigg[\int_0^{\Delta t}\left\{\frac{1}{2}q[X_u(t)]\,u^2[X_u(t)] + \theta\right\} \\ &\quad + V\left(x + [\mu + b(x)\,u(x)]\,\Delta t + \sum_{i=1}^{N(\Delta t)} Y_i\right)\Bigg] \\ &= \inf_{\substack{u[X_u(t)]\\ 0\le t\le \Delta t}} E\Bigg[\left\{\frac{1}{2}q(x)\,u^2(x) + \theta\right\}\Delta t \\ &\quad + V\left(x + [\mu + b(x)\,u(x)]\,\Delta t + \sum_{i=1}^{N(\Delta t)} Y_i\right) \\ &\quad + o(\Delta)\Bigg]. \end{aligned}$$

Proof. Bellman's principle of optimality implies that

(9)

Moreover, we deduce from the properties of the Poisson distribution that

$$P[N(\Delta t) = 0] = e^{-\lambda\Delta t} = 1 - \lambda\Delta t + o(\Delta t) \tag{10}$$

and

$$P[N(\Delta t) = 1] = \lambda\Delta t \; e^{-\lambda\Delta t} = \lambda\Delta t + o(\Delta t). \tag{11}$$

Hence, we can write that

$$\begin{aligned} &E\left[V\left(x + [\mu + b(x)\,u(x)]\,\Delta t + \sum_{i=1}^{N(\Delta t)} Y_i\right)\right] = \\ &E\left[V\left(x + [\mu + b(x)\,u(x)]\,\Delta t + Y_1\right)\right]\lambda\Delta t \\ &+ E\left[V\left(x + [\mu + b(x)\,u(x)]\,\Delta t\right)\right](1 - \lambda\Delta t) \\ &+ o(\Delta t). \end{aligned} \tag{12}$$

Next, assuming that the function $V(x)$ is differentiable with respect to x, Taylor's formula yields that

$$\begin{aligned} &E\left[V\left(x + [\mu + b(x)\,u(x)]\,\Delta t\right)\right](1 - \lambda\Delta t) = \\ &V(x) + [\mu + b(x)\,u(x)]\,\Delta t\,V'(x) - \lambda\Delta t\,V(x) \\ &\quad + o(\Delta t) \end{aligned} \tag{13}$$

and

$$\begin{aligned} &E\left[V\left(x + [\mu + b(x)\,u(x)]\,\Delta t + Y_1\right)\right]\lambda\Delta t = \\ &E[V(x + Y_1)]\,\lambda\Delta t + o(\Delta t) = \\ &\lambda\Delta t \int_0^\infty V(x+y)\,f_Y(y)\,\mathrm{d}y + o(\Delta t). \end{aligned} \tag{14}$$

It follows, substituting (13) and (14) into Eq. (9), that

$$\begin{aligned} 0 = \inf_{\substack{u[X_u(t)]\\ 0\le t\le \Delta t}} \Bigg\{ &\left(\frac{1}{2}q(x)\,u^2(x) + \theta\right)\Delta t \\ &+ [\mu + b(x)\,u(x)]\,\Delta t\,V'(x) - \lambda\Delta t\,V(x) \\ &+ \lambda\,\Delta t \int_{-\infty}^{\infty} V(x+y)\,f_Y(y)\,\mathrm{d}y + o(\Delta t)\Bigg\} \end{aligned} \tag{15}$$

Dividing each side of Eq. (15) by Δt and letting Δt decrease to zero, we obtain the *dynamic programming equation*

$$\begin{aligned} 0 = \inf_{u(x)} \Bigg\{ &\frac{1}{2}q(x)\,u^2(x) + \theta + [\mu + b(x)\,u(x)]\,V'(x) \\ &- \lambda\,V(x) + \lambda \int_{-\infty}^{\infty} V(x+y)\,f_Y(y)\,\mathrm{d}y\Bigg\}. \end{aligned} \tag{16}$$

From the above equation, we deduce that the optimal control $u^*(x)$ can be expressed in terms of the value function $V(x)$:

$$u^*(x) = -\frac{b(x)}{q(x)}\,V'(x) \tag{17}$$

for $x < 1$. Equation (7) is obtained by replacing this expression for $u^*(x)$ into Eq. (16) and by noticing that we can write

$$V(x) = \int_0^{\infty} V(x)\,\alpha\, e^{-\alpha y}\mathrm{d}y. \tag{18}$$

Finally, because the jumps are strictly positive, the controlled process $\{X_u(t),\ t \geq 0\}$ cannot be smaller than the endpoint a of the interval $[a, b]$. However, it can cross the boundary $x = b$. Hence, we obtain the boundary condition in Eq. (8). □

Now, in this paper, instead of choosing the density function $f_Y(y)$ and trying to find the corresponding value function $V(x)$ (and hence the optimal control from (17)), we consider the inverse problem: we fix the value of $V(x)$ and we look for admissible density functions $f_Y(y)$.

First, assume that the value function $V(x)$ is a constant V_0 in the interval $(-\infty,1)$ (so that $u^*(x) \equiv 0$). Then, we deduce from (7) that we must have

$$\begin{aligned} 0 \ &= \ \theta - \lambda V_0 + \lambda \left\{ \int_{-\infty}^{1-x} V_0 f_Y(y)\,\mathrm{d}y \right. \\ &\quad \left. + \int_{1-x}^{\infty} K(x+y) f_Y(y)\,\mathrm{d}y \right\}. \end{aligned} \tag{19}$$

If the function $K(x)$ is also equal to the constant V_0, the above equation reduces to

$$0 = \theta - \lambda V_0 + \lambda V_0 \int_{-\infty}^{\infty} f_Y(y)\,\mathrm{d}y. \tag{20}$$

Thus, this solution is valid for any (non-defective) density function $f_Y(y)$ if and only if $\theta = 0$.

Remark. When $\theta = 0$ and $K(x)$ is also equal to V_0, the optimal control is trivially identical to zero. However, when $K(x) \equiv K_0 \neq V_0$, Eq. (19) becomes

$$0 = \theta - \lambda V_0 + \lambda\, \{V_0 F_Y(1-x) + K_0 [1 - F_Y(1-x)]\}, \tag{21}$$

where $F_Y(\cdot)$ denotes the common cumulative distribution function of the random variables Y_1, Y_2, ... Then, the function $F_Y(1-x)$ must not depend on x. This is true if the jumps are always negative, so that $F_Y(y) = 1$ for any $y \geq 0$. It follows that the solution is valid again if and only if $\theta = 0$.

Next, we look for value functions $V(x)$ that are affine functions of x:

$$V(x) = c_1 x + c_0, \tag{22}$$

where $c_1 \neq 0$, so that

$$u*(x) = -c_1 \frac{b(x)}{q(x)}. \tag{23}$$

Remark. We assumed that the ratio $b^2(x)/2q(x)$ is a positive constant κ. However, the ratio $b(x)/q(x)$ is not necessarily a constant. Hence, the optimal control is not necessarily a constant either.

Substituting the function defined in (22) into the integro-differential equation (7), we obtain that

$$\begin{aligned} 0 \ &= \ \theta + \mu c_1 - \kappa c_1^2 - \lambda(c_1 x + c_0) \\ &\quad + \lambda \int_{-\infty}^{\infty} V(x+y) f_Y(y)\,\mathrm{d}y. \end{aligned} \tag{24}$$

The simplest case is when we choose $K(x) = c_1 x + c_0$ for any $x \geq 1$. Then, the above equation becomes

$$\begin{aligned} 0 \ &= \ \theta + \mu c_1 - \kappa c_1^2 - \lambda(c_1 x + c_0) \\ &\quad + \lambda \int_{-\infty}^{\infty} [c_1(x+y) + c_0] f_Y(y)\,\mathrm{d}y \\ &= \ \theta + \mu c_1 - \kappa c_1^2 + \lambda c_1 E[Y]. \end{aligned} \tag{25}$$

Thus, assuming that $E[Y]$ exists (and is finite), we deduce that the solution is valid for any random variable Y if and only if the constant c_1 is given by

$$c_1 = \frac{(\mu + \lambda E[Y]) \pm \sqrt{(\mu + \lambda E[Y])^2 + 4\theta\kappa}}{2\kappa} \tag{26}$$

whereas the constant c_0 is arbitrary. The parameter θ should be such that the term in the square root is non-negative.

In the special case when $E[Y] = 0$, Eq. (26) simplifies to

$$c_1 = \frac{\mu \pm \sqrt{\mu^2 + 4\theta\kappa}}{2\kappa} \tag{27}$$

which reduces further to $c_1 = \pm (\theta/\kappa)^{1/2}$ when μ is equal to zero as well.

Remark. When θ is positive, the value function $V(x)$ must also be positive. Therefore, the constant c_1 must be chosen appropriately.

Finally, when $K(x) \equiv 0$, Eq. (24) becomes

$$\begin{aligned} 0 &= \theta + \mu c_1 - \kappa c_1^2 - \lambda(c_1 x + c_0) \\ &\quad + \lambda \int_{-\infty}^{1-x} [c_1 (x + y) + c_0] f_Y(y) \, \mathrm{d}y \\ &= \theta + \mu c_1 - \kappa c_1^2 - \lambda(c_1 x + c_0) \\ &\quad + \lambda (c_1 x + c_0) F_Y(1 - x) \\ &\quad + \lambda c_1 \int_{-\infty}^{1-x} y f_Y(y) \, \mathrm{d}y. \end{aligned} \tag{28}$$

As in the case when $V(x) \equiv V_0$, we would like the distribution function $F_Y(1 - x)$ to be independent of x. We can again assume that the jumps are always negative, which implies that $F_Y(1 - x) \equiv 1$ for $x < 1$. It follows that the constant c_1 must satisfy the equation

$$\begin{aligned} 0 &= \theta + \mu c_1 - \kappa c_1^2 + \lambda c_1 \int_{-\infty}^{1-x} y f_Y(y) \, \mathrm{d}y \\ &= \theta + \mu c_1 - \kappa c_1^2 + \lambda c_1 \int_{-\infty}^{0} y f_Y(y) \, \mathrm{d}y \\ &= \theta + \mu c_1 - \kappa c_1^2 + \lambda c_1 E[Y]. \end{aligned} \tag{19}$$

Hence, we retrieve the equation for c_1 in (26). However, because we assumed that $Y < 0$, we must impose the condition $\mu > 0$, otherwise $T(x)$ will be equal to infinity.

III. Conclusion

In this paper, we considered an inverse LQG homing problem for one-dimensional jump-diffusion processes. Whereas in a previous paper the jump-size distribution was fixed and the aim was to solve the dynamic programming equation (and hence obtaining the optimal control), here we tried to find admissible density functions for the jumps when the form of the value function $V(x)$ is chosen.

We were able to obtain explicit solutions to our problem in the case when $V(x)$ is a constant or an affine function of x. We could try to generalize our results to a polynomial function.

Finally, either this problem or the original one (with the constant $\sigma > 0$) could be considered in two or more dimensions.

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Reduction programming in a technological programming environment

Igor Redko [1], ORCID: 0000-0002-3121-1412,
Petro Yahanov[1], ORCID: 0000-0001-7358-9846,
Maksym Zylevich[1], ORCID: 0000-0003-1646-0557
[1] Faculty of Electronics, dept. Chair of Electronic Computing Equipment in National Technical University of Ukraine «Igor Sikorsky Kiev Polytechnic Institute» Kyiv,Ukraine, zila@meta.ua

***Abstract*— This work is aimed at demonstrating, on a representative sample, the usefulness of programming concepts in the state of semantic patterns as relations in a program chain that specify particular types of programs. This is achieved via the use of program descriptors, which act as means of translating composites and basic functions of the technological programming system into their syntactic declarations at the last step of technological programming..**

***Keywords*— concept; concept; monad; composite; composition; programming environment; essential relation; programming system; reduction; descriptor.**

I. INTRODUCTION

According to the traditional individual-subjective paradigm, the understanding of programming comes from the fact that its consequence is dominant, which is most often interpreted as a text in one or another programming language. Programming itself was considered as a tool to achieve the goal. In such a paradigm, programming activity is maximally subjectivized and relies on the skills and abilities of the coder, who notates the software solution into code using programming languages. That is, the programming language acts only as a means of notation of the consequence of programming. Thus, there is no real support for the genesis of programs. Among all the known reasons for such a situation, in our opinion, the main one is an overly simplified understanding of programming that does not meet modern requirements. Therefore, productive modernization of the understanding of programming is a necessary condition for real support of programming. In [1] it is justified that taking into account the active role of the subject (ARS) in such modernization is essential. The following principle plays a key role in this: programming is an activity determined by a program and aimed at creating a program.

Although this understanding of programming differs from the traditional one in its focus on complementing the programming process and its result. It is still too amorphous and therefore needs further productive enrichment. Extending the understanding of the term "program" is key here. The proposed intersubjective paradigm (the name comes from the concept of intersubjectivity, introduced and developed in [2]) is based on the interpretation of the term "program" as a likeness (an outline, as a result of assimilation) of an essential feature. In [3-5] it is substantiated that such an interpretation firstly fully corresponds to the modern pragmatics of programming and secondly it allows further productive enrichment of programming. Directly programming is understood as a complement of two objectively irreducible to each other's modal and real (actual) types of abstractions - the essence - that which can be the subject of consideration, and the entity- the object of consideration, in the sense that the essence is an entity that is (available as a subject of consideration). In this way, we get a productive enrichment of the original premise: programming is an activity conditioned by program similarity (PS). Here, PS is a productive enrichment of essential simile (ES) determined by the program and aimed at creating a program [1, 6]. The content of the PS in the first approximation consists of the mutual complementation of the essence and the entity, oriented towards the creation of the program as a semblance of the essence. The latter, given the mentioned objective irreducibility of these types of abstraction, requires the involvement of the subject in this process, taking into account (objectification) his active role in it. From the above, it follows the importance and necessity of developing an intersubjective understanding of programming, as it is the key to the real technologization of programming.

The practice of programming testifies to the dominance of the "divide and rule" paradigm when solving problems. The main technique here is the reduction of the holistic understanding which comes down to a general methodical technique - reduction of the complex to the simpler [6]. Therefore, the role of productive reduction mechanisms is essential for the technologization of programming. In [1, 6-8] it is substantiated that the basis of such enrichments is the concept-program active-passive complementarity. Thus, we come to the following explanatory enrichment of the program simile:

$$\begin{cases} \text{concept = essense that determines the entity} \\ \text{monad = entity that conditioned by the concept} \end{cases}$$

Works [8-11] show that the conceptual programming platform provides a real objectification of the main factor of productive technologization - the active role of the programming subject. The productive enrichment of software assimilation as a special type of active-passive cause-and-effect relationship and its relativization is carried out quite naturally - the main factor of productive technologization. Accordingly, the technological programming environment (TPE) should naturally be considered as a productive intersubjective enrichment of the mentioned conceptual programming platform of programming analogies to the active-passive complementarity of two objectively irreducible types of abstraction: the closed oracle logic - the integral core of the programming environment and the open diversity of its productive software analogies - technological programming systems (TPS). Any TPS is a consequence of software relativization and a carrier of productive understanding of reduction. This ensures that the active role of the programming subject is taken into account.

The necessity of technological activity, modernization of methods, and its implementation are directly determined by the level of need to objectify the subject's participation in it. In the field of programming, this is manifested in the growth of requirements for software products and the awareness that the main properties of the latter are formed at the stage of their genesis and as a result are determined by the active role of the subject in it [11].

The defining principles of understanding programming technology are formed based on the principles of conditioning, subordination, and separability [4, 5]. The properties and aspects of programs in their complementarity follow from the specified principles. This determines the point of view of what productive programming technology (PT) should look like so that its product meets these basic requirements. In particular, these principles at a general level clearly outline the place and role of productive programming in programming technology. To a first approximation, this can be expressed by the following diagram at Fig.1:

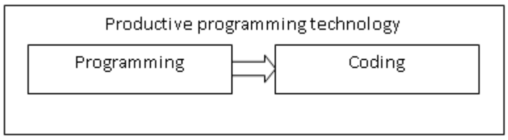

Figure 1. Block diagram of the productive programming technology.

The world practice of programming confirms the fact that despite the constantly growing number of problems and methods of their solution, all of them are subject to the "divide and conquer" paradigm, the main technique of which is reduction - reducing the complex to simpler [6]. Therefore, the role of reduction mechanisms is essential for the technologization of programming. The value of the above is determined by the fact that without an understanding of programming technology, programming technology is impossible.

In [6, 7], the solution to any programming problem is presented as a sequence of performing the stages of productive conceptualization, oracle schematization, composite-composite relativization, and reduction conceptualization. The meaningful essence of this sequence consists of the step-by-step productive enrichment of the solved problem within the framework of intersubjective TPE. The process starts from the subject's general ideas about the problem and ways of solving it and up to its final solution in the TPS- subject-oriented productive enrichment of the TPE. At the same time, the correctness of the solution follows directly from its construction. Many works are devoted to clarifying the content of TPE, the procedure for its creation, and individual steps (for example [1, 5, 6, 7] and their bibliography). Therefore (guided by the principle of reasonable sufficiency) let's allow ourselves a somewhat simplified, thesis to dwell on the construction of TPE and pay more attention to its use for solving problems.

Thus the subject of this work is the TPE mentioned above, its object is programming technology, and the goal is a technological programming system (TPS) based on TPE as a platform for productive programming and its application for problem-solving.

II. Reduction of Programming of Tasks in a Technological Programming Environment

It follows from the above that TPS as a subject-oriented closure of TPE is a real subject-oriented programming platform. The closure is a definition of composites as programming concepts, basic object operations, and composite-composite interfaces. In this way, we will build an arithmetic TPS based on the results of compositional programming and studies of the class of computational arithmetic functions and predicates [12, 13]. As a programming platform, we will use composite programming and a nominal model of data, functions, and operations, as composites - multiplication operations ^{o}, branching *IF,* cycling *WD* and the simplest compositions derived from them (in the sense of application operations *Ap* and *n*-ary superposition $S^n|_{n\in N}$), which specify the most used methods of synthesis of some programs from others [14-16], and as basic subject operations – arithmetic operations +,–, 0; logical operations $\vee, \wedge$,!, T, F; relation =,<,>. Parametric operations on nominal data will also be neede $A_{\downarrow} : A_{\downarrow}(a)\big|_{(a\in N)} = \{(A,a)\}$, $A^{\uparrow} : A^{\uparrow}(a)\big|_{(a\in N)} = \{(A,a)\}$, as naming and denaming, respectively and opening and closing parentheses.

In the following, data, functions and operations, unless otherwise specified, mean named data, named functions and named operations, respectively. As for the composite-composite interface, will use the apparatus of serial or, determined by the mentioned composites ^{o} - branched or *IF* – and cycled *WD* reductions [2, 4, 5]. Recall that a tuple of functions $\langle f_1, f_2, \ldots, f_s\rangle$ is ^{o} reduction of function f , if it is a solution of the equation $f = x_1{\circ}x_2{\circ}\ldots{\circ}x_s$ namely $f \equiv f_1{\circ} f_2{\circ}\ldots{\circ} f_s$. A couple of functions f_1, f_2 be *IF* reduction of function f if such a predicate as p exists , that this pair is a solution of the equation $f = IF(p, x_1, x_2)$, namely $f \equiv IF(p, f_1, f_2)$. Also, the function g is *WD* reduction of function f , if there exists a predicate p such that g is a solution of the equation $f = WD(x, p)$, namely $f \equiv WD(g, p)$ [6, 9]. A useful necessary condition for *WD*-reducibility directly follows from the latter.

Theorem. For the function g to be a WD-reduction of the function f, the following equality must hold $g{\circ} f = f$.

After producing the TPS, will demonstrate the method of programming it using the example of programming the integer division function $div : N\times N \leftrightarrow N$, where $div(a,b)$, is a natural number that $b\times div(a,b) \le a \le b\times(div(a,b)+1)$. To solve this problem, will use the property of this function:

$$div(a,b)|_{a,b\in N\&b>0} = \begin{cases} div(a-b,b)+1, a\ge b, \\ div(a,b)=0, a<b \, or \, a=0 \end{cases}$$

Taking into account the orientation of the described TPS on the nominal data structure and based on the specified property, we can enrich the *div* function with its nominal specification $DIV : \{(A,a),(B,b)\} \to \{(A,\bar{a}),(B,b),(C,c)\}|_{a,\bar{a},b,c\in N}$.

From here it is easy to understand that $DIV \equiv F_1{\circ}F_2$ where $F_1 = 0(C^{\uparrow}){\circ}C_{\downarrow} \equiv \{(C,0)\}$, $F_2 : \{(A,a),(B,b),(C,c)\} \to \to \{(A,a-k\times b),(B,b),(C,c+div(a,b))\}$ where $a,b\in N \,\&\, b\ne 0,$ $k : (k+1)\times b < a < k\times b.$ This specification is an oracle scheme [6] due to the composite of multiplication.

The F_1 obviously, does not require further detailing and is a so-called "cell reset" $C - \{(C,c)\} \to \{(C,0)\}$. From F_2 it follows directly from the definition that its WD-reduction will be a function $G : \{(A,a),(B,b),(C,c)\} \to \{(A,a-b),(B,b),(C,c+1)\}$, where $P : \{(A,a),(B,b)\} \to \begin{cases} T, if \; a\ge b \\ F, if \; a<b \end{cases}$ - nominal specification of the corresponding predicate. That mean $F_2 = WD(G,P)$. This specification is also an oracle scheme. But due to the WD composite. Without going into insignificant details, F_2 can be represented somewhat simplified as follows:

$$F_2 = WD(\left(A_{\downarrow}\left(A^{\uparrow} - B^{\uparrow}\right)\right){\circ}\left(C_{\downarrow}\left(C^{\uparrow}+1\right)\right), P\left(A^{\uparrow}, B^{\uparrow}\right)$$

respectively

$$DIV \equiv \left(0\left(C^{\uparrow}\right){\circ}C_{\downarrow}\right){\circ}$$

$${\circ}(WD\left(\left(A_{\downarrow}\left(A^{\uparrow} - B^{\uparrow}\right)\right){\circ}\left(C_{\downarrow}\left(C^{\uparrow}+1\right)\right), P\left(A^{\uparrow}, B^{\uparrow}\right)\right).$$

The simplification is that the given expression is not a compositional term in its "pure form". Several meta-expressions are deliberately used along with the means inherent in the constructed TPS $0(C^{\uparrow}), A_{\downarrow}\left(A^{\uparrow} - B^{\uparrow}\right), C_{\downarrow}\left(C^{\uparrow}+1\right), P\left(A^{\uparrow}, B^{\uparrow}\right)$.

The goal pursued by this is twofold. First, these expressions are mnemonically more familiar and at the same time, their representation in terms of TPS is not difficult to obtain. Secondly, their use makes it possible to demonstrate an essential feature of the proposed programming technology – its ability to take into account ARS. Strictly speaking, the activity of the programming subject is not limited to an exhaustive list of tools of any traditional programming system. On the contrary, the subject of programming actively influences the core of TPS, both in terms of the evolution of its concept and at the stage of encoding the solution. And the meta-expressions are examples of such influence. Below, what has been said will be reflected in the description of the corresponding definer.

As a result of the first stage of technological development, namely reduction programming, the above-described specification was obtained in the given system. Its correctness follows from the construction of the program. After receiving the specification, coding can be done.

III. Coding as a Semantic-Syntactic Transition

Most programming languages are the only means of syntactic notation of programming results. The productive technology of programming is meaningfully an implementation of the complementarity of the above-mentioned basic principles of programming - genetics (conditionality), subordination and separability, and targeted creation of a software product [17-19]. It is a micro-conveyor of stages, where the "programming" stage realizes the subordination of semantics to pragmatics and its result is a program - a subject-driven outline of a problem solution in the form of a corresponding semantic (composite-compositional) term. [20, 21]. The stage of "encoding" refers directly to the semantic-syntactic transition from the semantic specification of the solution (program) to its code in the form of a corresponding syntactically correctly written text in a specified programming language. It has already been noted that the semantic-syntactic transition can be automated due to the derivation of the syntactic aspect of programs from the semantic aspect (principle of subordination). The core of this process is the corresponding definer of the programming language [22-26]. Let's apply this to the *DIV* function programming example discussed above.

As an example, consider the part of the definer of the system given above. The definer data is sufficient to demonstrate the creation of the program. It presents the corresponding composites and functions with their syntax notations in a Pascal-like manner (tables 1 and 2).

TABLE I. PROGRAMMING AND CODING PATTERNS

The concept (patterns) of programming	***The concept (patterns) of coding***
...	...
F	F
(F)	F
$F_1 \circ F_2$	$begin\, F_1; F_2\, end$
$IF(F_1, F_2, F_3)$	$if\ F_1\, then\, F_2\, else\, F_3\ \ F_1\, F_2$
$F \circ X_{\downarrow}$	$X^{\uparrow} := F$
$X^{\uparrow} \circ S \quad X^{\uparrow} \circ S \circ Y_{\downarrow}$	$X^{\uparrow} + 1 \quad Y := X + 1$
$WD(F_1, F_2)$	$while\, F_2\, do\, F_1\, end$
$P(A^{\uparrow}, B^{\uparrow})$	$(A > B) or (A = B)$
$F_1[F_2]$	$F_1\ ; F_2$
$\text{meta} \left[\begin{array}{l} 0(C^{\uparrow}) \\ A_{\downarrow}(A^{\uparrow} - B^{\uparrow}) \\ C_{\downarrow}(C^{\uparrow} + 1) \end{array} \right.$	$\left[\begin{array}{l} 0(C) \\ A := A - B \\ C := C + 1 \end{array} \right.$
`...	...

TABLE II. BASIC FUNCTIONS AND THEIR CODES

Basic functions	***Basic function codes***
...	...
0	0
+	+
–	–
$\wedge$	*and*
$\vee$	*or*
!	*not*
<	<
=	=
>	>
$X^{\uparrow}$	X
$X_{\downarrow}$	X
`...	...

In the presented tables, the notation *F*, possibly with indices, F_i, i=1,2,3,... and only these are used as non-terminal symbols or non-terminals. Similarly, terminal characters $X^{\uparrow}, X_{\downarrow}, X$ can also be used with subscripts: $X_i^{\uparrow}, X_{i\downarrow}, X_i, i = 1, 2, 3...$

Through them, the recursiveness of constructions is ensured [22-26]. Concepts of programming and coding presented in Table 1 represent correctly written words in the combined alphabet of terminal symbols and non-terminal symbols. Table 2 lists terminal symbols for basic operations and their corresponding Pascal-like codes.

Let's turn to the above program. The previously used additional markup of the program demonstrates its inherent hierarchical structure. It is due to the step-by-step implementation of oracle updates in the programming system, starting from the *DIV* oracle and ending with the oracle-free one, that is, the compositional term locked in the programming system. Moving along this hierarchy, following the definer fragment specified in Tables 1 and 2, we recursively build a Pascal-like program code (Table 3).

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TABLE III. EXAMPLES OF PROGRAMS

Program	***Templates used***	***Updates of non-terminals***
$DIV \equiv \left(0\left(C^{\uparrow}\right)\circ C_{\downarrow}\right)\circ$ $\circ(WD\left(\left(A_{\downarrow}\left(A^{\uparrow}-B^{\uparrow}\right)\right)\circ\left(C_{\downarrow}\left(C^{\uparrow}+1\right)\right), P\left(A^{\uparrow},B^{\uparrow}\right)\right)$	$F_1\circ F_2$	$F_1 \Leftarrow 0\left(C^{\uparrow}\right)\circ C_{\downarrow}$ $F_2 \Leftarrow WD(\left(A_{\downarrow}\left(A^{\uparrow}-B^{\uparrow}\right)\right)\circ\left(C_{\downarrow}\left(C^{\uparrow}+1\right)\right), P\left(A^{\uparrow},B^{\uparrow}\right))$ $DIV \Leftarrow begin\, F_1; F_2\, end$
$F_1 \equiv 0\left(C^{\uparrow}\right)\circ C_{\downarrow}$	$F_{11}\circ F_{12}$ $X_{\downarrow}$ $X^{\uparrow}$	$F_{11} \Leftarrow 0(C)$ $F_{12} \Leftarrow C_{\downarrow}$ $F_1 \Leftarrow begin\, F_{11}; F_{12} end$
$F_2 = WD(\left(A_{\downarrow}\left(A^{\uparrow}-B^{\uparrow}\right)\right)\circ\left(C_{\downarrow}\left(C^{\uparrow}+1\right)\right), P\left(A^{\uparrow},B^{\uparrow}\right))$	$WD(F_1,F_2)$	$F_{21} \Leftarrow \left(A_{\downarrow}\left(A^{\uparrow}-B^{\uparrow}\right)\right)\circ\left(C_{\downarrow}\left(C^{\uparrow}+1\right)\right)$ $F_{22} \Leftarrow P\left(A^{\uparrow},B^{\uparrow}\right)$ $F_2 \Leftarrow while\, F_{22}\, do\, F_{21} end$
$F_{21} \Leftarrow \left(A_{\downarrow}\left(A^{\uparrow}-B^{\uparrow}\right)\right)\circ\left(C_{\downarrow}\left(C^{\uparrow}+1\right)\right)$	$F_{11}\circ F_{12}$ (F) $X_{\downarrow}$ $X^{\uparrow}$	$F_{31} \Leftarrow A_{\downarrow}\left(A^{\uparrow}-B^{\uparrow}\right)$ $F_{32} \Leftarrow C_{\downarrow}\left(C^{\uparrow}+1\right)$ $F_{21} \Leftarrow begin\, F_{31}; F_{32} end$
$F_{22} \Leftarrow P\left(A^{\uparrow},B^{\uparrow}\right)$	meta $P(F_1,F_2)$	$F_{22} \Leftarrow (A > B\, or\, A = B)$
$F_{31} \Leftarrow A_{\downarrow}\left(A^{\uparrow}-B^{\uparrow}\right)$	meta $A_{\downarrow}(A^{\uparrow}-B^{\uparrow})$ $F\circ X_{\downarrow}$ (F)	$begin$ $F_{31} \Leftarrow A := A - B$ end
$F_{32} \Leftarrow C_{\downarrow}\left(C^{\uparrow}+1\right)$	meta $C_{\downarrow}(C^{\uparrow}+1))$ $F\circ X_{\downarrow}$ (F)	$begin$ $F_{32} \Leftarrow C := C + 1$ end
$DIV \equiv F_1\circ(WD(F_{21}\circ F_{22})$	(F) $F_{11}\circ F_{12}$ $F\circ X_{\downarrow}$ $WD(F_1,F_2)$ meta $\left[\begin{array}{l} 0(C^{\uparrow}) \\ A_{\downarrow}(A^{\uparrow}-B^{\uparrow}) \\ C_{\downarrow}(C^{\uparrow}+1) \end{array}\right.$	$begin$ $while(A > B\, or\, A = B)do$ $begin$ $F_{31} \Leftarrow A := A - B$ $F_{32} \Leftarrow C := C + 1$ end $DIV \Leftarrow F_{32}$ end

IV. CONCLUSIONS

The fundamental role of productive reduction in the technologization of programming is shown.

It is substantiated that the new paradigm of programming should be based on the activation of the role of the programming subject, in which programming is considered as an activity determined by the program.

It is confirmed that programming technology uses reduction methods as a means of transforming an information resource into a software product in intersubjective TPE.

The reduction determined by the concept plays a fundamental role in the technologization of programming. The concept of the software product determines its semantics, and the syntactic notation of the programming results determined by the program is completed by one of the programming languages chosen by the programming subject.

With the help of reductive programming, a program specification was obtained in the given system, the correctness of which follows from its construction. Based on the received specification, the program code is obtained with the help of definers.

A representative example demonstrates the use of programming concepts in the form of semantic templates as links in a program chain that determine certain classes of programs. A program definer is used, which acts as a means of translating composites and basic functions of TPS into their syntactic representation.

The use of meta-expressions in program construction substantiates the objectivism of the active role of the subject and determines the place and significance of this activity in obtaining the result. Metaexpressions do not belong to the toolkit determined by the intersubjective programming environment but are the product of the TPS programmer's conceptualization of the means of achieving the final goal within the limits of personal competence..

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Human Motion Recognition Using Artificial Intelligence Techniques

Andrei Enachi [1], ORCID: 0000-0002-1000-457X
Cornel Turcu [2], ORCID: 0000-0002-3134-8769
George Culea [1], ORCID: 0000-0001-8286-1602
Ioan-Viorel Banu [1], ORCID: 0000-0002-7722-8017
Dragos-Alexandru Andrioaia [1], ORCID: 0000-0002-0244-7688
Puiu-Gabriel Petru [1], ORCID: 0000-0003-2864-3422
Sorin-Eugen Popa [1], ORCID: 0000-0002-1939-587X
[1] "Vasile Alecsandri" University of Bacău, Calea Mărășești 157, Bacău, 600115, Romania
[2] "Stefan cel Mare" University of Suceava, 13, University Street, Suceava, 720225, Romania
andrei.enachi@ub.ro

***Abstract*— The goal of this paper's research is to develop learning methods that promote the automatic analysis and interpretation of human and mime-gestural movement from various perspectives and using various data sources images, video, depth, mocap data, audio, and inertial sensors, for example. Deep neural models are used as well as supervised classification and semi-supervised feature learning modeling temporal dependencies, and their effectiveness in a set of tasks that are fundamental, such as detection, classification, and parameter estimation, is demonstrated as well as user verification.**

A method for identifying and classifying human actions and gestures based on utilizing multi-dimensional and multi-modal deep learning from visual signals (for example, live stream, depth, and motion - based data). A training strategy that uses, first, individual modalities must be carefully initialized, followed by gradual fusion (called ModDrop) to learn correlations between modalities while preserving the uniqueness of each modality specific representation. In addition, the suggested ModDrop training approach assures that the classifier detect has weak inputs for one or maybe more channels, enabling these to make valid predictions from any amount of data points accessible modalities. In this paper, inertial sensors (such as accelerometers and gyroscopes) embedded in mobile devices collect data are also used.

Keywords*— *learning methods; ModDrop; neural models; sensors; mime-gesture

I. Introduction

Computer vision is a field of research that deals with the analysis of human motion from visual input. Over the years, this has been a daunting task, but much progress has been made. The problem of obesity is a focus for many people, as it is a serious health issue. Hundreds of applications that could benefit from this technology currently exist, including applications that control navigation and manipulation in real and virtual environments, interaction between humans and robots, telepresence systems, and more, portals that assist the hearing and speech impaired, learning tools and games, engineering systems as well as computer-aided design, as well as automatic video annotation and indexing are all geared towards aiding those with hearing and speech disabilities. Forensic identification and lie detection are other applications that may be helpful to those with impaired senses [1] – [5].

Different research communities have approached application-driven research in human motion analysis from various perspectives. Today, facial expression interpretation and crowd movement analysis have become more standardized tasks. There are many taxonomies However, most existing work in this domain focuses on group or individual activities, primitive actions or gestures. Each problem can be thought of as a variant recognition or reconstruction, one of two classic computer vision challenges [2], [3].

The gesture and myth, the hand movement accompanied by the speech, can not only provide meaningful meaning, but also provide information about the personality and cultural differences of the speaker, immediate emotional state, intentions and attitudes toward the audience, and the topics ahead of the eye. Some psychological studies suggest that motor movements are not only used to illustrate spoken words, amplify their emotional impact, or compensate for a lack of linguistic fluency, but in turn will influence the process of speech production. In addition to verbal information, the ability to perceive and comprehend nonverbal clues would be advantageous to make human-machine communication easier and more intuitive regarding the interpersonal differences between the subjects or gestures, here the object of distinction is changed so that the individual is recognized regardless of the tasks or gestures used or performed [3], [4].

II. Visual Recognition

In this section we will look at traditional training techniques and strategies for recognizing human movements and mime-gestures from visual data, using static descriptors of a frame, and last but not least dynamic ones, together with their anatomical links.

Although most of the discussed manuscripts are unrelated in relation to the research presented in this article (in terms of the methodology used, deep learning) but still provide the background and insights necessary to understand the challenges of the presented field here. For more general methods that can help inspire our work, the scope of the analysis of human movement and gesture is very broad, covering several tasks performed simultaneously both temporally and spatially (through recognition of mimic and gesture, action and activity performed). Similar problems can be used to solve other problems, with a significant role, being abstracted according to level.

The problems to be studied in here will focus on the action and/or activity of a person, in a supervised manner intervening only where appropriate. Identity, gesture and mimic recognition (as well as sign interpretation), is done by introducing a visual input as a category within the sign language or existing signs. Learning can be done through videos, but also dimensionally from a third-person perspective.

The research area(s), covering hand motion modelling and analysis, can then be fur quantified into a set of typical problems, listed below (see Fig. 1): identification of the person from gestures, the reverse of the previous stage, and no need to classify the person performing a gesture into a category. Another aspect of this research, associated from the same group, is the recognition of the whole body and not just the position and/or hand, gait; approximation of the hand position, from a mapped dimensional point for high visualization of the possible hand positions a person performs, taking into account the person's anatomical constraints.

Figure 1. Detection of human movements: mimic-gesture identification, mocap, position from which the person was captured understanding and plausibly simulating human behaviour

Hand position estimation can also be extrapolated within the body; in order to train the algorithm from the hands, will be by optimizing the optics and creating specific conditions to achieve high accuracy (thus achieving accuracy on the stored data). For capturing the movements performed by the body, it is not difficult to capture; the interpretation of the hand-object position, being involved its recognition as well as the remodelling for the gestures and mimicry performed, but also the issues concerning the interaction with the object(s).

Traditional methods in following steps are typically used for action recognition and location estimation: the pre-processing operations are those that are carried out before the data is analyzed. This includes things like cleaning up the data, removing errors, and formatting it correctly, locating and assembling or acquiring knowledge visualizations (for example, measuring, background subtraction, segmentation, and noise). As a cascade of following data reformulations and compressions, this procedure can be performed in a sequence of phases. Classification, involving one or more machine learning algorithms; or optimization based on a predefined metric. Deep learning techniques, as was described at the beginning of this chapter [6].

III. Preprocessing and Manual Detection

The preliminary steps consist of a collection of well-known depending on the type of input data, techniques and routines are used in various combinations. The goal of this step is to locate and segment the object of interest. (in our case, hands) in the background, eventually, noise and other artifacts will be compensated. Some methods and datasets make assumptions that this step is done ahead of time; however, in practice, the quality of preprocessing data is an issue that can have a significant impact on the performance of an algorithm. Various approaches to hand localization that rely on color images frequently include skin color detection. It works well in simple contexts because skin tones work well in appropriately chosen color spaces (see Fig. 2).

Pixel figures are created by combining the corresponding colors. Several studies have been conducted on color spaces and skin detection methods. HSI, in particular, has been shown to be one of the best color spaces for this task. Hand detection, on the other hand, which is solely based on skin color, remains extremely sensitive to illumination, ethnic divergence, and individual and background differences.

Figure 2. Example of pixel-based hand detection (left) and a case of failed hand position estimation in a poorly segmented hand case (right). [6]

A more robust face detector is frequently used as a practical ad hoc solution first to compensate for illumination differences and estimate the expected skin tint, as well as to define an approximate expected hand position. By training an SVM on extracted HoG descriptors, for instance, it is possible to learn a hand detector from a large amount of data. Van den Bergh and van Gool proposed utilizing a post Gaussian Mixture Model (GMM) to identify distinct skin hues in varied light levels. The GMM is combined with skin color estimation from a given face of each user in this approach, and the resulting probability that each pixel belongs to a skin region is then reported to a threshold value to produce a model.

They also improve their method by calculating and applying a face-to-hand distance priority in three dimensions utilizing depth data from a time-of-flight camera with the advancement of range sensors, the number of dimensions available is the number of spatial dimensions and color channels available for extracting spatial features has been increased to 6 (or, technically accurate, 5.5). But, most present systems don't really consider these equally. For example, color pictures are generally utilized solely for hand detection. Color images, for example, are frequently used exclusively for hand detection, whereas depth maps are used to compute discriminative features for the following gesture classification. Simultaneously, a number of papers use the opposite strategy, in which hand positions are computed using color or intensity descriptors are used in point cloud segmentation and spatial features.

IV. Conclusions

The primary goal of this work is to develop the most advanced automatic methods for analyzing and interpreting human and mime-gesture movements, as well as sign language interpretation, from various perspectives and using various data sources such as images, videos, depth maps, mocap analysis data, audio, and inertial sensors. In the end, is proposed a set of deep neural network models with specific algorithms for classification by surveillance and semi-surveillance for learning, for modeling time and spatial dependencies, and for achieving efficiency and effectiveness on a set of fundamental tasks such as detection, classification, and user identity verification parameters.

Here is presented a method for recognizing human and mimic-gesture activities, classification-based fusion of multiple neural network models, and visual data learning. The training strategy that will be the foundation of this work, as it will be the fusion of deep neural models with separate data channels (ModDrop) to achieve intersecting model learning while preserving the uniqueness and specific mode of data representation.

Moving away from 1-to-n mapping and toward continuous evaluation of user gesture and mimicry parameters, the hand position problem, and a new method for the regression step within the image depth map using deep convolutional neural networks, where imprecise, incomplete data are merged into an intermediate representation of the hand in segmented form are all addressed. In papers related to this topic, we investigate deep convolutional neural network models for identifying users based on their movements. The data that will be stored based on embedded inertial sensors in cameras and/or mobile devices.

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A Set of Smart Ring Gestures for Drone Control

Alexandru-Ionuț Șiean [1], ORCID: 0000-0002-3166-7495
[1] MintViz Lab, MANSiD Research Center, Ștefan cel Mare University of Suceava, 13 Universitatii, Suceava 720229, Romania
alexandru.siean@usm.ro

Abstract—**We present in this paper the results of a frequency analysis of gesture commands frequently employed for human-drone interaction in the scientific literature, and we propose a set of gestures for controlling drones that can be performed with smart rings. Our method consists in the analysis of thirty-seven articles, which we examined closely to extract commands for human-drone interaction, including voice, gesture, and multi-modal input. Based on our meta-analysis, we present a set of six groups of commands for human-drone interaction together with a set of smart ring gestures to interact with and control drones. Our results can be used to inform the design of new interactive applications for controlling smart-ring drones.**

Keywords—user; human; drone; uav; interaction; control

I. Introduction

Application with drones can improve the quality of life of the people that interact with these devices. The great advantage drones present is their ability to fly and implicitly move quickly from one location to another without human supervision. Therefore, we find applications in all domains with drones, such as intelligent transportation [1], live construction inspection [2], security [3], etc. Enriching the users' experiences regarding personal drones has a great effect on multiple domains, in which we find haptic feedback in Virtual Reality [4], Mixed Reality [5], taking selfies [6], etc. Therefore, motivated by the desire to integrate drones into public space and interact with them using devices other than conventional ones with which drones come in basic equipment e.g., a controller, we propose a set of gestures using smart ringsfor the most common commands in the literature that aim to control the drone in order to extend to new applications that include these wearable devices.

We believe that our inventory will be useful to researchers and practitioners interested in the gestural commands that are most commonly used to interact with the drone and our proposed set of smart ring gestures designed to execute these commands. Even with small drones such as Parrot Mambo FPV, illustrated in Figure 1, and with Smart Rings ZERO, applications can be created to enrich the dictionary of gestures proposed by us in order to make the perfect photo [7] or new applications of human-drone interaction.

Fig. 1. Parrot Mambo Fly personal drone and Smart Ring ZERO

II. Related work

A wide variety of applications include human-drone interaction. These include: entertainment applications [8], [9], hands-free [10], emergency situation [11], search and rescue missions [12]. These applications recognize gesture commands [8], [9], [11], [12], voice commands [10], [13], [14], and even multimodal interactions [10], [15], [16], [17], [18]. User feedback is provided in different ways, such as visual [19], [20], haptic [4], [21], or with the help of a controller [22]. All these applications are intended to shape new ways of interacting with drones, such as using voice commands [13], multimodal interactions [15], or receiving feedback from the drone through different modes e.g., visual [20]. Therefore, this multitude of applications offer, in turn, a multitude of gestural commands that we have extracted and grouped to propose new ways to interact with drones usingsmart rings.

A. Interaction modalities with Drone and Users in Studies

As the popularity of drones has grown, drones have become more and more present in our lives, being integrated into many applications. For example, photo/video [11], [19], user security [15], [23], etc. Therefore, drones have led to new applications and implicitly to new ways of interaction. From the analysis of the 37 papers, we extracted all the interaction ways presented in each scientific paper. In the third chapter, we explain the methodology for identifying and selecting articles. Our results show that 81% of the interactions were gestural, 38% were multimodal, 27% used voice, 14% used a BCI/EEG headset, and 8% used mobile devices. For example, MohaimenianPour *et al.* [9] use a BCI/EEG neural headset for real-time detection of facial gestures to improve human- robot interaction. Brock *et al.* [17] propose an interactive map for drone users to open the space for more direct interactionswith drones. The analysis of the thirty-seven papers continued users' perspectives in the studies; 46% of the papers did not report any participants in the study, even if they discussed a certain way of interaction. A total of 473 participants were reported. The maximum number of participants was 110 in the work of Peshkova *et al.* [14], in which he made a participatorydesign of the most intuitive ways to control a drone. A single participant was reported in the work of Higuchi *et al.* [24], who developed a system that directly connects body movementwith drone movements.

B. Type of Scientific Contributions for Drone Applications

The thirty-seven scientific papers were divided into the following categories: (1) empirical research, (2) artifact, (3) methodological, (4) theoretical, (5) data-set, (6) survey, and (7) opinion, according to Wobbrock *et al.* [25] classification. The greatest scientific contribution was of the type of empirical research found in 95% of the articles. Following the artifact, which was present in 16% of the articles, we found the design of a controller [26] and eye gaze tracking systems [19]. We classified 11% of the works as theoretical publications. The rest of the contributions were less representative. For example,we found the work of Lee *et al.* [27], which presents a new human gesture prediction framework using computer vision forthe human-drone interaction where the set presents the date. This category represents 8% of the total number of works that complete the list of works [9], [28]. A single paper [29] has been classified as a survey proposing a graphical interface designed and centered on the human body for drone interac- tions. No paper has published a methodology or an opinion on human-drone interaction in our analysis.

III. A SET OF SMART RING GESTURES FOR DRONE CCONTROL

A. Methodology

We surveyed the specialty literature to identify all com- mands whose purpose is human-drone interaction. We searched for the most popular international databases of sci- entific articles, ACM DL[1], IEEE Xplore[2], and SpringerLink[3],

TABLE 1. DICTIONARY GESURES DRONE ASSOSASION WITH SMART RING

Commands		Count[1]	One Ring Gestures		Two Rings Gestures		Description commands
			First association	*Second association*	*First association*	*Second association*	
C1	forward	13	Circle clockwise	Flick to the right	Circle clockwise	Touch both rings simultaneously	The hands move away from the body
	backward	9	Circle counter-clockwise	Circle counter-clockwise	Circle counter-clockwise	Flick to the right using both hands	The hands approach the body
C2	right	13	Flick to the right	Clap once	Flick to the left	Use the hands as a hands fan	Hand moves to the right
	left	11	Flick to the left	Swipe on the ring upwards	Flick to the right	Raise hand and touch the ring	Hand moves to the left
C3	up	9	Raise hand and touch the ring	Touch the ring once	Touch both rings simultaneously	Flick upwards	Extends right hand
	down	9	Touch the ring once and flick to the left	Circle clockwise	Spread palms horizontally	Flick downwards	Extends left hands
C4	fly higher	6	Clap once	Raise hand and touch the ring	Clap once	Flick downwards using both hands	The right hand rises next to the body
	fly lower	6	Touch the ring once	Press imaginary button in mid-air	Rub hands	Circle clockwise	The right hand sits next on the body
C5	turn right	4	Draw letter “S” in mid-air[3]	Touch the ring once and flick to the left	Flick upwards	Clap once	Rotate right hand on the right
	turn left	4	“Call me” sign[2]	Press button on an imaginary remote control	Flick downwards	Rub hands	Rotate left hand on the left
C6	take off	13	Press button on an imaginary remote control	“Call me” sign[2]	Bring both hands in front and towards the body	Press several imaginary buttons in mid-air	Index finger moves upwards
	land	9	Press imaginary button in mid-air	Draw letter “S” in mid-air[3]	Press several imaginary buttons in mid-air	Bring both hands in front and towards the body	The two hands from a rectangle

[1]Total number of gesture commands form specialty literature.
“[2]*Thumb placed near the ear, little finger pointed at the mouth;* [3]*Letter “S” stands for “Security.*”, Gheran *et al*. [45].

[1]https://dl.acm.org/
[2]https://ieeexplore.ieee.org/Xplore/home.jsp
[3]https://link.springer.com/

using:

```
"query": {
   Abstract: ((user OR human) AND
   (drone OR UAV) AND (Interaction
   OR Control))
}
"filter": {NOT VirtualContent: true}
```

Following the query of the three databases, we analyzed from the title and abstract the articles that would be of interest to us. We saved 105 papers published between 2002 and 2021 that target the human-drone interaction from this analysis. The 37 papers that we analyze in detail present commands for interaction with drones. Therefore, the discussion was limited to articles showing the gestural human-drone interaction. The total number of commands extracted from the thirty-seven articles was 341. Investigating the articles, extracting orders, and proposing gestures with smart rings is the major contribution of this paper.

B. Results

We grouped the commands most frequently encountered in the specialty literature whose purpose is the interaction between human and drone in six categories; see Table 1.

- C_1: - *'forward/backward'*, the drone moves forward or back [6], [8], [11], [14], [29], [30], [31], [32], [33], [34], [35], [5], [24], [14].
- C_2: - *'right/left'*, drone moves left or right [8], [23], [11], [14], [29], [30], [31], [32], [33], [34], [35], [5], [24], [14], [14].
- C_3: - *'up/down'*, raises or lowers the altitude of the drone [32], [33], [34], [12], [24], [14], [28], [22], [36], [37].
- C_4: - *'fly higher/fly lower'*, the drone raises/decreases altitude but moves forward/back [13], [15], [16], [38], [39], [14].
- C_5: - *'turn right/turn left'*, drone spins around its axis to right or left [8], [40], [22], [37].
- C_6: - *'take off/land'* includes the launch of the drone for flight [8], [13], [15], [16], [27], [30], [31], [32], [41], [14], [42], [37].

Table 1 shows the commands most frequently met identified in our survey (thirty-seven articles out of one hundred and five) grouped into six categories, followed by two gesture proposals using a single smart ring, and two gesture proposals that are made with two smart rings, and the last column describes the gesture. The results of our study show that the distribution of commands in terms of frequency is uneven. For example, in categories *C1*, *C2*, and *C6* we find the most frequent commands in the literature: forward, right, and take off. We notice that the categories *C1*, *C3*, *C5*, and C6 present the most uniform distribution of commands so far, followed by *C4* with the least used gesture commands. Note that the other commands were also present in the literature e.g., 'fly-where-you-look' [19], 'precise location' [15], 'speed and hover' [20], [43], 'continue and take a picture' [12], [9], but we have focused on the most common. Therefore, for each category, we proposed four gestures using smart rings. Two gestures with a single ring are proposed and the other two with two smart rings. Associating smart-ring gestures with drone commands opens up new ways to interact with smart rings. The four proposals for smart ring gestures for the most common gesture commands in the literature are taken from the work of Gheran *et al.* [44], [45]. In which he presents a detailed study of smart ring gestures. The association of gestures with drone commands is our proposal to researchers to form new applications and interactions that include gestures with smart rings and drones.

IV. Conclusion and Future Work

In this paper we have presented the six categories of gestures that control drones, and for each we have proposed a set of commands using smart rings. Our study covered thirty-seven papers out of one hundred returned by queries to international databases according to the methodology in chapter three. Our work implements an important step in the human-drone interaction using smart rings, but also the effective proposal of the gestures that will be used for the most frequent control commands of the drone. Our study continued with the analysis of the type of article in which the researchers described their work, the type of gestures that were encountered in human-drone interaction, and also the number of study participants. These metrics are useful for extending new smart ring gesture sets. Our next plan is to implement an application to control the Parrot Mambo FPV drone with SDK available for Android[4], and its control with Smart Rings ZERO, present in Figure 1, also using SDK for Android. After the implementation of this application, we want to conduct studies with users in which to propose new gestures with smart rings for the most frequent drone control commands. Continuing these ideas will lead to new gesture input models using smart rings for human-drone interaction.

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The first boundary value problem for the nonlinear equation of heat conduction with deviation of the argument

Yaroslav Drin' [1], ORCID: 0000-0003-0945-7325
Iryna Drin' [2], ORCID: 0000-0002-0258-7007
Svitlana Drin' [3], ORCID: 0000-0002-5576-3756
Yuriy Stetsko [1], ORCID: 0000-0002-4664-8844
[1] Yurii Fedkovych Chernivtsi National University, y.drin@chnu.edu.ua, y.stetsko@chnu.edu.ua
[2] Chernivtsi Trade and Economic Institute of the State Trade University, iryna.drin@gmail.com
[3] National University of Kyiv-Mohyla Academy, svitlana.drin@gmail.com

Abstract **- The initial-boundary problem for the heat conduction equation with the inversion of the argument are considered. The Green's function of considered problem are determined. The theorem about the Poisson integral limitation is proved. The theorem declared that the Poisson integral determine the solution of the first boundary problem considered and proved.**

Keywords — heat nonlinear equation, boundary value problem, Green function; deviation argument

INTRODUCTION

In this paper the solution of the first boundary value problem for the heat conduction equation with the inversion of the argument is found. The process of heat conduction was first described by Jean Baptiste Joseph Fourier (1768 - 1830) in 1807 in the work "Equations with partial derivatives for heat conduction in solids". A description of the results of other scientists who studied and developed this theory is presented in [1]. Thermal conductivity is the molecular distribution of thermal energy in various solids, liquids and gases due to the difference in temperature and due to the fact that the particles are in direct contact with each other. Based on different criteria, models of heat conduction processes are divided into two groups of models using integral and fractional order derivatives. Models with derivatives of an integer order are stationary and non-stationary.

Non-stationary models of one-dimensional heat conduction are described by the equation of heat conduction [4]. Different methods of solving this problem are described in [2, 3, 4]. Applied aspects of such problems are described in [5, 6, 7].

If the evolution of the concentration of impurities, point defects, and the temperature field is studied, then the corresponding transfer coefficients are not constant values. Processes with spatially dependent transfer coefficients or the desired field are well studied (see, for example, [2]) and sufficiently describe processes in heterogeneous and nonlinear media [8]. Also described here are applied problems for modeling and research of which the transfer coefficients depend on the time change. At the same time, physically adequate modeling of situations most often requires research in a semi-limited area [7].

Our work examines the first boundary value problem for the non-homogeneous nonlinear heat conduction equation with argument deviation, which generalizes the corresponding problem from [7].

FORMULATION OF THE FIRST BOUNDARY VALUE PROBLEM

Let $a>0, b>0$ be real numbers; $x\in R^+, t\in R^+$, are independent variables; f, φ,μ are known continuous functions; $u(x, t)$ is the desired function that describes the evolution of the system defined on the semi-axis $x\in R^+$ for all $t\in R^+$,. We will study the problem

$$u_t = a^2 u_{xx} + f(x,t,u(x,t-h)), x>0, t>h, \quad (1)$$

$$u(x,t)|_{0\le t\le h} = \varphi(x,t), x\ge 0, \quad (2)$$

$$u(0,t)=\mu(t), t\ge h \quad (3)$$

which is the first boundary value problem, where the functions $\varphi(x,t)\in C(R^+\times\{0\le t\le h\})$ is initial function, $\mu(t)\in C(R_h^+)$ is boundary function, $R_h^+\equiv\{t; t\ge h\}$, $R^+\equiv\{x; x\ge 0\}$), $f(x,t,u)\in C(R^+\times R_h^+\times R)$ is the inhomogeneity of equation (1) is well known. If a smooth solution of the problem (1) – (3) is sought up to the limit, then the initial and marginal functions must be consistent $\varphi(0,h)=\mu(h)$.

THE STEPS METHOD

Let $h \le t \le 2h$, then $t-h \ge 0$, $u(x,t-h) = \varphi(x,t)$. $x > 0$. Then in (1) – (3) we get the problem:

$$u_t = a^2 u_{xx} + f(x,t,\varphi(x,t)), x>0, h<t<2h, \quad (4)$$

$$u(x,t)|_{t=h} = \varphi(x,h), x \ge 0, \quad (5)$$

$$u(0,t) = \mu(t), t \ge h \quad (6)$$

with the conditions of agreed $\varphi(0,h) = \mu(h)$.

We are looking for a solution of problem (4) – (6) in the form of sum of three functions

$$u(x,\ t) = u_1(x,t) + u_2(x,\ t) + u_3(x,\ t), \quad (7)$$

where $u_i, 1 \le i \le 3$, respectively, take into account the influence only initial condition, the boundary condition and the inhomogeneity of the, that is, they are the solutions of such problems.

Problem 1. Find a function $u_1(x,\ t)$ that satisfies the conditions

$$\frac{\partial u(x,t)}{\partial t} = a^2 \frac{\partial^2 u(x,t)}{\partial x^2}, x>0, h<t<2h, \quad (8)$$

$$u(x,h) = \varphi(x,h), x \ge 0, \quad (9)$$

$$u(0,t) = 0, h \le t \le 2h, \quad (10)$$

moreover, $\varphi(0,h) = u(0,h) = 0$ is a condition of agreed.

Problem 2. Find a function $u_2(x,\ t)$ that satisfies equation (8) and conditions

$$u(x,h) = 0, x \ge 0, \quad (11)$$

$$u(0,t) = \mu(t), h \le t \le 2h, \quad (12)$$

moreover, $\mu(h) = 0$ is a condition of agreed.

Problem 3. Find the function $u_3(x,\ t)$ that satisfies equation (1) and conditions (10), (11), which are agreed.

2.1. Solving problem 1

Let's expand the domain of definition of equation (8) and the initial condition to $x \in R, h \le t \le 2h$ and solve it with help of separation of variables method ($\tilde{u}_1(x,t) = X(x)T(t)$ and after rearrangement in (8) and separation of variables, we obtain that $T(t) = C(\lambda)e^{-\lambda^2 a^2 (t-h)}, X(x) = e^{i\lambda x}$, where λ is the variable separation parameter. Then the solution is $u_1(x,t,\lambda) = C(\lambda)e^{-\lambda^2 a^2 (t-h) + i\lambda x}, \lambda \in R$ and to take into account all $\lambda \in R$ \$ we create a function

$$\tilde{u}_1(x,t) = \int_{-\infty}^{\infty} C(\lambda) e^{-\lambda^2 a^2 (t-h) + I\lambda x} d\lambda, x \in R, h \le t \le 2h,$$

which satisfies condition (9). Then we get that

$$\varphi(x,h) = \int_{-\infty}^{\infty} C(\lambda) e^{i\lambda x} d\lambda \quad ,$$

and

$$C(\lambda) = \frac{1}{2\pi} \int_{-\infty}^{\infty} \varphi(\xi,h) e^{-i\lambda\xi} d\xi \lambda \in R$$

and

$$\tilde{u}_1(x,t) = \int_{-\infty}^{\infty} \frac{1}{2\pi} \left\{ \int_{-\infty}^{\infty} e^{-\lambda^2 a^2 (t-h) + i\lambda (x-\xi)} d\lambda \right\} \varphi(\xi,h) d\xi.$$

The inner integral calculated in [4]

$$\frac{1}{2\pi} \int_{-\infty}^{\infty} e^{-\lambda^2 (t-h) a^2 + i\lambda (x-\xi)} d\lambda = \frac{1}{2\sqrt{\pi(t-h}} e^{-\frac{(x-\xi)^2}{4a^2(t-h)}}$$

is denoted by $G(x-\xi; t-h)$ and is the fundamental solution of equation (8). Then

$$\tilde{u}_1(x,t) = \int_{-\infty}^{\infty} G(x0\xi; t-h) \varphi(\xi,h) d\xi, x \in R, h<t<2h. \quad (13)$$

We use formula (13) to construct a solution to problem 1. For this, instead of equation (8), we consider equations

$$\frac{\partial U(x,t)}{\partial t} = a^2 \frac{\partial^2 U(x,t)}{\partial x^2}, x \in R, t>h, \quad (14)$$

with conditions (9), (10), extending in condition (9) the initial function $\varphi(x,h)$ for $x < 0$ nonearly, and we leave condition (10) unchanged:

$$U(x,h) = \Psi(x,h) = \begin{cases} \varphi(x,h), x \ge 0, \\ -\varphi(-x,h), x<0. \end{cases} \quad (15)$$

Then, according to formula (13), the solution of problem (14), (15), (10) is

$$U(x,\ t) = \int_{-\infty}^{\infty} \{G(x-\xi; t-h) - G(x+\xi; t-h)\} \varphi(\xi,h) d\xi.$$

In the integral where $\xi < 0$, we replaced $\xi = -\xi$. Simplifying the difference of the exponents included in the expression for the function *G*, we obtain that

$$u_1(x,t) = \frac{1}{\sqrt{\pi(t-h)}} \int_0^{\infty} \varphi(x,h) e^{-\frac{x^2+\xi^2}{4a^2(t-h)}} sh \frac{x\xi}{2(t-h)} d\xi,$$

where $x > 0$, $h < t < 2h$. Using the method of mathematical induction, we prove that in case $x \ge 0, kh < t < (k+1)h$ the solution to problem 1 takes the form

$$u_1(x,t) = \frac{1}{\sqrt{\pi(t-kh)}} \int_0^{\infty} \varphi(\xi,kh) e^{-\frac{x^2+\xi^2}{4a^2(t-kh)}} sh \frac{x\xi}{2a^2(t-kh)} d\xi \quad (16)$$

Therefore, the following theorem is true.

Let's mark

$$G_1(x,y,t-kh) = \frac{1}{\sqrt{\pi(t-kh)}} e^{-\frac{x^2+y^2}{4a^2(t-kh)}} sh \frac{xy}{2a^2(t-kh)}, \quad (17)$$

$x \geq 0, y > 0, kh < t < (k+1)h, k \in N$.

Definition. A function $G_1(x, y, t-kh)$ is called a Green's function of problem (1), (2), (3) if it satisfies the following conditions:

1) the function $G_1(x, y, t-kh)$ is continuous on *x*, *y*, *t*, continuously differentiable on *t* and twice continuously differentiable on *x*, *y* when $x > 0$, $y > 0$, $kh < t < (k+1)h$, $k \in$ N, and possibly with the exception in the point $x = y$, $t = kh$;

2) the function $G_1(x, y, t-kh)$ by variables *x* and *y* satisfies the equation $\frac{\partial G_1}{\partial t} = a^2 \frac{\partial^2 G_1}{\partial x^2}$ everywhere except in the points $x = y$, $t = kh$, $k \in$ N;

3) the function $G_1(x, y, t-kh)$ satisfies the boundary condition $G_1(0, y, t-kh) = 0$.

The Green's function satisfying this definition is constructed above and takes the form (17)

$G_1(x, y, t-kh) = G_1(y, x, t-kh)$.

2.2. Properties of the solution of the problem 1

Given that

$$G_1(x, y, t-kh) = \frac{1}{2\sqrt{\pi(t-kh)}} \left\{ e^{-\frac{(x-\xi)^2}{4a^2(t-kh)}} - e^{-\frac{(x+\xi)^2}{4a^2(t-kh)}} \right\}$$

we get from (16), when $|\varphi(\xi, kh)| \leq M$

$$|u_1(x,t) \leq M \frac{1}{2\sqrt{\pi(t-h)}} \left\{ \int_0^\infty e^{-\frac{(x-\xi)^2}{4a^2(t-kh)}} d\xi - \int_0^\infty e^{-\frac{(x+\xi)^2}{4a^2(t-kh)}} d\xi \right\} \equiv$$

$\equiv M\{I_1 - I_2\}$.

In the integral I_1 we will do replacement $\alpha = \frac{\xi - x}{2\sqrt{a^2(t-kh)}}$, and in the integral I_2 $\alpha = \frac{\xi + x}{2\sqrt{a^2(t-kh)}}$. Then

$$I_1 = 2\int_{-z}^{\infty} e^{-\alpha^2} d\alpha, \ I_2 = 2\int_{z}^{\infty} e^{-\alpha^2} d\alpha,$$

where $z = \frac{x}{2\sqrt{t-kh}}$ and we get an estimate

$$|u_1(x,t)| \leq M \text{erf}\left(-\frac{x}{2\sqrt{t-kh}}\right), , \tag{18}$$

$x > 0$, $kh < t < (k+1)h$.

So, the following theorem is proved.

Theorem 1. If there exists a number $M > 0$ such that the initial function $\varphi(x, kh)$ is bounded when $x > 0$, $h > 0$, $k \in$ N, $|\varphi(x, kh| \leq M$, then the function $u_1(x, t)$ (16) when $x > 0$, $kh < t < (k+1)h$ is also bounded and the estimate (18) is true for it.

If $\varphi(\xi, kh) = \varphi_0$, where φ_0 is a number, then

$$u_1(x,t) = \varphi_0 \text{erf}\left(\frac{x}{2\sqrt{t-kh}}\right),$$

$x > 0, kh < t < (k+1)h$, $\text{erf}(x) = \frac{2}{\sqrt{\pi}} \int_0^x \exp\{-\xi^2\} d\xi$ is the error function.

By direct verification, it is possible to make sure that the Green's function (17) satisfies the homogeneous heat conduction equation (item 2 of the definition). When formally differentiating the function (16) under the sign of the integral, we obtain expressions

$$\frac{1}{(a^2(t-kh))^r} \int_0^\infty \varphi(\xi, kh) \, |x \pm y|^m \, e^{-\frac{(x \pm y)^2}{4a^2(t-kh)}} dy,$$

$x > 0$, $kh < t < (k+1)h$, where integrable functions are majored by an expression of the form $M|\xi|^m e^{-\xi^2}$ that is integrable on the entire numerical axis. This ensures uniform convergence of the integrals obtained after differentiation under the sign of the integral. Then the Poisson integral (16) is a continuous function, differentiable of arbitrary order with respect to *x* and *t* when $x > 0$, $kh < t < (k+1)h$, $k \in$ N, bounded with a bounded initial function, satisfying the homogeneous heat conduction equation (8) , since the Green's function (17g) satisfies equation (8). The implementation of the initial condition (9) and the boundary condition (10) is carried out similarly as in [4, 8]. Let us prove the uniqueness theorem of the solution to problem 1.

Theorem 2 (the uniqueness for an infinite straight line).

Let there be a number $M > 0$ such that in the domain $x \geq 0$ and $kh \leq t \leq (k+1)h, k \in N$ the functions $u_1(x, t)$ and $u_2(x, t)$ are bounded, that is $|u_i(x,t)| < M$, $i = 1, 2$, satisfy the equation (8) and condition

$u_1(x, kh) = u_2(x, kh), x \leq 0, k \in N,$

then

$u_1(x,t) = u_2(x,t), x \geq 0, kh \leq t \leq (k+1)h$.

Proof. Consider the function

$$v(x,t) = u_1(x,t) - u_2(x,t),$$

which is continuous, equation (8), bounded by

$$|v(x,t)| \leq |u_1(x,t)| + |u_2(x,t)| < 2M,$$

$$x \geq 0, kh \leq t \leq (k+1)h, v(x, kh) = 0.$$

Consider the domain $0 \leq x \leq L, kh \leq t \leq (k+1)h$, where *L* is a real number and a function

$$V(x,t) = \frac{4M}{L^2}\Big(\frac{x^2}{2} + a^2(t - kh)\Big),$$

for which

$$\frac{\partial V}{\partial t} = \frac{4Ma^2}{L^2},\ \frac{\partial V}{\partial x} = \frac{4Mx}{L^2},\frac{\partial^2 V}{\partial x^2} = \frac{4M}{L^2}$$

and which satisfies the thermal conductivity equation (8), as well as

$$V(x,kh) \ge v(x,kh) = 0$$

$$V(\pm L,t) \ge 2M \ge | v(\pm L,t) |, \qquad (19)$$

For each limited region $0 \le x \le L,$ $kh \le t \le (k+1)h, k \in N$, the principle of the maximum value is true [4, p. 194]. From Corollary 2 [4, p. 198] for the functions $\underline{u} = -V(x,t),\ u = v(x,t),$ $\bar{u} = V(x,t)$, taking into account (19), we obtain that

$$-\frac{4M}{L^2}\Big(\frac{x^2}{2} + a^2(t - kh)\Big) \le v(x,t) \le$$

$$\le \frac{4M}{L^2}\Big(\frac{x^2}{2} + a^2(t - kh)\Big).$$

We fix (x, t) and use the fact that L is arbitrary and can be increased indefinitely. Passing to the limit at $L \to \infty$, we obtain that $v(x,t) \equiv 0$ for $x \ge 0,$ $kh \le t \le (k+1)h$

Theorem 2 is proved.

Therefore, the following theorem is true.

Theorem 3. If $| \varphi(x,h) | \le M, \quad x \ge 0, \quad M > 0,$ $h > 0$, then the solution of problem (8), (9), (10) exists, is unique and is determined by formula (16).

2.3. Solving the problems 2 and 3

It is necessary to solve equation (8) when the zero initial condition (11) and the general boundary condition (12) are met. First, let's solve the auxiliary problem of cooling a heated rod, at the boundary of which a constant zero temperature is maintained. Then, for equation (8), the Cauchy condition and the boundary condition are given as follows:

$$V_1\big(x,t_0\big) = T,\ v_1\big(0,\ t\big) = 0,\ x > 0,\ t > h.$$

Then, according to formula (16), we get that

$$\bar{v} = T\ \mathrm{erf}\,(\frac{x}{2\sqrt{a^2(t-t_0)}}),\ x \ge 0,\ t > t_0, \qquad (20)$$

Let $\mu(t) = \mu_0 \equiv const$ in condition (12). Then, according to (20), the function

$$\bar{v} = \mu\ \mathrm{erf}\,(\frac{x}{2\sqrt{a^2(t-t_0)}}),\ x \ge 0,\ t > t_0,$$

is a solution of problem (8), (11), (12). Then the function

$$v(x,t) = \mu_0 - \bar{v}(x,t) = \mu_0\left[1\text{- erf}\,(\frac{x}{2\sqrt{a^2(t-t_0)}})\right],$$

$$x > 0,\ t > 0. \qquad (21)$$

We denote the expression in parentheses of formula (21) by $U(x, t - t_0)$, which makes sense when $t > t_0$. If for $t < t_0$ the value of this function is extended by zero, then this definition is consistent with the zero value of the function at $t = t_0$. The limit value of this function at $x = 0$ is a step function equal to zero at $t < t_0$and equal to 1 at $t > t_0$. The constructed function is often found in applications and is an auxiliary link in constructing the solution to problem 2.

The second auxiliary task is to find a solution of the equation (8) under the following conditions:

$$v(x,t_0) = 0, x \ge 0,$$

$$v(0,t) \equiv \mu(t) = \left\{\begin{matrix} \mu_0, t_0 < t < t_1, \\ 0, t > t_1 \end{matrix}\right\}.$$

It is directly verified that

$$V(x,t) = \mu_0[U(x,t-t_0) - U(x,t-t_1)],$$
$$x \ge 0, t > t_0.$$

If

$$\mu(t) = \begin{cases} \mu_0, t_0 < t \le t_1, \\ \mu_1, t_1 < t \le t_2, \\ \ldots\ldots\ldots \\ \mu_{n-1}, t_{n-2} < t \le t_{n-1}, \\ \mu_{n-1}, t_{n-1} < t \le t_n, \end{cases},$$

and then the solution of the corresponding problem can be written in the form

$$u(x,t) = \sum_{i=0}^{n-2} \mu_i [U(x,t-t_i) - U(x,t-t_{n+1})] +$$
$$+\ \mu_{n-1} U(x,t-t_{n-1})$$

Using the theorem on finite increments, we get

$$u(x,t) = \sum_{i=0}^{n-2} \mu_i \frac{\partial}{\partial t} U(x,t-\tau)\Big|_{\tau=\tau_i} +$$
$$+\ \mu_{n-1} U(x,t-t_n), \qquad (22)$$

where $x \ge 0,\ t_i \le \tau_i \le t_{i+1}$

The approximate solution of problem 2 can be obtained by formula (22), if replace the function $\mu(t)$ with a piecewise-constant function.

Heading to the limit when the interval of constancy of the auxiliary function decreases, we obtain that the limit of the sum (22) will take the form

$$\int_0^t \frac{\partial U}{\partial t}(x,t-\tau)\mu(\tau)d\tau ,$$

because when $x \geq 0,$ we have

$$\lim_{t-t_{n-1}\to 0} \mu_{n-1}U(x,t-t_{n-1}) = 0 .$$

If we consider that

$$\frac{\partial U}{\partial t}(x,t) = -2a^2 \frac{\partial G}{\partial x}(x,0,t) = 2a \left.\frac{\partial G}{\partial \xi}\right|_{\xi=0}$$

then we will get the final result

$$u_2(x,t) = \frac{a^2}{2\sqrt{\pi}} \int_{kh}^{t} \frac{x}{[a^2(t-\tau)]^{3/2}} \times$$

$$\times \exp\left\{-\frac{x^2}{4a^2(t-\tau)}\right\}\mu(t)d\mu , \qquad (23)$$

$x > 0,$ $kh \leq t \leq (k+1)h .$

The solution of problem 3 using the Green's function (17) can be written in the form of a Poisson integral

$$u_3(t,x) = \int_{kh}^{t} d\tau \int_0^{\infty} f(y,\tau)G_1(x,y,t-kh)dy \qquad (24)$$

$x > 0,$ $kh \leq t \leq (k+1)h$, $k \in$ N, for the existence of which the function $f(x,t)$ must be such that the improper integral in formula (24) coincides.

So, the following theorem is proved.

Theorem 4. The solution of problem (8), (11), (12) is determined by formula (24). The solution of problem (4), (5), (6) is determined by formula (7), where the terms u_1, u_2, u_3 are the solutions of problems 1, 2, and 3, respectively.

CONCLUSION

In this paper was formulated the first boundary value problem for the heat conduction equation containing a nonlinear term dependent on the searched function with a deviation of the argument for the first time. For such equations, the initial condition is set on a certain interval. Physical and technical reasons for lateness can be transport delays, delays in information transmission, delays in decision-making, etc. The most natural are delays when modeling objects in ecology, medicine, population dynamics, etc. Features of the dynamics of vehicles in different environments (water, land, air) can also be taken into account by introducing a delay. Other physical and technical interpretations are also possible. The study of the molecular distribution of heat energy in various substances (solid bodies, liquids, etc.) leads to heat conduction equations. The Green's function of the first boundary value problem is constructed for the nonlinear equation of heat conduction with a deviation of the argument, its properties are studied, and the formula for the solution is established.

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Kolmogorov-Chaitin Algorithmic Complexity for EEG Analysis

Victor Iapascurta [1,2], ORCID: 0000-0002-4540-7045
Ion Fiodorov [2], ORCID: 0000-0003-0938-3442
[1] N. Testemitanu State University of Medicine and Pharmacy, 165, Stefan cel Mare si Sfant Blvd., Chisinau, MD – 2004, Republic of Moldova, victor.iapascurta@doctorat.utm.md
[2] Technical University of Moldova, 168, Stefan cel Mare si Sfant Blvd., Chisinau, MD – 2004, Republic of Moldova, ion.fiodorov@ati.utm.md

Abstract— **Electroencephalography as a generally accepted method of monitoring the electrical activity of brain neurons is widely used both in diseases and in healthy conditions. The recorded electrical signal is usually obtained from several electrodes located on the scalp. While EEG recording techniques are largely standardized, the interpretation of some aspects is still an open question. There is hardly questionable progress in detecting abnormal EEG signals known as seizures.**

A less explored field is the detection and classification of non-pathological conditions such as emotional and other functional states of the brain. This requires special approaches and techniques that have been widely developed over the past decade.

The current paper describes an attempt to use algorithmic complexity concepts and tools for EEG transformation making it possible to combine this approach and machine learning for classification purposes.

Keywords—Electroencephalography; EEG analysis; algorithmic complexity; block decomposition method; machine learning

I. Introduction

The goals of using EEG as a monitoring method can be summarized as: (a) to help researchers gain a better understanding of the brain; (b) to assist physicians in diagnosis and treatment choices; (c) to boost brain-computer interface (BCI) technology [1].

There are many ways to roughly categorize EEG analysis methods. As shown in a review article [2] most EEG analysis methods can be divided into four categories: (1) time domain, (2) frequency domain, (3) time-frequency domain, and (4) non-linear methods. There are also more recent methods, including machine learning (ML). As for specific mathematical signal analysis methods, there is a multitude of approaches in every of de domains listed above: linear prediction (LP) and independent component analysis (ICA), fast Fourier transform (FFT), autoregressive (AR) methods, short-time Fourier transform (STFT), wavelet transform (WT), etc.

Since the EEG signal is far from stationarity and may contain much noise, linear methods of analysis were thought not the best choice, at least in some situations. Nonlinear dynamical analysis has been a powerful approach to understanding these physiological signals. It has been observed that nonlinear dynamics theory will be a better approach than traditional time domain and frequency domain methods in analyzing and characterizing the EEG signals. The collection of non-linear methods also looks impressive: higher order spectra (HOS) techniques, phase space plot (PPS) methods, correlation dimension (CD) and fractional dimension (FD) methods, largest Lyapunov exponent (LLE), entropy estimators, etc.

Among the non-linear methods, there is a group of Entropy estimators (e.g., Spectral entropy (SEn), Approximate Entropy (ApEn), Sample entropy (SampEn), etc.). Most of them are based on Shannon's entropy, which is also presented as a measure of algorithmic complexity (AC) [2,4].

However, recent researches question the use of Shannon's entropy as the best (and sometimes even appropriate) estimation for algorithmic complexity (AC) and the Kolmogorov-Chaitin definition of AC is used instead [3,4].

The current research is trying to use the algorithmic complexity (by Kolmogorov-Chaitin approach) as a metric and data representation method for processing the data before they are fed to a machine learning algorithm.

II. EEG Data and Processing Methods

A. Data

The dataset [5] on which this research is based was originally collected to study the EEG correlates of mental activity during an intense cognitive task (mental arithmetic task—serial subtraction). The arithmetic tasks in this study involved the serial subtraction of two numbers. Each trial started with the oral communication of the 4-digit (minuend) and 2-digit (subtrahend) numbers (e.g., 4753 and 17, 3141 and 42, etc.).

In this experiment all subjects were divided into two groups: (a) group "G" (or “good counters”) - performing good quality count (mean number of operations per 4 minutes = 21, standard deviation (SD) = 7.4) and (b) group "B" (or “bad counters”) - performing bad quality count (mean number of operations per 4 minutes = 7, SD = 3.6).

Table 1 and Figure 1 show the general characteristics and appearance of the data.

TABLE I. General Characteristics of Data

Data source	36 healthy volunteers performing an arithmetic task
Data type	Multimodal multivariate time series: EEG and ECG, with 500 Hz sampling rate
The volume of the set and format	175 MB “.edf”
The volume of a subset and format	1285-3883 KB “.edf”
Parameters present in data	EEG signals from 20 electrodes and one-lead ECG
Data set peculiarities	EEG clip duration equal to 60-180 seconds
The task to be solved with the data	Two class classification: (a) good counters and (b) bad counters

The appearance of the data is shown in Fig.1.

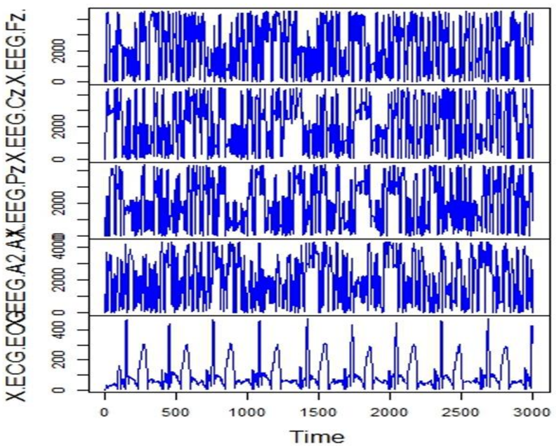

Figure 1. Appearance of EEG and ECG signals.

Figure 2.

B. Methods

A central role in data processing flow in this research is assigned to the estimation of *Algorithmic (Kolmogorov-Chaitin) Complexity* performed using the *Block Decomposition Method* which comes from the field of *Algorithmic Information Dynamics* [4, 6].

Of primary importance here is the definition of algorithmic (Kolmogorov–Chaitin or program-size) complexity (Kolmogorov, 1965; Chaitin, 1969) [6]:

$$K_T(s) = min\{|p|, T(p) = s\}, \qquad (1)$$

that is, the length of the shortest program p that outputs the string s running on a universal Turing machine T.

Algorithmic Information Dynamics (AID) is an emerging field of complexity science based on algorithmic information theory, which comprises the literature based on the concept of Kolmogorov–Chaitin complexity and related concepts such as algorithmic probability, compression, optimal inference, the universal distribution, Levin’s semi-measure, and others.

AID strives to search for solutions to fundamental questions about causality: why a particular set of circumstances leads to a particular outcome. In this aspect, it essentially differs from traditional statistics. As an applied science, AID is a new type of discrete calculus based on computer programming and aimed at studying causation by generating mechanistic models to help find the first principles of physical phenomena, building up the next generation of machine learning [6].

In the AID toolkit, there is a special tool for providing reliable estimations to uncomputable functions, namely the online algorithmic complexity calculator (OACC) [7], which provides estimations of algorithmic complexity and algorithmic probability for short and long strings and for two-dimensional arrays better than any other traditional tool, none of which can capture any algorithmic content beyond simple statistical patterns. The OACC uses the BDM method [3,7,8], which is based upon algorithmic probability defined by the coding theorem method (CTM) :

$$BDM = \sum_{i=1}^{n} CTM(block_i) + log_2(|block_i|). \qquad (2)$$

The OACC is available as an online version as well as standalone packages in R and a number of other languages and it is used for respective calculations for the scope of the current work.

III. Data Processing Steps and Their Results

Each file (subset) in the original data is a ".edf" file describing the EEG signal voltage variations for "n channels" for 60 to 180 seconds duration. The subset is unfolded and a matrix with columns representing "n channels/electrodes" and rows denoting observations of EEG signal variation over time corresponding to particular channels is generated. The resulting matrix is split into a series of 20 x 20 (depending on the number of channels/electrodes) matrices, keeping the tie with the electrodes and time. Table 2 shows the appearance of a fragment of such a matrix (4 channels and 4 observations only).

TABLE II. Appearance of an EEG Fragment (4 Channels)

Ch - 1 (μV)	Ch - 2 (μV)	Ch - 3 (μV)	Ch - 4 (μV)
4.476	-2.741	-2.502	0.095
1.208	-3.309	-4.418	-0.529
-2.546	-3.709	-6.411	-1.003
-6.187	-3.681	-8.03	-1.103

A. Calculating algorithmic complexity

These small (i.e., 20 x 20) matrices are binarized (using "BASCA" method, "Binarize" package in R) [8]. Table 3 shows what the fragment of an original matrix above looks like after binarization, with the respective thresholds and p-values.

TABLE III. Binarized Matrix and Statistics

Binarized matrix				Threshold	p-value
1	0	0	0	2.2855	0.001
1	0	0	1	-1.9190	0.001
1	1	0	1	-5.0600	0.001
0	1	0	1	-4.9340	0.001

The algorithmic complexity (by BDM) of this matrix equals 32.7241 bits. Based on (2), for a 20 x 20 matrix the AC value will be much higher. The BDM value for each such matrix is calculated with BDM values arranged over time axis obtaining time series that describe BDM value variation over time (Fig. 2).

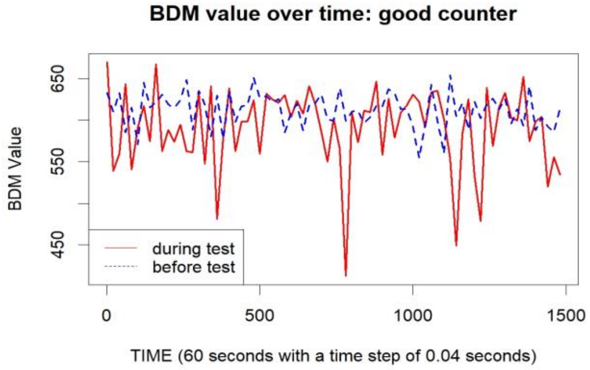

Figure 3. BDM value over time in good counter (before – blue line and during the test – red line)

Since the volume of data BDM value is to be calculated on is large, neither online nor the regular stand-alone version of the OACC is suitable. For the purpose of this research, the "core" of the R version of OACC was extracted and integrated into the data processing flow.

The binarization and BDM calculation on these large data are quite computationally expensive. To address this the E2C Amazon Web Service is being used. Considering the sampling rate of 500 Hz and the dimension of a small matrix (e.g., 20 x 20) described above, 1500 matrices are generated with each 60 seconds subset (i.e., 500Hz*60seconds/20).

B. Plotting algorithmic complexity

After calculating the BDM value, it can be plotted along the time axis with a total number of steps equal to 1500, which represents the BDM value over time for a particular subject. A detailed explanation of the data processing steps is provided in [8].

The BDM values are aggregated (using the average of ten observations/time steps) to better capture possible underlying patterns. As can be seen from Fig.2, the AC during the test fluctuates in a much larger range compared to the before-the-test AC.

In order to identify additional patterns that would help discriminate EEG before and during the test, EEG clips were randomly sampled from groups of good and bad counters (10 files from each group). After estimating the BDM value for each file ("before-the test" and "during-the-test"), the BDM value density distribution was estimated on mean per-time-step BDM values for each group. Figure 3 shows the situation in the good-counters group.

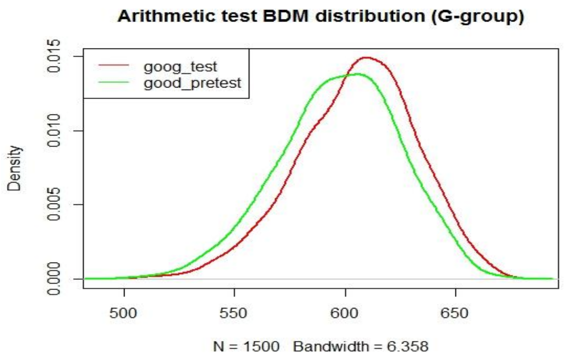

Figure 4. BDM values distribution in good counters

According to the plot above, there is a shift of mean BDM to the right (or towards increased complexity).

In the bad-counters group, the pattern seems to differ (Fig. 4). The BDM value distribution curves look quite similar. This seems to imply that AC of the brain functioning is activity agnostic in this group, or does not change depending on the type of brain activity (e.g., mental counting, as in this research).

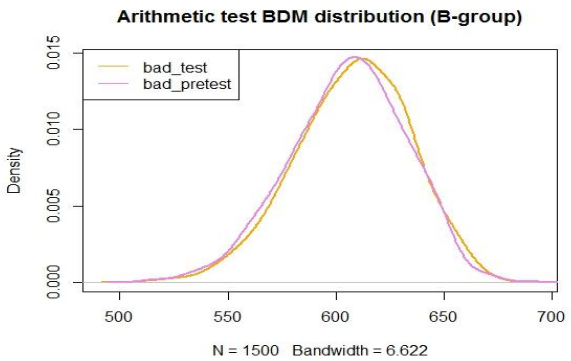

Figure 5. BDM values distribution in bad counters

IV. Discussions and Conclusions

Nonlinear dynamics has been used in neurophysiology to understand complex brain activity from EEG signals. Although linear methods have been the most commonly used in EEG analysis, non-linear approaches have expanded their presence as they reveal aspects that cannot be measured with linear approaches. However, published works in this scientific field are still rare.

The EEG signals reflect the electrical activity of the brain. They are considered to be highly random in nature and may contain useful information about the brain state. However, it is difficult to get useful information from these signals just by observing them. They are basically non-linear and nonstationary in nature. Hence, important features can be extracted using advanced signal-processing techniques. This paper describes the effect of a mental arithmetic task on the EEG signal using a less traditional processing method, namely algorithmic complexity estimation. This method allows the extraction of hidden information from the signal.

The main steps for extracting this information are presented based on the block decomposition method, which is a tool from the newly emerging field of algorithmic information dynamics. Although the Kolmogorov-Chaitin complexity (as the core of the method) apparently resembles the Shannon entropy approach as a measure of complexity, they are different, and this is explained in detail in [3, 4, 7].

According to the results presented in this paper, it seems possible to use AC of the brain functioning to gain insights into the brain state and use it to potentially classify the brain functional state (e.g., relaxed/background functioning vs performing a mental arithmetic task).

The EEG signals obtained from two groups of human subjects performing mental arithmetic tasks (good and bad counters) were split into two groups: (a) before the test and (b) during the test, processed and finally analyzed for differences using the Kolmogorov-Smirnov test.

The two-sample Kolmogorov-Smirnov (KS) test for good counters provides the following statistics: $D = 0.08$, p-value = 0.0001355. Since the p-value is much less than 0.05, it can be inferred that the distribution of BDM values as a measure of the algorithmic complexity of brain functioning differs before and during the arithmetic test activity in good counters.

The statistics for the two-sample KS test in bad counters are: $D = 0.046$, p-value = 0.08367. Since the p-value is higher than 0.05, it can be concluded that the algorithmic complexity of brain functioning in this group does not differ regardless of mental activity.

Thus AC by BDM can be used as a metric that can help distinguish between these two groups (i.e. good counters vs bad counters). The distance (D) between paired (i.e., before and during the test) states for good counters is almost twice that for bad counters. But given the small value of D in both groups, special care will be required when using this approach for specific tasks such as machine learning.

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Computer Engineering

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The choice of DVB-T2 signal transmission technology in the shadow areas of the Republic of Moldova

Mihail Iacob [1], ORCID:0000-0002-3301-050X
[1] State Enterprise «Radiocomunicatii», Drumul Viilor st., 28/2, Chisinau, 2029, The Rebublic of Moldova,
mihail.iacob@radiocom.md

***Abstract*—This article presents the results of research into the opportunity to use Gap Fillers in the shadow areas of the first national digital terrestrial television multiplex of the Republic of Moldova. A basic condition related to the expansion of the population's access to the DVB-T2 signal in the "shadow areas" was - the use of the existing terrestrial broadcasting infrastructure. It was demonstrated that, to achieve the proposed goal, the use of Gap Fillers is not appropriate, but for the signal emission in the "shadow areas" it is necessary to use low-power DVB-T2 transmitters. In this case, the transport of the T2-MI flow to the entrance of the mentioned transmitters will be ensured by means of the existing fiber optic networks.**

Keywords—Gap Filler, digital terrestrial television multiplex, DVB-T2, SFN, T2-MI, "Echo" signal, isolation, "shadow areas".

I. Introduction

During the years 2016-2018 S.E. "Radiocomunications" put into operation in the Republic of Moldova the first national digital terrestrial television multiplex, so called "MUX-A". For the "MUX-A" implementation, 6 DVB-T2 SFN SISO service areas were built. Therefore, using the infrastructure of the existing terrestrial broadcasting networks, 8 high-power transmitters and 9 medium-power transmitters were put into operation throughout the country. In accordance with the technical specifications of the DVB-T2 networks [1], the T2-MI digital data stream was transported to the input of 17 transmitters, mentioned above, via IP networks. The implementation of "MUX-A" ensured access to the DVB-T2 signal for about 95% of the country's population. At the same time, due to the peculiarities of the relief, in the Republic of Moldova there are about 60 localities located in the so-called "shadow areas", where the terrestrial signal cannot be received. Between the years 1970 - 2008, low-power analog TV signal retransmission stations of the f_1/f_2 type were installed in the mentioned localities, but for the suspension of the broadcast antennas in the overwhelming majority of cases, typical masts of a height of 27 m were built. Resulting from the need to expand the population's access to terrestrial digital signal, Î.S. "Radiocomunications" took the decision to research the opportunity of using in "shadow areas" the low-power f_1/f_1 repeaters, so-called Gap Fillers. A basic condition related to the expansion of the population's access to the DVB-T2 signal in the "shadow areas" was - the use of the existing infrastructure of low-power analogue TV signal retransmission stations.

Gap Filler, is an f_1/f_1 terrestrial digital signal repeater with signal processing and amplification, see Figure 1 [2]. Consequently, a certain part of the signal (the echo) from the output of the transmitting antenna will return back to the input of the Gap Filler (with a delay, relative to the other input signals, equal to the signal processing time).

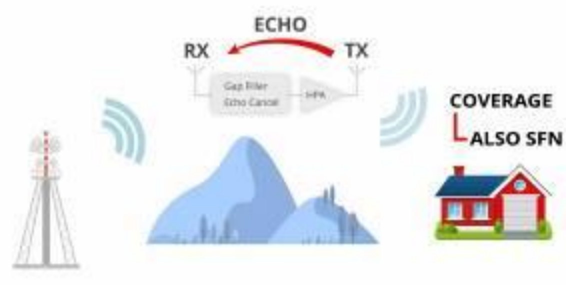

Figure 1. Gap-Filler in a digital Terrestrial Broadcasting Network

So, one of the important functions of the Gap Filler is to suppress its own echo. According to the technical specifications of the manufacturers [3,4], the echo level at the Gap Filler input should not exceed the signal level at the network input by more than 12-15 dB (depending on the manufacturer's model). When this ratio at the Gap Filler input is exceeded, the signal idices at the repeater output drift outside the MER < 24 dB quality tolerances. As a result, the protection algorithms stop the Gap Filler from working. Therefore, to ensure reliable operation of the Gap Filler, adequate signal isolation (not less than 80 dB [2]) must be ensured between the transmitting and receiving antennas. At the same time, the requirement to limit the echo level also imposes a limitation on the output power of the Gap-Filler. Unfortunately, there are other factors that limit the effectiveness of using a Gap-Filler, such as: 1. The amplitude of the signal from the repeater output, as well as the echo, can vary according to weather conditions; 2. The phase difference between the signal from the repeater output and the echo may change due to antenna vibrations due to wind; 3. Multipath signal reception conditions can be disturbed by waves reflected from local objects located near the input or output antennas of the repeater, etc.

In order to investigate the possibility of using f_1/f_1 low-power repeaters in "shadow areas", field tests of the Gap Filler, produced by the TRedess company, were carried out at the ground signal relay station located in the Holercani town. The tests were carried out in the DVB-T2 SFN SISO channel 31 cluster, using the existing infrastructure of analogue TV repeaters (already decommissioned).

II. The infrastructure of the retransmission station

The external appearance of the relay station in the town of Holercani is shown in Figure 2. The height of the pylon H = 42 m, the height of the pylon base above sea level h = 108 m. On the pylon are suspended: a receiving antenna LAP 4/5-50/16 and 2 transmitting antennas - TVA 31/50 and TVA 51/50. The technical parameters of the receiving and transmitting antennas are presented in Tables I and II. The external appearance of the transmitting and receiving antennas is shown in Figure 3.

TABLE I. TECHNICAL PARAMETERS OF THE LOG-PERIODIC RECEIVING ANTENNA LAP 4/5-50/16

Parameter	Antenna LAP 4/5-50/16
Polarization	H
Azimuth, gr	240
Orientation	Towards broadcasting station № 2
Reception	Channel 31
Suspension above the ground, m	40
Amplification coefficient, dBd	9.0
Number of panels	1

TABLE II. TECHNICAL PARAMETERS OF TVA 31/50 AND TVA 51/50 BROADCAST ANTENNAS

Parameter	Antenna	
	TVA 31/50	***TVA 51/50***
Polarization	H	V
Azimuth, gr	130	135
Broadcast channel	31	31
Suspension above the ground, m	34	33
Amplification coefficient, dBd	11	11
Number of panels	1	1

Figure 2. The exterior of the relay station in the town of Holercani

Figure 3. External appearance of the antennas: TVA 31/50 and TVA 51/50 (from the left); LAP 4/5-50/16 (from the right)

III. Measurement of signal isolation

Since the primary mode of echo reduction is to provide isolation between the transmit and receive antennas, as the first step of the study, the A_{tx-rx} crosstalk attenuation on the 564 MHz frequency between the input of the transmit antennas and the output of the receive antenna was measured. At the same time, the dynamics of the A_{tx-rx} change was evaluated according to the value of the angle Δφ between the directions of maximum amplification of the transmitting and receiving antennas, and according to their polarization. The results of the measurements are presented in Tables III, IV, where L - is the distance between the antennas, Δφ – is the angle between the directions of the maximum radiation of the antennas.

TABLE III. A $_{TX-RX}$ VALUE MEASUREMENT RESULTS BETWEEN TVA 51/50 TRANSMIT ANTENNA INPUT AND LAP 4/5-50/16 RECEIVE ANTENNA OUTPUT

Polarization	L, m	Δφ, gr	A_{tx-rx}, dB f=564MHz
V-H	6	105	88.84

TABLE IV. A $_{TX-RX}$ VALUE MEASUREMENT RESULTS BETWEEN TVA 31/50 TRANSMIT ANTENNA INPUT AND LAP 4/5-50/16 RECEIVE ANTENNA OUTPUT

Polarization	L, m	Δφ, gr	A_{tx-rx}, dB f=564MHz
H-H	7	110	92.37
		55	73.02
		0	74.15

From the results of the presented measurements, the following preliminary conclusions were drawn:
1. Changing the polarization of the transmit antenna relative to the polarization of the receive antenna provides no noticeable gain in improving A_{tx-rx} signal isolation. At the same time, this technical action can be used to put into operation a Gap Filler in the shadow area of the DVB-T2 SFN cluster;
2. To ensure maximum isolation of the signal between the input of the transmitting antenna and the output of the receiving antenna, an angle of 180º must be ensured between their maximum radiation directions. With the practical implementation of the Gap Filler in the shadow area of a DVB-T2 SFN network, this angle must (at least) exceed 90 degrees. At the same time, in the case when it will be necessary to install a transmitting antenna with a circular directivity, this requirement will not be able to be met, and the necessary amount of signal isolation can only be ensured by increasing the distance between the suspension heights of the receiving antennas and emission, consequently, for the practical realization of this scenario it will be necessary to be provided with a sufficient height of the pillar.

IV. Input signal level measurement

In order to estimate the level of DVB-T2 SFN signals at the entrance of the tested Gap Filler and at the same time their arrival time, measurements were made at the feeder output of the receiving antenna. The results of the measurements are shown in Figure 4. From the image we can see that at the entrance of the Gap-Filler, there are 3 falling waves, transmitted on channel 31 by three transmitters: Station № 1 - signal level (-64.6 dBm); Station № 2 - signal level (-54.3) dBm; Station № 3 - signal level (-86.7) dBm. The receiving antenna is oriented in the direction of Station № 2. Thus, three DVB-T2 signals are applied to the input of the Gap Filler, shifted in time relative to each other by 80.934 µs and 72.934 µs. The level of the second signal is maximum. The summary level of the signal has a value of (-54.2) dBm.

Figure 4. Measurement of input signal levels and their arrival time

So, the peculiarities of the Holercani relay station (geographical location, height of the pylon, suspension height of the receiving antenna, gain of the receiving antenna) ensure a sufficient level of the signal from the Gap Filler (-54.2) dBm. However, in the Republic of Moldova, the vast majority of existing analogue signal repeaters are located at the edge of the service areas with DVB-T2 signal, but the height of the pylons (from their composition) is 27 m. Under these conditions, the DVB-T2 signal level of at the entrance of the repeaters it will be lower. For the purpose of correct network planning it is necessary to estimate this level. For this, we will assume that the field intensity at the entrance of the repeater reception antenna reaches the level of the admissible threshold Emed = 53 dBµV/m (for channel 31), but the R&S HL 040 reference antenna is used for reception. At the same time, we will assume that the losses in the feeder- of the receiving antenna is about 2 dB (estimated length of the feeder (½)" about 30 - 35 m).

The field strength measurement at the input of the receiving antenna can be performed by measuring the voltage at the antenna terminals connected to a 50 Ohm load. The field intensity value E [dµV/m] in this case is calculated by formula (1) [5]:

$$E = U_{50\Omega} + F_a + A_f \quad (1)$$

where Fa [dBm^{-1}] is the antenna factor in the direction of maximum radiation; $U_{50\Omega}$ [dµV] is the signal level at the output of the feeder of the reception antenna, Af [dB] are losses in the feeder. Table V shows the R&S HL 040 antenna factor.

TABLE V. R&S HL 040 ANTENNA FACTOR

Frequency, MHZ	Antenna factor, dBm^{-1}
500	16.37
550	17.27
600	17.96

Applying Formula 1 and the data of Table V we will calculate the signal voltage at the output of the feeder of the reception antenna:

$$U_{50\Omega} = 53\ dB\mu V/m - 17.3\ dBm^{-1} - 2\ dB = 33.7\ dB\mu V =$$

$$= (-73.3)\ dBm.$$

$$(-73.3)\ dBm = (-54.2)\ dBm - 19.1 dB$$

Therefore, the signal level at the entrance of the repeater implemented on the H = 27 m pillar and located at the edge of the service area can be reduced by about 19 dB compared to the signal level at the entrance of the Holercani repeater. In this case we can conclude about the need to ensure an isolation value of the A_{tx-rx} signal around 100 – 110 dB, which in local conditions will not be possible.

V. Gap Filler Testing

In order to continue the planned research, testing of the Gap Filler, produced by TRedess, was carried out. The mentioned repeater was connected consecutively to the TVA 31/50 and TVA 51/50 transmission antennas installed on the H= 42 m pillar in the town of Holercani. In the course of the research, the DVB-T2 terrestrial signal quality indicators were measured at the input and output of the Gap Filler. The measurement results were compared and analyzed.

In Figure 5 shows the constellation of the DVB-T2 signal from the feeder output of the receiving antenna. In this case, the input signal level has a value of (-53.0) dBm, but the MER (PLP, rms) indicator is 33.1 dB.

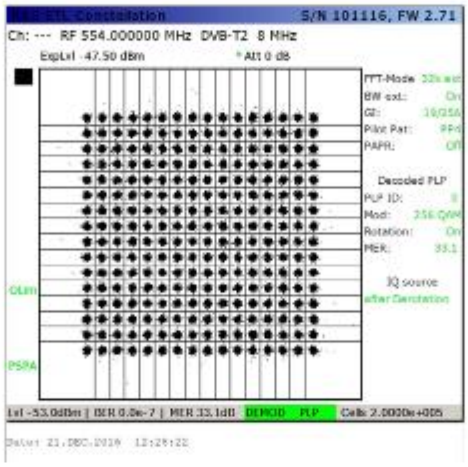

Figure 5. DVB-T2 signal constellation at the feeder output of the receiving antenna

In Fig. 6 shows the levels and time lags of the signals transmitted by the Gap Filler connected to the artificial antenna. The maximum power of the Gap Filler was set to 75 W. The value of the MER parameter is 30.9 dB. Only the signal transmitted from station № 2 was highlighted on the device screen. From the image we notice that, in addition to direct signals, at the input of the Gap Filler there are also signals reflected from local objects in the vicinity of the receiving antenna. The levels of these echoes are significantly lower and their delay time is insignificant (tenths, units of microseconds).

Figure 6. The levels and time lags of the signals at the output of the Gap Filler, connected to the artificial antenna

In Figure 7, the echo of its own emission signal is demonstrated, reaching the input of the Gap Filler. The repeater is connected to the TVA 51/50 transmission antenna, the transmission power is 10 W. The angle between the maximum radiation directions of the transmission and reception antennas is 105 degrees. On the screen, only the signal emitted by the transmitter of station № 2 is highlighted. From the drawing, we notice that, in addition to the signal of the transmitter of station № 2 (Time - (76.541 µs), Level (- 12.7 dB)), at the input of the repeater there is also the echo of its own signal (Time - (81.087 µs), Level (0.0 dB)). Thus, the echo level at the input of the Gap Filler exceeds the level of the input signal by 12.7 dB. The appearance of the echo of its own input signal negatively affects the quality of the Gap Filler output signal, MER (PLP, rms) is 28.3 dB. Therefore, simultaneously with signal processing and amplification, one of the important tasks of the Gap Filler is the partial suppression of its own echo. In Figure 8 shows the levels and time lags of the signals transmitted by the Gap Filler. Only the signal of station № 2 is highlighted on the screen of the device. The image shows that, in addition to the direct signal of station № 2 (Time – (81.144 us), Level (0.0 dB)), there is also an echo of the signal at the output of the Gap Filler own (Time – (85.984 us), Level (- 32.0 dB) Thus, we notice that the Gap Filler's own echo has been suppressed by 44.7 dB (12.7 dB + 32.0 dB).

Afterwards the 20 W emission power of the Gap Filler was set. In Figure 9 shows the echo of the own signal from the input of the Gap Filler. Only the signal emitted by station № 2 is highlighted on the screen. From the drawing we notice that, in addition to the signal of station № 2 (Time – (76.524 us), Level (- 14.6 dB)), at the input of the repeater there is also the echo of its own signal (Time – (81.113 us), Level (0.0 dB)). Thus, the echo level at the input of the Gap Filler exceeds the level of the input signal by 14.6 dB. We notice that the value of the MER quality indicator (PLP, rms) has decreased to 28.1 dB, but the operational margin of this indicator has become quite narrow – about 4 dB (28dB - 24dB).

In Figure 10 shows the echoes of the own signals from the input of the Gap Filler for the case when it is connected to the TVA 31/50 broadcast antenna, Pout = 20 W, Δφ = 110 gr. The signals of stations №1, № 2 and № 3 are highlighted on the screen. The signal of station № 2 is located in the middle of the screen: direct signal - (Time (- 4.546 us), Level (- 12.8 dB)); the echo of the own signal - (Time – (0.000 us), Level (0.0 dB)). Thus, the echo level of the own signal at the input of the Gap Filler exceeds the level of the input signal by 12.8 dB, but the MER parameter at the output has reached a value of 28.2 dB

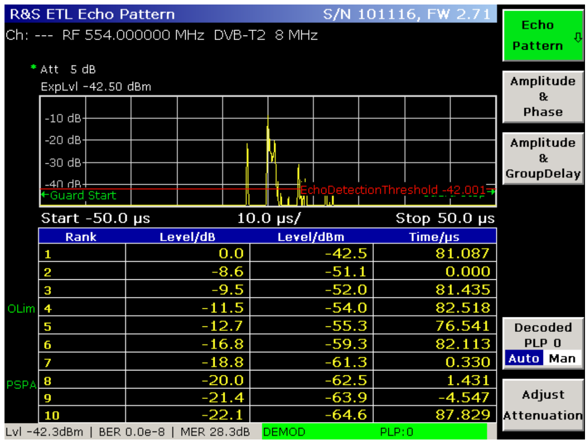

Figure 7. The echo of its own signal at the input of the Gap Filler (P_{out} = 10 W), TVA 51/50 transmission antenna, Δφ = 105 gr.

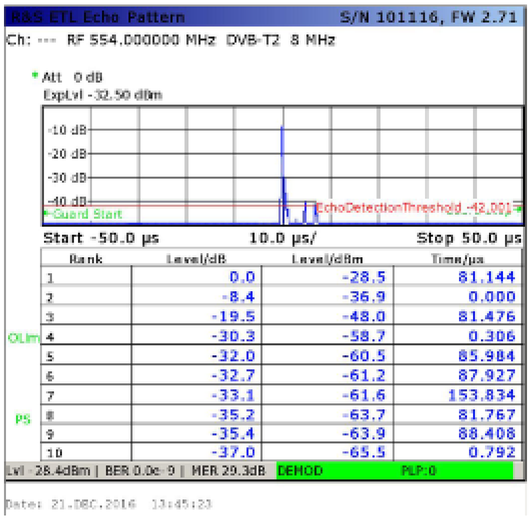

Figure 8. The levels and time lags of the signals transmitted by the Gap Filler (Pout = 10 W), TVA 51/50 broadcast antenna, Δφ = 105 gr.

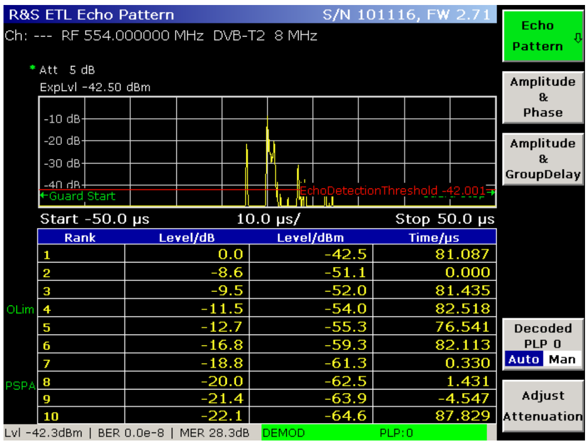

Figure 9. The echo of its own signal at the input of the Gap Filler (Pout = 20 W), TVA 51/50 transmission antenna, Δφ = 105 gr.

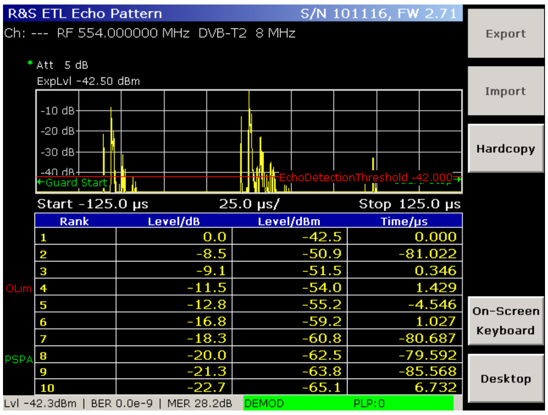

Figure 10. The echo of its own signal at the input of the Gap Filler (Pout = 20 W), TVA 31/50 transmission antenna, Δφ = 110 gr.

In Fig. 11 we can visualize the signal from the output of the Gap Filler. All signals retransmitted to the viewer are highlighted on the screen:

- the signals of the direct falling waves of the transmitters of the SFN network;
- the suppressed echoes of the Gap Filler's own signal;
- waves, reflected from local objects placed in front of the reception and emission antennas.

Figure 11. The levels and time lags of the signals transmitted by the Gap Filler (Pout = 50 W), TVA 31/50 broadcast antenna, Δφ = 110 gr.

The final reports regarding the testing of the Gap Filler, manufactured by TRedess, in the DVB-T2 SFN cluster (channel 31) are presented in Tables VI and VII. To complete the tables, the following abbreviations were used: $P_{in\text{-}tx}$ - signal level at the input of the antenna emission; Pout-rx - signal level at the feeder output of the receiving antenna; Pecho - the Gap filter's own echo level; ΔP = (Pecho - Pout rx) – the ratio between the Gap Filler's own echo level and the network input signal level.

TABLE VI. FINAL TEST RESULTS OF THE GAP FILLER, CONNECTED TO TVA 51/50 TRANSMIT ANTENNA

$P_{in\text{-}tx}$, dBm	$P_{out\ rx}$, dBm	P_{echo}, dBm	ΔP, dB	MER, dB	Δφ, gr	L, m
40	- 55.3	-42.5	12.8	28.3	105	7
43	- 55.7	- 41.1	14.6	27.9	105	7

TABLE VII. FINAL TEST RESULTS OF THE GAP FILLER, CONNECTED TO TVA 31/50 TRANSMIT ANTENNA

$P_{in\text{-}tx}$, dBm	$P_{out\ rx}$, dBm	P_{echo}, dBm	ΔP, dB	MER, dB	Δφ, gr	L, m
40	- 55.3	-48.3	11.5	29.0	110	6
43	- 55.2	- 42.5	12.7	28.2	110	6
47	-	-	-	25.6	110	6

VI. Conclusions

Following the testing of Gap Filer on the existing infrastructure of the retransmission station located in the town of Holercani, the following conclusions were drawn:

1. The reliable operation of the Gap Filler in local conditions can only be ensured with 10W(40 dBm) amplification power. In this case, the operational reserve of the MER quality parameter will be around 4-5 dB. Increasing the emission power will lead to the degradation of the MER parameter.
2. Exploitation of Gap Fillers based on the existing infrastructure of Î.S. Radio communication is not appropriate for the following reasons: a) due to the low height of the existing pylons, it will not be possible to ensure the appropriate level of signal isolation; b) due to the low level of the input signal, it will not be possible to reduce the echo/signal ratio from the Gap Filler input.
3. For signal emission in the "shadow areas" of the Republic of Moldova, it is appropriate to use DVB-T2 transmitters of low power (50 W). In this case, the transport of the T2-MI flow to the entrance of the mentioned transmitters will be ensured by means of the existing fiber optic networks, access to the infrastructure of which is practically available in any locality of the Republic of Moldova.

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The PID Tuning Procedure for Performance Optimization of the Underdamped Second-Order Processes

Irina Cojuhari [1], ORCID: 0000-0003-2248-1338
[1] Technical University of Moldova, Chisinau, Republic of Moldova, e-mail: irina.cojuhari@ati.utm.md

***Abstract*— In this work, it is proposed the procedure for tuning the PID controller to the underdamped second-order systems, that offers the possibility to optimize the performance of the system. The analytical expressions for calculation the tuning parameters of the PID controller were obtained according to the maximum stability degree criterion. These analytical expressions permit to calculate the tuning parameters according to the values of the damping ratio, natural frequency and transfer coefficient, that can be determinate from the step response of the underdamped system. The proposed procedure for performance optimization permits to optimize the value of rise time and percentage of overshoot. To demonstrate the efficiency of proposed method the computer simulation was performed.**

Keywords—PID controller; maximum stability degree criterion; underdamped systems; performance of the control system

I. INTRODUCTION

The practice of the automation of the technological processes demonstrates that most of the industrial processes can be controlled by PID control algorithms and its variation. The are a lot of tuning methods of the PID controller that permits to achieve the imposed performance and good robustness to the automatic control systems. There is a relevant issue, as there are many processes (robot arms, cranes, power system electronics etc.) in automation practice that exhibit oscillatory behaviour. These processes are described by the second order models and can required the transient response of the closed loop system with minimum overshoot and perturbation rejection [1].

There are proposed several tuning methods of the PID controller for underdamped systems as Ziegler-Nichols method, frequency methods, Posicast Input Command Shaping (PICS) method. Some of these methods require to be known the mathematical model that approximates the dynamics of the process [1-3].

In this paper, there are proposed the analytical expressions for calculation the tuning parameters of the PID controller for the processes that are described by the second order model of objects. These analytical expressions were developed based on the maximum stability degree criterion and they depend on the values of the damping ratio, natural frequency and transfer coefficient of the system, which are obtained from the step response of the open-loop system.

II. THE TUNING PROCEDURE OF THE PID CONTROLLER TO THE UNDERDAMPED SECOND-ORDER PROCESSES

It is considered given the conventional structure of the automatic control system (Fig. 1), which includes the control object with inertia second order and the controller that represents the generalized form of the PID controller, which it is described by the following transfer function [1]

$$H_R(s) = k_p + \frac{k_i}{s} + k_d s = \frac{k_i + k_p s + k_d s^2}{s}, \qquad (1)$$

where k_p, k_i, k_d are the tuning parameters of the controller.

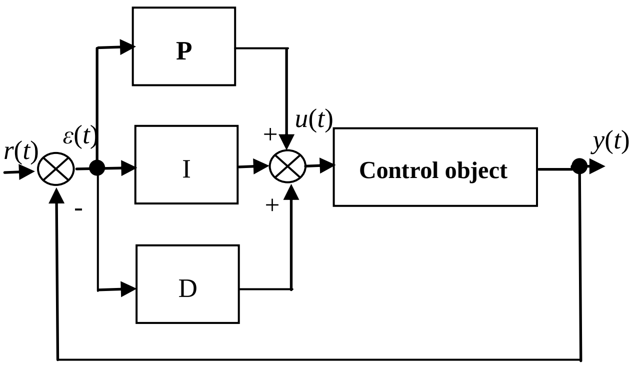

Figure 1. Block scheme of the automatic control system.

The control object is described by the transfer function with inertia second order [1]:

$$H_F(s) = \frac{k\,\omega_n^2}{s^2 + 2\xi\omega_n s + \omega_n^2} = \frac{k}{a_0 s^2 + a_1 s + a_2}, \quad (2)$$

where k is the transfer coefficient of the control object; ω_n - is the natural frequency, ξ - is the damping ratio, and $a_0 = \frac{1}{\omega_n^2}; a_1 = \frac{2\xi}{\omega_n}; a_2 = 1.$

The value of transfer coefficient, natural frequency and damping ration can be calculated from the step response of the open system:

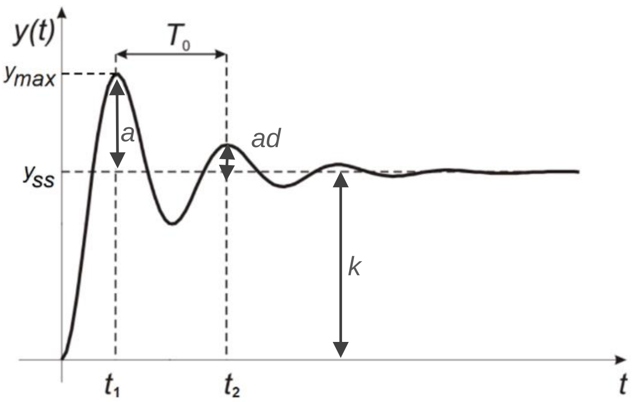

Figure 2. Step response of the underdamped system.

From Figure 2, the damping ratio is calculated according to the [6, 9]:

$$\xi = \frac{1}{\sqrt{1 + (2\pi / \log d)^2}} \quad (3)$$

where d is decay ratio.

The value of the natural frequency is given by:

$$\omega_n = \frac{2\pi}{T_0\sqrt{1-\xi^2}} \quad (4)$$

where $T_0 = t_2 - t_1$ is period of oscillations.

One of the criterion that is used for tuning the PID controller is maximum stability degree (MSD) criterion [4, 8]. This criterion supposes the maximum displacement in the complex half-plane of the nearest characteristic equation's roots of the designed system to the imaginary axe $Re\, p_i \leq 0$.

The characteristic equation of the closed-loop control system is:

$$A(s) = \frac{1}{k}(a_0 s^3 + a_1 s^2 + a_2 s) + k_d s^2 + k_p s + k_i. \quad (5)$$

In the work [9], was proposed for the case when number of the tuning parameters is equal or less then the characteristic equation order, the maximum stability degree value is calculated by the following expression:

$$J = \frac{a_1}{2a_0}. \quad (6)$$

In the paper [9], has been defined the expression for calculation the value of maximum stability degree of the system in dependency of the tuning parameters:

$$J = \frac{k_p}{2k_d}. \quad (7)$$

In this case, by doing the equalling of the expressions (6) and (7), it is obtained

$$\frac{k_p}{2k_d} = \frac{a_1}{2a_0}. \quad (8)$$

From expression (8), it can be presented the analytical expression for calculation the derivative tuning parameter:

$$k_d = \frac{a_1}{a_0} k_p. \quad (9)$$

Next, according to the maximum stability degree method with iterations [7], there are obtained the analytical expressions for calculation the tuning parameters of the PID controller:

$$k_p = \frac{1}{k}(-3a_0 J^2 + 2a_1 J - a_2) + 2k_d J, \quad (10)$$

$$k_i = \frac{1}{k}(a_0 J^3 - a_1 J^2 + a_2 J) - k_d J^2 + k_p J, \quad (11)$$

$$k_d = \frac{1}{2k}(6a_0 J - 2a_1). \quad (12)$$

In this way, using the (7)-(9) expressions, the dependencies (10)-(12) can be rewritten as:

$$k_p = 2J \cdot k_d, \quad (13)$$

$$k_i = \frac{a_2}{k} J, \quad (14)$$

$$k_d = \frac{a_1}{2k}. \quad (15)$$

According to the expressions (3)-(4) the analytical expressions (13)-(15) can be rewritten in the following form:

$$k_p = 2J \cdot k_d, \quad (16)$$

$$k_i = \frac{1}{k} J, \quad (17)$$

$$k_d = \frac{\xi}{k\omega_n}. \quad (18)$$

The tuning parameters depend on the object parameters that are known and can be determinate from the experimental curve of the open loop system and depend on the value of the maximum stability degree *J*, that can be calculated from the (6) expression.

The procedure for optimization the performance of the automatic control system supposes the variation of the stability degree value *J*>0. According to this variation it is possible to obtain the transient responses with different system performances as overshoot and settling time.

III. Study Case and Computer Simulation

It is considered that the underdamped second-order process has the step response presented in the Figure 3.

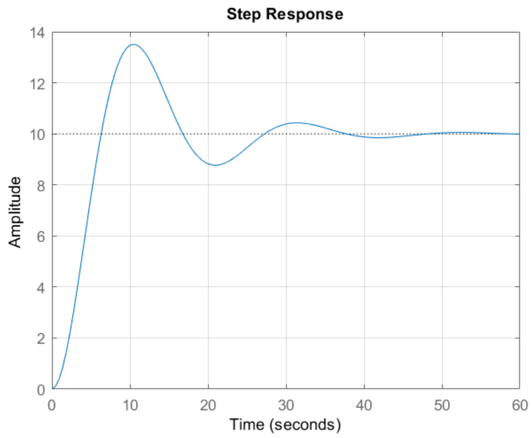

Figure 3. The step responses of the open-loop system.

Based on the expressions (3)-(4) according to the step response, there are calculated parameters of the control object:

$$\omega_n = 0.315,\ \xi = 0.317,\ k = 10.$$

The obtained transfer function, that describes the process is the following:

$$H_F(s) = \frac{k\,\omega_n^2}{s^2 + 2\xi\omega_n s + \omega_n^2} = \frac{0.99225}{s^2 + 0.1997\,s + 0.09922}. \quad (19)$$

Based on the analytical expressions for calculation the tuning parameters of the PID controller (16)-(18), there are obtained the different sets of the tuning parameters presented in the Table I, for the different values of the stability degree.

TABLE I. Tuning Parameters of the PID Controller and Performance of the Control System

No	J	k_p	k_i	k_d	t_s	t_r	σ
1	0.099	0.0199	0.009	0.1006	39.50	39.50	0
2	0.13	0.0262	0.013	0.1006	29.39	29.39	0
3	0.16	0.0322	0.016	0.1006	26.26	9.734	0.81
4	0.2	0.0403	0.02	0.1006	39.93	7.09	3.52
5	0.25	0.0503	0.025	0.1006	47.56	5.66	10.89

The simulation results of the control system with PID controller tuned by the proposed method is presented in the Figure 4, for differents values of the stability degree: curve 1 – transient response for J = 0.099, curve 2 – transient response for J = 0.13, curve 3 – transient response for J = 0.16, curve 4 – transient response for J = 0.2, curve 5 – transient response for J = 0.25.

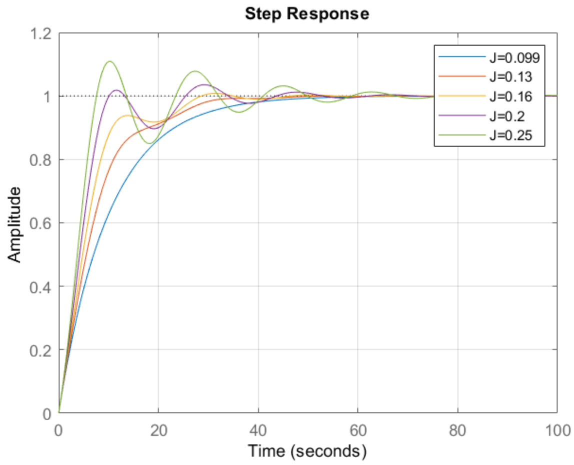

Figure 4. The step responses of the control system.

IV. Conclusions

In this paper, it is proposed the method for tuning the PID controller to the second order underdamped systems. These method can be easily applied for the case then it is known just the step response of the open loop underdamped system and according to the proposed analytical expressions can be calculated the tuning parameters of the PID controller based on the values of the: damping ratio, transfer coefficient and natural frequency.

These expressions were development based on the maximum stability degree criterion, which ensures the good robustness to the control system. The optimization procedure permits to obtain the different performance of the automatic control system by varying the value of the maximum stability degree.

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Tuning the PID Controller to the Object Model with Second-Order Inertia with Identical Elements and Time Delay by the Modified Polynomial Method

Bartolomeu Izvoreanu [1], ORCID: 0000-0001-9886-5878
Adrian Secrieru [1], ORCID: 0000-0002-5816-3246
Ion Fiodorov [1], ORCID: 0000-0003-0938-3442
Irina Cojuhari [1], ORCID: 0000-0003-2248-1338
Dumitru Moraru [1], ORCID: 0000-0001-8957-6046
Mihail Potlog [1], ORCID: 0000-0002-3400-4478
[1] Technical University of Moldova, Chisinau, Republic of Moldova, bartolomeu.izvoreanu@ati.utm.md, adrian.secrieru@ati.utm.md, ion.fiodorov@ati.utm.md, irina.cojuhari@ati.utm.md, dumitru.moraru@ati.utm.md, mihail.potlog@ati.utm.md

***Abstract*—The paper presents the procedure for tuning the PID control algorithm to the object model with second-order inertia with identical elements and time delay according to the modified polynomial method. Methods that can be applied for tuning the PID control algorithm to this control object model are analyzed. The modified polynomial method of tuning the PID algorithm to the second-order inertial control object model with identical elements and time delay is developed, which presents as a simple procedure. To compare the obtained results, tuning methods are applied: the maximum stability degree method in analitycal form and with iterations, Ziegler-Nichols method and parametrical optimization of the PID controller to the model of the given object. The tuning algorithm according to the method of the maximum degree of stability with iterations and the modified polynomial method is synthesized for an example of the object model with second-order inertia with identical elements and time delay, and the results obtained for the variation of the object model parameters are analyzed. The advantages of the maximum stability degree methods with iterations and modified polynomial are highlighted.**

Keywords – second-order inertial object model with identical elements and time delay; tuning methods; PID algorithm; maximum stability degree method with iterations; modified polynomial method; performance; robustness

I. INTRODUCTION

In the automation of slow and very slow industrial and technological processes after the step response of the system the mathematical model of the control object is approximated. The paper analyzes the approximation of the step response of these processes with the transfer function with second-order inertia with identical elements and time delay, described by the transfer function:

$$H_P(s) = \frac{ke^{-ds}}{(Ts+1)^2}, \tag{1}$$

where k is the transfer coefficient, T – the time constant, d - the time delay.

The time delay component is a transcendent function, which has a strong influence on the stability and quality of the synthesized automatic system [1-2].

Dead-time transfer elements do not have finite-dimensional systematic realizations, but have an infinite number of poly-zeros, and to obtain rational representations the transcendental component is approximated by Pade approximants with minimum and non-minimum phase etc. [1-2].

Next it is necessary to tune the PID controller to the control object model (1). Methods for synthesizing control algorithms are developed: frequency, experimental methods, integral criteria etc. [1-7].

The frequency methods for synthesis the controllers are applicable for the model (1), but the calculations are accompanied by graphical constructions and the procedure becomes difficult [1-2].

The basic experimental method presents the Ziegler-Nichols (ZN) method, which is widely used in the practice of tuning the typical P, PI, PID algorithms to the model of object (1), but the system performances are reduced [1].

For the use of the integral criteria method, it is necessary that the time delay component be approximated with rational functions, which leads to raising the order of the object model and create difficulties in synthesizing the control algorithm.

The paper uses maximum stability degree method in analytical form (AMSD) [8], maximum stability degree method with iterations (MSDI) [9-10] and the polynomial method [2] for the tuning the PID controller to the control object (1).

An example of tuning the PID controller to the second-order inertia control object model with identical elements and time delay is presented, and the variation of the control object parameters from the nominal values is analyzed.

II. PID Controller Tuning Algorithms

In the study, the structural block diagram of the automatic control system is used, consisting of the object model with transfer function $H_P(s)$ and the controller with transfer function $H_R(s)$ as it is shown in Figure 1, subjected to the action of the unit step input $r(t)$ and $e(t)$ is the system error, $u(t)$ – the command developed by the controller and $y(t)=h(t)$ – the step response of the system.

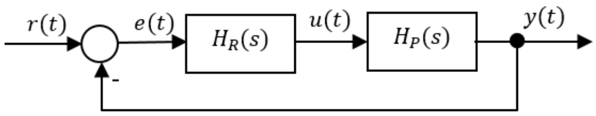

Figure 1. Structural block scheme of the automatic system.

Consider the standard PID control algorithm in parallel connection described with the transfer function:

$$H_{PID} = k_p + \frac{k_i}{s} + k_d s = \frac{k_d s^2 + k_p s + k_i}{s}, \qquad (2)$$

where k_p, k_i, k_d are tuning parameters of the proportional, derivative and integrative component of the PID control algorithm.

To tune the parameters of the PID control algorithm to the model of object (1), the method AMSD, MSDI methods and the polynomial method and the modified polynomial method are used.

For the method of the maximum stability degree in analitical form, the analytical expressions for calculations the parameters of the PID controller to the model of the control object (1) for the order of the model n are presented in the general form [9-10]:

$$(1-TJ)^n(-c_0J^4 + c_1J^3 - c_2J^2 + c_3J - c_4) = 0 \qquad (3)$$

$$\begin{aligned}
&c_0 = d^3T^3,\ c_1 = 3d^2T^2(T(n+1)+d),\\
&c_2 = 3dT(d^2 + dT(2n+3) + T^2n(n+1)),\\
&c_3 = d^3 + 3d^2T(n+3) + 3dT^2n(n+3) + T^3n(n^2-1),\\
&c_4 = 3d^2 + 6ndT + 3nT^2(n-1).
\end{aligned}$$

$$\begin{aligned}
k_p &= \frac{e^{-dJ}}{k}(1-TJ)^{n-2}(d^2T^2J^4 + dT(T(2n+1)+\\
&+2d)J^3 + (d^2 + 2dT(n+1) + T^2(n^2-1))J^2 -\\
&-(d+T(n-2))J - 1) = \frac{e^{-dJ}}{k}(1-TJ)^{n-1}(-dTJ^2 +\\
&+(T(n+1)+d)-1)J + 2k_dJ = f_p(J) \qquad (4)
\end{aligned}$$

$$\begin{aligned}
k_i &= \frac{e^{-dJ}}{2k}(1-TJ)^{n-2}(d^2T^2J^2 - 2dT(d+nT)J +\\
&+d^2 + 2dTn + T^2n(n-1))J^3 =\\
&= \frac{e^{-dJ}}{k}(1-TJ)^nJ - k_dJ^2 + k_pJ = f_i(J) \qquad (5)
\end{aligned}$$

$$\begin{aligned}
k_d &= \frac{e^{-dJ}}{2k}(1-TJ)^{n-2}(d^2T^2J^3 - 2dT(d+\\
&+T(n+1))J^2 + (d^2 + 2dT(n+2)+\\
&+T^2n(n+1))J - 2(d+Tn)) = f_d(J), \qquad (6)
\end{aligned}$$

where J is the degree of stability of the system.

From the algebraic equation (3), the maximum degree of stability J_{opt} of the system is determined as the smallest after the positive real root value or the positive real part of the complex root [8-10].

Knowing the parameters of the object model (1) and the optimal degree of stability J_{opt}, from (4)-(6) the numerical values of the optimal parameters k_p, k_i, k_d of the PID controller are calculated.

Determining the parameters of the PID algorithm according to relations (4)-(6) does not guarantee the automatic system the stability and the highest performance of the designed system.

In this case, the maximum stability degree method with iterations is applied, which reduces to the following procedure. According to relations (4)-(6) as functions $k_p = f_p(J)$, $k_i = f_i(J)$, $k_d = f_d(J)$ of the degree of stability argument J , the argument $J = 0...\infty$ is varied and the curves $k_p = f_p(J)$, $k_i = f_i(J)$, $k_d = f_d(J)$ are constructed. Next, on these curves, sets of J_i values for $k_{pi} = f_p(J_i)$, $k_{ii} = f_i(J_i)$, $k_{dl} = f_d(J_i)$ are chosen iteratively on the slope of the curves in the vicinity of the optimal value of J_{opt}, the automatic system is simulated and the possible high performances of the automatic system are determined [9-10].

The polynomial method of tuning the PID controller to the object model (1) is based on the following arguments [2,6]. From the formulation of the controll algorithm synthesis procedure, the formula is applied to determine the transfer function of the controller $H_R(s)$ [1,2]:

$$H_R(s) = \frac{H_0(s)}{1-H_0(s)}\frac{1}{H_P(s)} = \frac{H_0(s)}{1-H_0(s)}\frac{(Ts+1)^2}{e^{-ds}}\frac{1}{k}, \quad (7)$$

where $H_0(s)$ is the transfer function of the unknown closed system, $H_P(s)$ is the transfer function of the controller.

1. It is considered that tuned automatic system ideally reproduces the unit step input signal and $H_0(s) = 1$.

2. The transcendental function e^{-ds} is approximated, applying the series presentation and keeping only the first two terms:

$$e^{-ds} \approx 1 - ds. \quad (8)$$

Based on conditions (8), relation (7) is presented in the following form:

$$H_R(s) = \frac{H_0(s)}{1-H_0(s)}\frac{1}{H_P(s)} = \frac{1}{1-1}\frac{(Ts+1)^2}{e^{-ds}}\frac{1}{k} =$$
$$= \frac{1}{1-(1-ds)}\frac{T^2s^2+2Ts+1}{k} = \frac{T^2s^2+2Ts+1}{kds} =$$
$$= \frac{T^2s^2}{kds} + \frac{2Ts}{kds} + \frac{1}{kds} = k_p + \frac{1}{T_i s} + k_d. \quad (9)$$

where $k_p = 2T/kd$ is the coefficient of the proportional part, $T_i = kd$ represents the integration time constant and $k_i = 1/T_i$, $k_d = T_d = T^2/kd$ are the derivation time constant.

Relation (9) shows the proportional-integrative-derivative PID controller with parameters k_p, k_i and k_d.

After an analysis of the stability conditions and the simulation of the automatic system for the case of the model (1), the solution is adopted to introduce the weighting coefficient n in the formula (9) for calculating the controller parameters according to the modified polynomial method to satisfy the stability and performance conditions of system:

$$k_p = \frac{T}{nkd},\; T_i = nkd,\; k_i = \frac{1}{nkd}, \quad (10)$$

where $n = 2...4$ depending on the desired performance of the automatic system.

III. Applications and Simulation on the Computer

Let's consider the model of the controller object with inertia of the first order with identical elements and time delay with the parameters: transfer coefficient $k = 2$, time constant $T = 10\,s$, time delay $d = 2\,s$.

Calculations are performed to tune the PID algorithm to the model (1) according to the AMSD method. From (3) as an algebraic equation of the fourth degree, the optimal stability degree $J_{opt} = 0.2728$ was obtained and the parameters of the PID controller were calculated according to relations (4)-(6), which are presented in row one of Table I. After an analysis with the GMSI method, the degree of stability $J_{opt} = 0.2728/2 = 0.1364$ was determined and the parameters of the PID controller presented in row two of Table I were determined, and the calculation of the parameters of the PID controller for $J = 0.14$ is given in row three of Table I.

TABLE I. THE TUNING PARAMETERS AND AUTOMATIC CONTROL SYSTEM PERFORMANCE

No	Method	Max. degree J	Tuning parameters				Performance of the system			
			k_p	k_i, s^{-1}	T_i, s	k_d, s	t_c, s	c, %	t_r, s	n
1	AMSD	0.2728	2.9834	0.217	2.9394	11.195	6.49	49.17	30.81	3
2	MSDI1	0.1364	1.5275	0.0828	12.0773	11.0857	10.83	-	10.83	-
3	MSDI2	0.14	1.595	0.0874	11.4416	1.17	10.17	3.14	10.17	-
4	PM		5	0.25	4.000	25	Unstable system			
5	PM1 $n=2$		2.5	0.125	8.00	12.5	6.59	29.05	21.15	2
6	PM2 $n=3$		1.6667	0.0833	12.0048	8.3333	9.37	2.75	9.37	-
7	ZN		3.186	0.0822	12.165	2.535	8.27	46.06	55.77	4
8	OP		1.35	0.064	15.62	6.5447	15.82	-	15.82	-

The calculations according to (10) were performed to assign the parameters of the PID controller for the polynomial method, the modified polynomial method for two values of the weighting coefficient $n=2$ and 3 and the results are shown in Table I: row 4 polynomial method MP, row 5 method modified polynomial PM1 and row 6 modified polynomial method PM2.

To compare the results obtained by the MSDI and modified polynomial methods, the known methods of tuning the PID algorithm to the given model are applied and the results are presented in Table I: row 6 ZN method, row 7 – parametric optimization method.

According to the data in Table I, the automatic system with the given PID controller was simulated on the computer in MATLAB and some of the responses are shown in Figure 2 for the methods: AMSD - curve 1, MSDI1 with $J=0.1364$ – curve 2, modified polynomial PM2 – curve 3 and the parametric optimization method – curve 4 and the performances for all simulated systems are also presented in Table I.

With increasing k, the system with the controller tuned according to the MSDI method has 1.41 times less overshoot and 1.42 times less settling time, than the system with the controller tuned according to the modified polynomial method, and with decreasing k the systems have the same robustness (aperiodic processes).

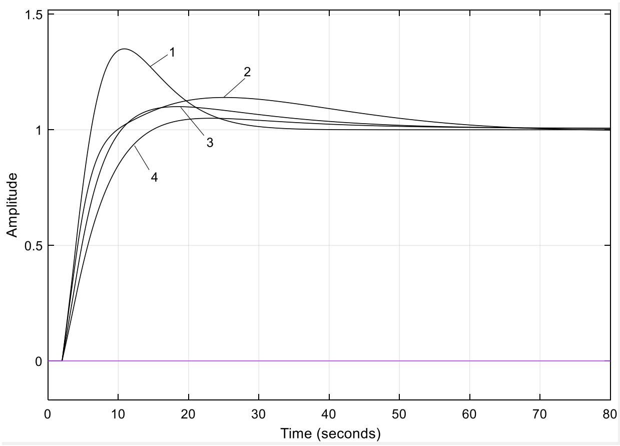

Figure 2. Response of the automatic system

Next, the parameters k, T, d of the object model (1) were changed by $\pm 50\%$ from the nominal values and the system was simulated with the tuned controller according to the MSDI method and the modified polynomial method (PM) at unit step input and the data are presented in Table II.

TABLE II. THE PERFORMANCE OF THE AUTOMATIC CONTROL SYSTEM AT THE VARIATION PARAMETERS OF THE MODEL OF CONTROL OBJECT

Method	Variation parameters of the object			Performance of the system			
	$k=2$	$T=10$	$d=2$	t_c, s	c, %	t_r, s	n
MSDI1	3/1	10/10	2/2	7.06/30.14	18.09/0	14.22/30.14	1/0
	2/2	15/5	2/2	16.68/4.55	17.70/45.0	50.5/60	1/11
	2/2	10/10	3/1	10.30/14.15	12.65/0	19.55/14.15	1/0
PM2	3/1	10/10	2/2	6.51/32.93	25.60/0	20.29/32.93	2/0
	2/2	15/5	2/2	15.60/oscil	14.30/oscil	43.87/oscil	1/oscil
	2/2	10/10	3/1	9.38/14.06	17.81/0	26.30/14.06	2/0

With the increase of T, the system with the controller tuned according to the modified polynomial method PM2 has higher performances: the rise time t_c by 1.06 times, the overshoot n by 1.24 times and the settling time t_r by 1.15 times, and with the reduction of T, the system with the controller tuned by the MSDI1 method is much more robust than the PM2 modified polynomial tuned controller system, which destabilizes – highly oscillating responses.

With the increase of d, the system with the controller tuned according to the MSDI1 method is 1.41 times more robust after overshoot and 1.34 times after the settling time, than the system with the controller tuned according to the PM method, and with the reduction of k the systems have the same robustness (aperiodic processes).

IV. CONCLUSIONS

1. For tuning the PID controller to the second-order inertial object model with identical elements with time delay with the parameter values from the analyzed example, it is recommended to use the modified polynomial method, for which the calculations are very simple.

2. The system with the controller tuned according to the MSDI1 method and the system with the controller tuned according to the modified polynomial method PM2 within the limits of the 5% steady state error have the same performance. The system with the tuned controller according to the modified polynomial method PM2 has destabilizing tendencies.

3. When the parameters of the object model in the analyzed example (Table II) are varyed, the automatic system with the controller tuned according to the MSDI1 method is more robust than the automatic system with the controller tuned according to the modified polynomial method PM2.

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Analysis of Code Sequences for Multichannel Data Transmission Systems

Tatiana Sestacova [1], ORCID: 0000-0002-6995-4254
Gherman Sorochin [1], ORCID: 0000-0003-0136-1759
[1] Technical University of Moldova, MD-2004, Chişinău, bd. Ştefan cel Mare şi Sfânt, 168,
tatiana.sestacova@sde.utm.md, gherman.sorochin@sde.utm.md

Abstract — **A comprehensive indicator of the quality of information transmission systems under the influence of interference of natural or artificial origin is noise immunity. The paper presents the results of studies on improving the noise immunity of systems through the use of broadband or noise-like signals based on Walsh functions for information transmission.**

Keywords— noise-like signal; pseudo-random sequences; Walsh function derivative; generating function.

I. INTRODUCTION

Any data transmission system, as an open system, is generally affected by interference and multipath fading caused by natural origin, and the communication channel is also subjected by artificial interference from systems of deliberate destruction of information, suppression or interception of data.

Noise immunity is the main comprehensive indicator of the quality of information transmission systems (ITS), which includes: noise immunity, energy secrecy, structural or parametric secrecy, cryptographic stability, imitation resistance, protection of information from deliberate interference, suppression and interception of signals, protection of information from unauthorized access [1].

At the same time, many of these indicators are successfully solved by using broadband or noise-like signals for information transmission.

II. MAIN PART

A. Theoretical statements

The broadband transmission method was discovered by C. Shannon, who first introduced into consideration the concept of channel capacity:

$$C = W \log_2\left(1 + \frac{P_s}{P_n}\right) \tag{1}$$

where C – channel capacity, bit/s; W – the bandwidth, Hz; P_s – signal power; P_n – noise power [1], [2].

This equation establishes a relationship between the possibility of error-free transmission of information over a channel with a given signal-to-noise ratio (SNR) and the bandwidth allocated for information transmission. It follows from the Shannon formula that an interchange between signal power and bandwidth is possible - the same channel bandwidth ability can be provided with a high useful signal level and a narrow bandwidth, or can de provided with a low useful signal level and a wide bandwidth. Moreover, the second option is preferable.

Noise-like radio signals **(NLS)** or spread spectrum radio signals refer to CDMA (Code Division Multiple Access) technology.

There are two code division multiple access methods:

– ***asynchronous (non-orthogonal)*** multiple access using sign-alternating periodic chip *non-orthogonal pseudo-random sequences (PRS);*

– ***synchronous (orthogonal)*** multiple access based on sign-alternating periodic chip *orthogonal* Walsh functions.

The term "chip" refers to an elementary pulse signal. The duration of the PRS chips or Walsh function chips is much shorter than the duration of the information signal bit *($T_{ch} << T_b$).*

Asynchronous (not orthogonal) access in multichannel communication is characterized by the fact that radio signals are transmitted simultaneously by many unsynchronized transmitters from different geographical locations on the same carrier frequencies by one of the types of manipulation. In each transmitter, the bits of information signals are encoded (modulated) by individual PRSs, the chip rate of which is significantly higher than the bit rate. The PRS period T characterizes the length of the PRS and contains L chips. If each bit of the information signal is encoded by L chips of PRS, then its spectrum is expanded by L times, which leads to the expansion of the radio signal spectrum also by L times.

With asynchronous access, a correlation technique is used, based on the selection of an outlier of the ***autocorrelation function (ACF)*** of a separate PRS. Pseudo-random sequences are chosen in such a way that they can be separated in the receiver, and then the desired information signal can be separated from its SRP.

To separate the SRP, it is necessary that they have a small cross-correlation (close to zero), i.e. they were almost independent.

Synchronous (*orthogonal*) access in multi-channel communication is characterized by the fact that a plurality of information signals are transmitted synchronously by one transmitter at one carrier frequency. In this case, the bits of each of the information signals in the transmitter are pre-coded (modulated) by the corresponding Walsh function of length J, the chip rate of which is significantly greater than the bit rate. The *Walsh functions are orthogonal, i.e. have a mutual correlation equal to zero.* Next, the second stage of coding (modulation) is carried out using a certain SRP of length $L = J$. In this case, the spectrum of each information signal is expanded by L times.

The resulting signals are added and form a single digital stream with an L-fold extended spectrum, which performs some kind of manipulation of the transmitter carrier frequency. In this case, a radio signal is formed with a spectrum extended by L times.

Synchronous access uses a correlation technique based on the orthogonality (independence) of the Walsh functions. The orthogonality property of the Walsh functions makes it possible to separate signals by chip integration with accumulation and thus to extract the transmitted information signals.

In this case, the complete SRP ensemble must be chosen such that the cross-correlation between any pair of sequences is sufficiently small. This allows to minimize the level of interference on adjacent channels. Theoretically, the cross-correlation value is equal zero for ensembles of orthogonal spreading signals (eg, basis functions of Fourier series and Walsh functions).

The dominant role in choosing the type of SRP for the formation of NLS in data transmission systems is played, first of all, by the mutual and autocorrelation characteristics of the signal ensemble, its volume, and the ease of implementation of devices for signals generating and "compressing" (convolution) in the receiver [1] –[4].

Discrete signals with the best ***cross-correlation function (CCF)*** structure include signals which are encoded using the corresponding Walsh function [1], [2].

The most common orthogonal system used in multichannel code division systems are Walsh-Hadamard matrixes of order $N = 4k$ (k is an integer), which is determined by the recursive rule:

$$W_{2N} = \begin{bmatrix} W_N & W_N \\ W_N & -W_N \end{bmatrix}, \tag{2}$$

where W_N is the Walsh–Hadamard matrix of order N, is assumed that $W_1 = 1$, or in the signed form $W_1 = +$.

However, a feature of orthogonal codes is that the orthogonality of these codes is performed only at the "point", i.e. in the absence of time shifts. In reality, such conditions are not met, orthogonality is violated. This, in turn, leads to an increase in the level of multiple access interference and to the appearance of errors in the processing of input data. Therefore, to eliminate these shortcomings various methods are used.

One of the ways to improve the properties of correlation functions (ACF and CCF) of the Walsh signal system is the construction of the so-called systems of *derivative* signals [5].

A ***derivative*** signal is such a signal that is obtained as a result of element-wise (symbol-by-symbol) multiplication of two signals. A system composed of derivative signals is called a derivative system [1], [2].

As a generating signal, such a signal is chosen so that the *derivative* system has good correlation properties.

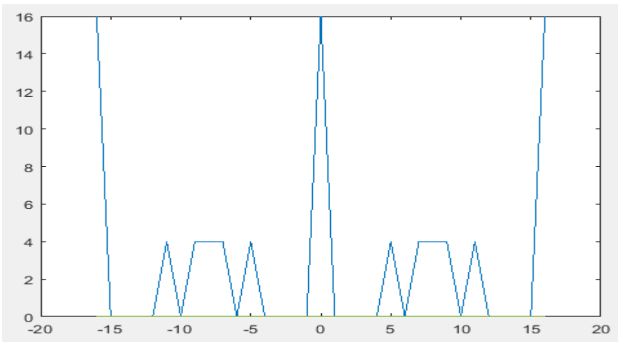
B. Experimental data

Let's consider the correlation properties of the *derivatives* of the Walsh functions, if we take as the *generating* functions M–sequence with a generating polynomial $f(x) = x^4 \oplus x^3 \oplus 1$ and a composite combination of 5 and 11-bit Barker codes [5].

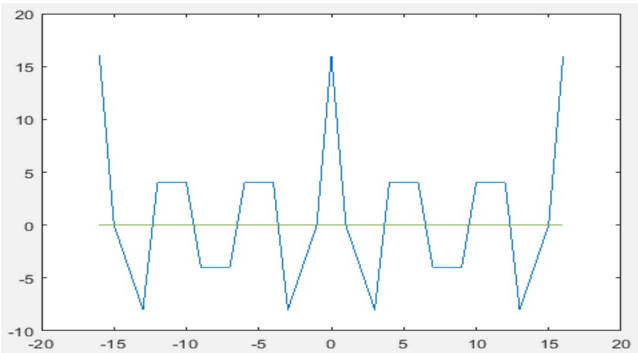
The PRS, that is generated by generator for M - sequence in the form of a shift register with linear feedback under certain initial conditions (A = 1000), in the bipolar representation will be B_1 = +1+1+1+1-1+1 -1+ 1+1-1-1+1-1-1-1, and the sequence of Barker codes will be B_2 = +1+1+1 -1+1+1+1+1-1-1-1+1-1- 1+1-1.

Consider the correlation functions of the derivatives of the Walsh functions (for example, the 2nd and 12th [1]), with the generating functions B_1 and B_2, respectively. Since the length of M - sequence is $L = 2^n - 1 = 2^4 - 1 = 15$, then in the original Walsh matrix, when constructing the derivatives of the Walsh functions, the highest bit remains unchanged. In this case, the 2nd and 12th derivatives of the Walsh function with the generating function *in the form of M - sequence* B_1 will look like B_3 = +1+1+1-1+1+1+1+1+1-1-1+ 1+1+1-1+1 and B_4 = +1-1-1+1+1+1-1-1-1+1-1+1-1-1-1+1 respectively. And the 2nd and 12th derivatives of the Walsh function with the generating function *in the form of a composite combination of Barker codes* will look like: B_5 = +1-1+1+1+1-1+1-1-1+1-1-1 -1+1+1+1 and B_6 = +1-1-1-1+1-1-1+1+1-1-1-1+1-1+1+1 respectively.

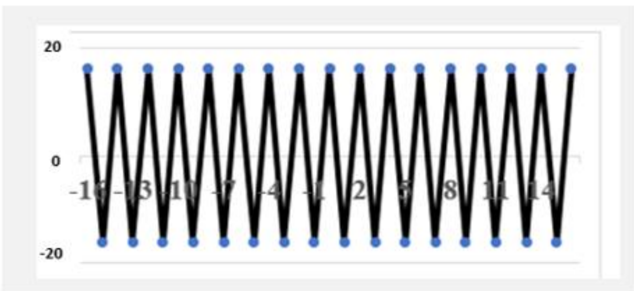
On fig. 1 is shown the results of calculating the *periodic autocorrelation functions* ***(PACF)*** of the selected derivatives (a, b) and the *original* (c) Walsh functions.



a)



b)



c)

Figure 1. PACF of the 2nd (a) and 12th (b) derivatives of the Walsh functions with generating function $\mathbf{B_1}$, PACF of the 2nd original Walsh function (c)

As can be seen from Fig. 1, the considered PACFs have better autocorrelation functions, in contrast to the PACFs of the original Walsh functions (where there is no central maximum and side lobes).

To ensure the synchronization during reception, it is necessary to eliminate the influence of side lobes, while the suppression coefficient - *the ratio of the amplitude of the main lobe of the ACF to the maximum value of the amplitude of the side lobe* - ranges from 4 for the 2nd PACF to 2 for the 12th PACF of the Walsh function derivative.

Fig. 2 presents the cross-correlation function **(CCF)** of the 2nd and 12th derivatives of the Walsh functions with the generating function in the form of M - sequence $\mathbf{B_1}$**.**

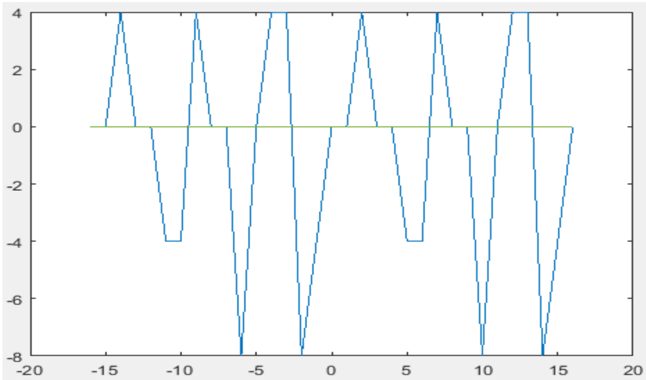
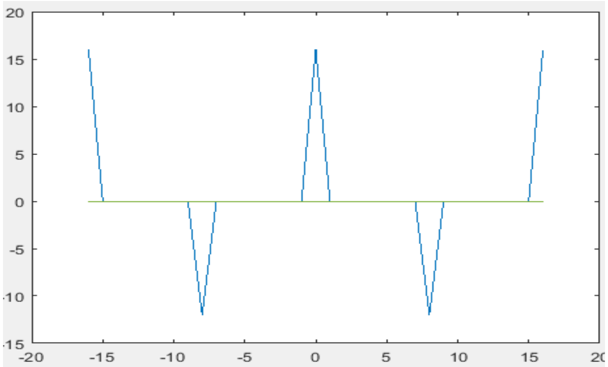


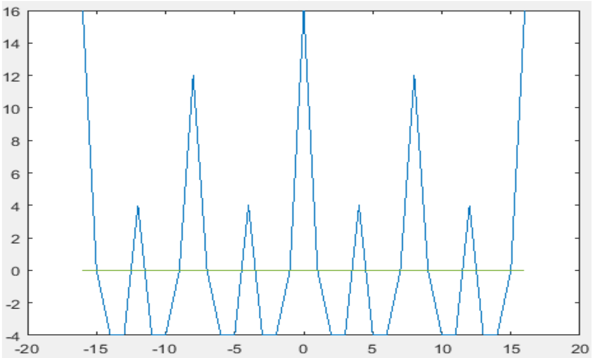
Figure 2. CCF of the 2nd and 12th derivatives of the Walsh functions with the generating function **B1**

From Fig. 2 follows that the CCF of the considered *derivatives* of the Walsh functions can be considered satisfactory, the CCF is more or less uniform, without extreme emissions and can be used in code division systems using decision devices that do not respond to CCF emissions within the specified limits.

On fig. 3 shows the PACFs of the *derivatives* of the Walsh functions with the other generating function - $\mathbf{B_2}$. As can be seen from fig. 3, the PACFs of the *derivatives* of the Walsh functions do not have very good autocorrelation functions. The suppression coefficient for both functions is only 1.33. In contrast to the periodic one, the *cross-correlation function* CCF of the derivative functions shown above can be considered satisfactory, as they have no extreme outliers, which are within values ±4 (Fig. 4).



a)



б)

Figure 3. PACF of the 2nd (a) and 12th (b) derivatives of the Walsh functions with the generating function $\mathbf{B_2}$

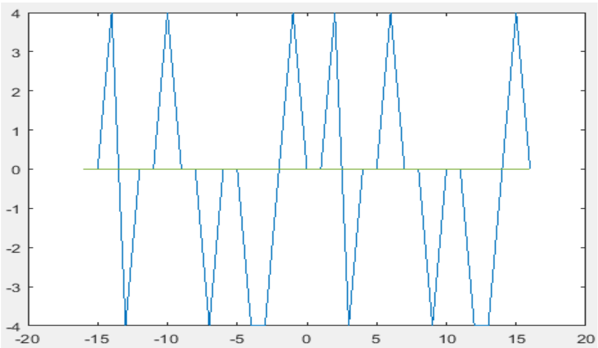


Figure 4. CCF of the 2nd and 12th derivatives of the Walsh functions with a generating function $\mathbf{B_2}$

III. Conclusion

The carried out researches and analysis of their results allows to make following conclusions:

1. To increase the noise immunity of data transmission systems, it is necessary to use broadband (noise-like) signals, which must have certain correlation properties: the autocorrelation function of the ACF of such signals must have one central maximum and a minimum level of side lobes, and the mutual correlation function must be equal to 0.

2. It is known that such properties are possessed by orthogonal functions, on the basis of which orthogonal signal systems are built, for example, signals based on Walsh functions.
Correlation characteristics of Walsh functions that are orthonormal have good cross-correlation functions, which are equal to zero between two different Walsh functions. However, these functions have such properties only at the point of zero shift. In real conditions, orthogonality is violated and the cross-correlation function is nonzero. This leads to an increase in the level of multiple access interference and signal (or channels) separation errors.

3. The analysis of the correlation properties of the ***derivatives*** of the Walsh functions (for different generators) has shown that they have a much better suppression coefficient in contrast to the original Walsh functions.

4. To reduce the level of interference of multiple access, the ***derivatives*** of the Walsh function must be orthogonal, since in CDMA all subscribers operate in the same frequency band. The cross-correlation function (CCF) will be zero for any shifts τ if the signals are orthogonal. However, due to the linearity of the Fourier transform, this is possible only if the product of the spectral densities of both signals $U(\omega)V^*(\omega) = 0$ on the entire frequency axis. The zero CCF means that two signals are orthogonal for any τ only if their spectra do not overlap. However, *this cannot be achieved in multi-channel code division systems.* The consequence of this is the occurrence of inter-user interference, i.e. non-zero response of the receiver of the k-th user to the signals of other subscribers. Therefore, *the article analyzes what form the CCF of derivatives of Walsh functions must have, depending on the type of generating functions, to obtain the best correlation characteristics*, that ***is very important for CDMA systems. This is the first time such a specific analysis has been carried out.***

5. It was found that a large length of the extension code based on the *derivatives* of the Walsh functions makes it possible to distribute the signal energy over the spectrum, which *increases the noise immunity* of the system. In addition, by masking the useful signal with noise, *reliable protection against unauthorized access is provided.* Also, a low signal level *improves electromagnetic compatibility* with neighboring radio systems.

The obtained research results can be used in the development of broadband communication systems and information transmission systems *with reliable* *protection against unauthorized access*. Such systems with the studied signals make it possible to reduce the energy characteristics, i.e. improve the efficiency of information transmission systems.

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Tuning the Fuzzy Controller for Speed Control of the DC Motor

Vladimir Melnic [1], ORCID: 0000-0003-4180-3654
Irina Cojuhari [2], ORCID: 0000-0003-2248-1338
[1]National Centre of Space Technologies
[2]Department of Software Engineering and Automatics, Technical University of Moldova, Chisinau, Republic of Moldova, vladimir.melnic@mate.utm.md, irina.cojuhari@ati.utm.md

Abstract— **In this paper, it is developed the fuzzy controller for speed control of the DC motor. The obtained results of tuning the controller were compared with maximum stability degree method with iterations and genetic algorithm. To verify the efficiency of the developed fuzzy controller the computer simulation was done. The algorithm of tuning the fuzzy controller was designed according to the error and the rate of change of the error signal, so that performance of the closed-loop step response to be satisfied.**

Keywords—fuzzy controller; PID controller; system performance; automatic control system; maximum stability degree method with iterations

I. INTRODUCTION

The control of the processes is usually used for production in series. The most used control algorithm in industrial applications is the PID controller and its variation P, PI, PD, due to simplity and good performance that they offer to the automatic control system. The PID controller consists from three terms: P – the proportional component (present error), I – the integral component (past errors) and D – derivative component (future variation of the error) [3-6].

However, in some cases the PID controller has a suboptimal performance in the industrial applications. For the last decades, there are developed a lot method for tuning the PID control algorithm and its variation as P, PI, PD controller. These methods and algorithms are mostly insufficient to synthesize the PID controller for a nonlinear process. Some techniques and algorithms that are used to tune the PID controller involve the implication of the operator or engineer. The fuzzy logic for the last period becomes so popular for different industrial domains and achieved a certain degree of success in design the fuzzy controllers. The operation of the fuzzy controller is based on the transfer of experience of the qualified operators. Due to the success of fuzzy controllers, fuzzy PID controllers have been studied in the last ten years and wide used in industrial applications. Also, the application of autonomous or intelligent fuzzy PID controllers has become popular recently, and many researchers have explored the research in the field of self-tuning fuzzy PID controllers. For example, self-tuning fuzzy PID controller has been applied for load and frequency control in energy conversion, heating, ventilation and air conditioning, etc. The self-tuning fuzzy PID controller is a controller with self- learning module.

An automatic system with the fuzzy controller is presented in Figure 1 [7-8].

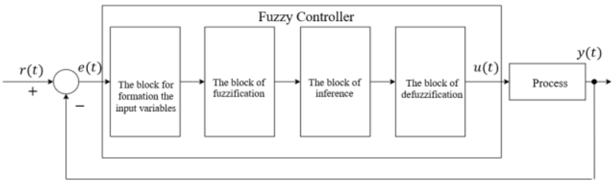

Figure 1. Block scheme of the automatic control system with fuzzy PID controller.

The fuzzy controller has four main components as shown in the Figure 1:

- The block for formation the input variables, in which is defined the input and output variables for fuzzy controller.
- The fuzzification block is the block that helps to convert inputs to language variables. It allows the conversion of crisp numbers into fuzzy sets. The inputs measured by the sensors and passed to the control system for further processing.
- The interference block is the decision-making block, it represents the core of the fuzzy controller, that materializes the human decision-making process.
- The defuzzification block is performed to convert the fuzzy sets into a crisp value. There are many types of techniques for defuzzification. So this block transforms

the fuzzy values of the interference block into well-determined values. The values resulting from the defuzzification are subjected to the inverse normalization operation in order to be brought into an interval close to the range of command quantities [7-8].

In this paper, it is proposed to design the fuzzy controller for speed control of the DC motor, according to the imposed performance.

II. Description of the Designed System

It was used the DC motor FK130SH motor for testing several reaction wheels, that is controlled by the STM32F303K8 microcontroller. The system was implemented based on the NUCLEO-F303K8 platform from ST Microelectronics and the reaction wheel is coupled directly to the motor, Figure 2. As the speed sensor, the EE-SX4235A-P2 transmissive photomicrosensor is used [2].

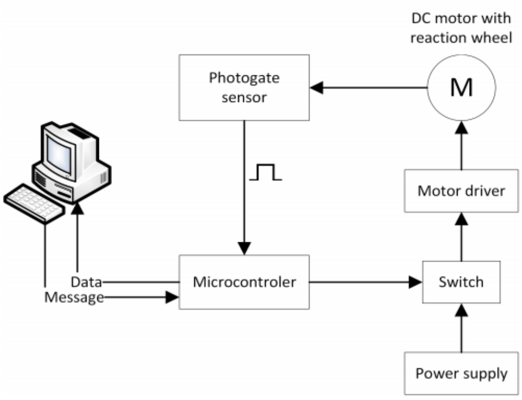

Figure 2. Block diagram of the designed system [1].

It was done the experimental identification of the mathematical model of the DC motor, using the System Identification Toolbox from Matlab. For experimental identification, it was raised the experimental curve of the variation the DC motor speed, for the reference speed of 7330 rpm, Figure 3.

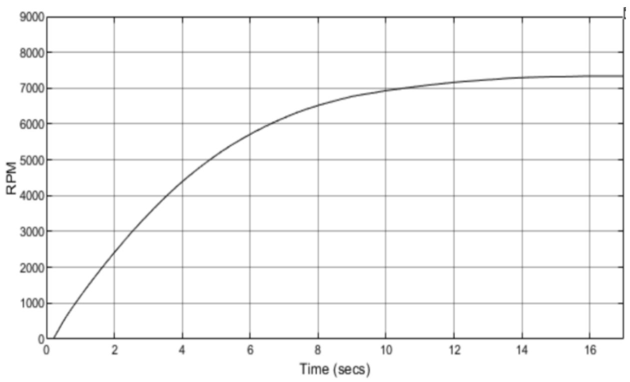

Figure 3. Experimental curve.

The experimental curve of the speed variation of the DC motor, it was approximated with the model of object with inertia second order [1-2]:

$$H(s)=\frac{k}{(T_1 s+1)(T_2 s+1)}=\frac{1.0069}{3.1695s^2+5.0289s+1}. \quad (1)$$

III. Synthesis of the Fuzzy Controller

The fuzzy controller is a controller with two inputs: the error e and the derivative of the error $\grave{e}$ and a single output, which represents the input variable of the process, denoted by the u. The universe of discourse of variables $e, \grave{e}$ and u are $E \subset R$, $\grave{E} \subset R$ and $u \subset R$ respectively. The linguistic values of e and $\grave{e}$ are set on the following sets $A_i(i \in I = [-m, \dots, -2, -1, 0, 1, 2, \dots, m])$ and $B(j \in J = [-n, \dots, -2, -1, 0, 1, 2, \dots, n])$.

If e is A_i and $\grave{e}$ is B_j then u is u_{ij}, where $U_{ij} \in u(i \in I, j \in J)$ is the clear value instead of a fuzzy subset, u_{ij} are not immediately different from each other. The fuzzy controller with such control is called a clear-type fuzzy controller. At a time instant , the observation values e and $\grave{e}$, are shown, which correspond to the system error and the rate of change of the error, respectively. Then the truth values of A_i and B_j are $A_i(e)$ and $B_j(\grave{e}), (i \in I, j \in J)$. Using the sum-of-product inference method, the truth value of the antecedent part of a fuzzy control rule will be [8]:

$$f_{ij} = A_i(e)B_j(\grave{e})(i \in I, j \in J).$$

Reasoning from the antecedent part to the consequent part will generate a fuzzy subset conclusion which is called as C, C will be a discrete fuzzy subset with a finite number of points.

$$C = \{\frac{f_{ij}}{u_{ij}} | i \in I, j \in J\}.$$

Applying the centre of gravity method to defuzzify the fuzzy set *C*, the actual controller output is obtained:

$$u = \frac{\sum_{i,j} f_{ij} u_{ij}}{\sum_{i,j} f_{ij}}.$$

Table I shows the fuzzy rules of the system, based on which the operating conditions of the system are realized [8].

TABLE I. THE BASE OF THE FUZZY RULES

ΔE \ E	NL	NM	NS	ZR	PS	PM	PL
NL	NL	NL	NL	NM	NS	ZR	PS
NM	NL	NL	NM	NS	ZR	PS	PM
NS	NL	NM	NS	ZR	PS	PM	PL
ZR	NM	NS	ZR	PS	PM	PL	PL
PS	NS	ZR	PS	PM	PL	PL	PL
PM	ZR	PS	PM	PL	PL	PL	PL
PL	PL	PL	PL	PL	PL	PL	PL

The rules that were entered using the Fuzzy Logic Toolbox from MATLAB are represented in Figure 4.

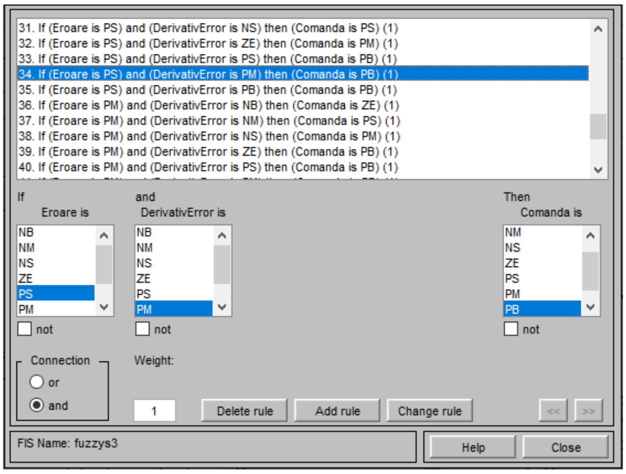

Figure 4. The rules generated based on the rule table from MATLAB.

The rule visualization is presented in the Figure 5.

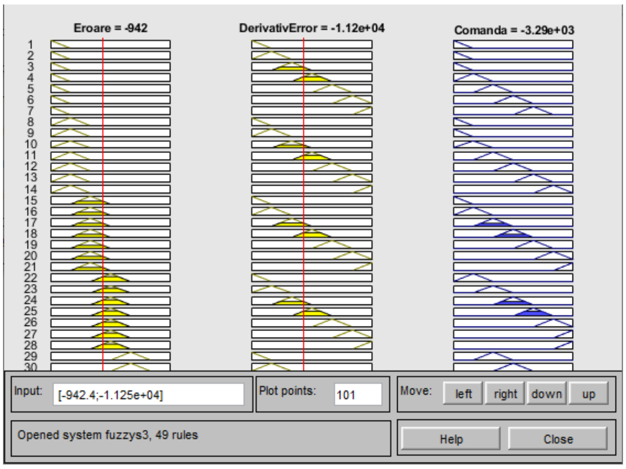

Figure 5. Graphical representation of fuzzy rules.

The membership functions for the input and output variables are presented in the Figure 6.

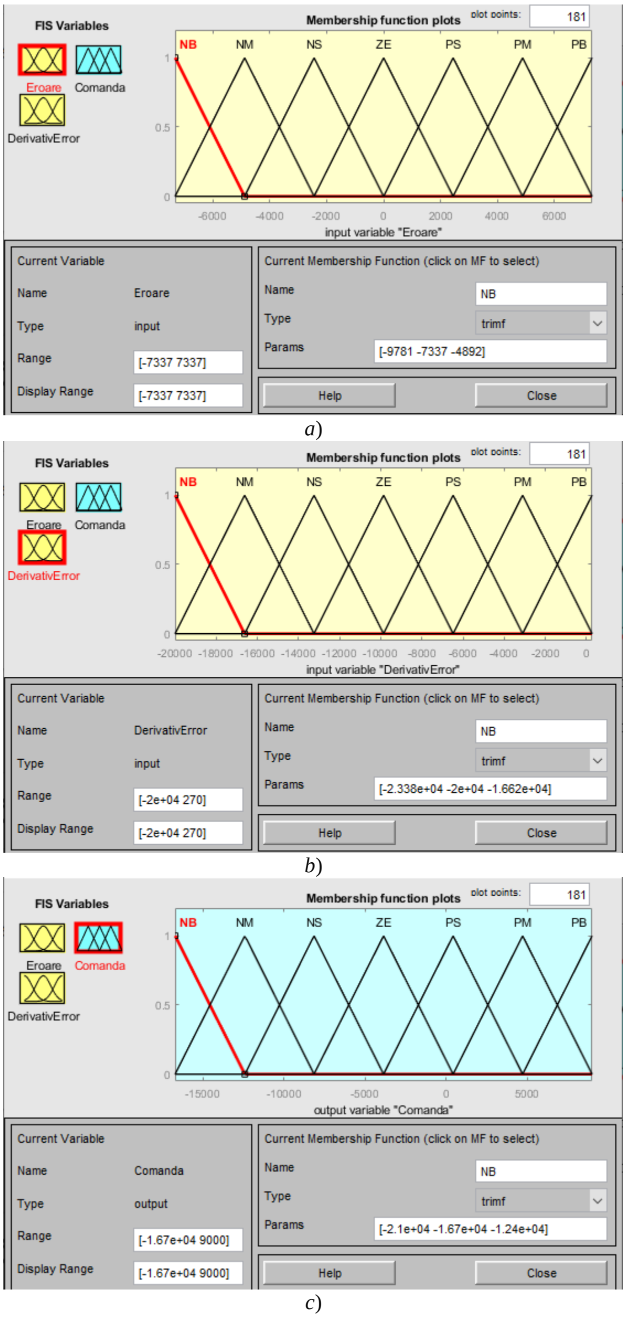

Figure 6. The membership functions: *a*) error signal; *b*) rate of change of the error signal; *c*) command signal.

The obtained results of tuning the fuzzy controller are presented in the Figure 7. The results were compared with maximum stability degree method with iterations and genetic algorithm.

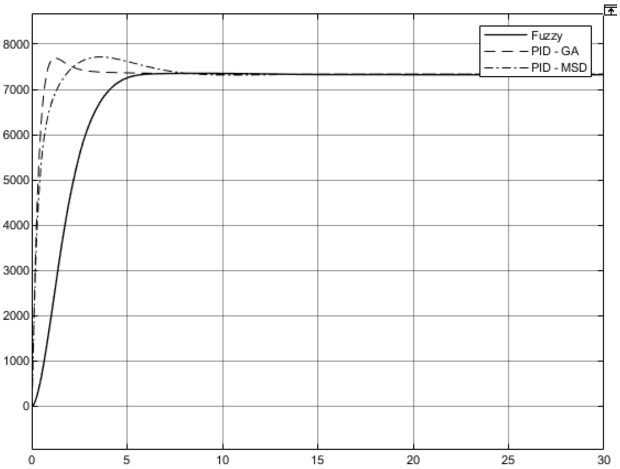

Figure 7. The transient responses of the control system with PID controller.

The obtained performance of the automatic control system are presented in the Table II.

TABLE II. PERFORMANCE AUTOMATIC CONTROL SYSTEM

No	Controller	Method	Performance of the system			
			t_r	t_s	σ	λ
1	PID	GA	0.55	2.00	3.99	1
2	PID	MSD	0.93	5.039	7.83	1
3		Fuzzy controller	4.2	4.2	-	-

IV. CONCLUSIONS

In this work, it was proposed to design the fuzzy controller for speed control of the DC motor. As DC motor it was proposed to use the FK130SH motor and the system was implemented based on the NUCLEO-F303K8 platform from ST Microelectronics.

It was realized the experimental identification of the mathematical model, that approximates the dynamics of the DC motor by the transfer function with inertia second order. It was done the comparison of the obtained results with maximum stability degree method with iterations and genetic algorithm. The fuzzy controller permitted to obtain critically damped step response of the automatic control system.

ACKNOWLEDGMENT

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Design of Specialized Hardware Architectures for Industry 4.0

Silvia Munteanu [1], ORCID: 0000-0003-0749-8457
Viorel Cărbune [1], ORCID: 0000-0002-1556-4453
[1] Technical University of Moldova, Chișinău, Republic of Moldova, silvia.munteanu@calc.utm.md, viorel.carbune@calc.utm.md, http://www.utm.md

***Abstract*— In the process of transition to Industry 4.0, the importance of applying cutting-edge technologies such as machine learning and artificial intelligence to replace human operators in industrial processes is explained by the need to automate industrial production processes. Replacing qualified human experts with artificial neural networks opens up a lot of possibilities for the implementation of new methods of industrial process automation. The problem of industrial process automation is quite complex because the decision-making process of the human expert is accompanied by uncertainty.**

Artificial neural networks represent one of the basic branches of artificial intelligence. At the moment, they are used in various fields to solve problems for which classical methods are unable to provide practical solutions. Thus, the problem of developing and training artificial neural networks for solving industrial process automation problems acquires major importance in the design of artificial intelligence systems. The training process directly depends on the data set on the basis of which the neural network is designed.

Keywords—Industry 4.0; machine learning; artificial intelligence; industrial processes; artificial neural networks; FPGA.

I. General Aspects of USING Neural Networks in Industrial Processes

The article presents a method of hardware implementation of artificial intelligence systems, the key elements for the application of these systems in the automation of industrial processes and the technologies used to implement intelligent solutions in the automation of industrial production systems.

Starting from the problem of implementing artificial neural networks [5, 6, 8, 9, 13] for the automation of industrial processes, it was proposed to implement artificial neural structures based on programmable circuits [4, 7, 10-12]. The problem of automating industrial processes is quite complex, and various alternative methods are used to solve it, including artificial intelligence. In order to solve this problem, it is proposed to develop the architectural support for the implementation of artificial neural networks. Emerging from the computation behavior of artificial neural networks, there is the need to ensure their hardware support by designing specialized architectures.

For assisted training of artificial neural networks, it is necessary to have a consistent set of data collected from the human expert and to choose the appropriate learning algorithm. The use of artificial intelligence in industrial processes offers enormous application potential for command and control of industrial processes.

II. Design of Artificial Neuron Architecture

The need to develop neural hardware architectures is driven by the actual requirements in industry. Artificial neural architectures have been developed and implemented with orientation to the requirements stipulated in the standards for the automation of industrial processes in Industry 4.0 [1-3].

Based on the specifics of the neural network implementation problem, programmable circuits were selected as the most suitable architectural support. Thus, the use of these architectures offers the possibility of parallelization and as a result the optimization and efficiency of neural calculations through the direct implementation of vector operations in hardware.

For the implementation of neural models, specialized hardware architectures are needed that would be able to perform the computational process. The hardware implementation of neural models requires the implementation of the architecture of the neuron based on programmable circuits. Since the basis of any neural network is the classical model of the neuron, the task is reduced to implementing its model in hardware [5, 13]. In order to simplify the implementation process of the artificial neuron, the modular design of its internal architectures was realized [4, 7]:

- *inputs;*
- *synaptic weights;*
- *adder;*
- *activation function;*
- *outputs.*

Thus, the operating principle of the artificial neuron can be described by summing the weighted inputs and generating at the output the activation function applied to the obtained sum. The architectural model of the neuron must have a sufficient number of inputs that can be determined based on the conditions of the problem for the solution of which its model will be involved. in general, each neuron has *n* external inputs. The artificial neuron model was divided into five functionally different components: *Inpts, Wghts, Snpss, Smtr, Trnsfr* and *Otpt,* Figure 1, where:

Inpts – inputs;
Wghts – weights;
Snpss – synapses;
Smtr – sumator;
Trnsfr – activation function;
Otpt – outputs.

The modular structure of the artificial neuron model will provide increased flexibility in the process of developing neural architectures, giving developers the opportunity to implement their own specialized architectures to solve certain problems. Thus, in the development process, engineers can select, for example, the activation function of each neuron.

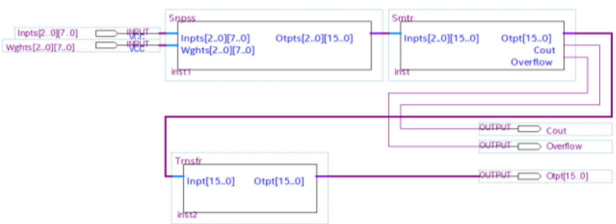

Figure 1. Structure of the digital neuron.

The synaptic block – *Snpss* (Figure 2), performs the multiplication of each input with its corresponding weight, Figure 1. The synaptic component in the structure of the neuron is elaborated using the multipliers that calculate the products between the respective pairs in parallel. The input vector of the RNA and the vector of weights are applied to the inputs of the synaptic component, and the output signal represents the vector of products obtained by multiplying each input with the respective weight.

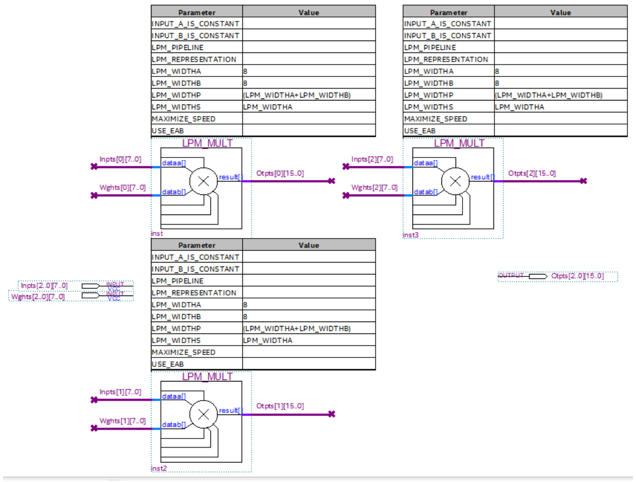

Figure 2. Structure of the synapses module.

The summation block – *Smtr* (Figure 3), performs the summation of all inputs. The summing component in the neuron structure is realized on binary adders. The vector of synaptic products is applied to the inputs of this component and the output is a scalar.

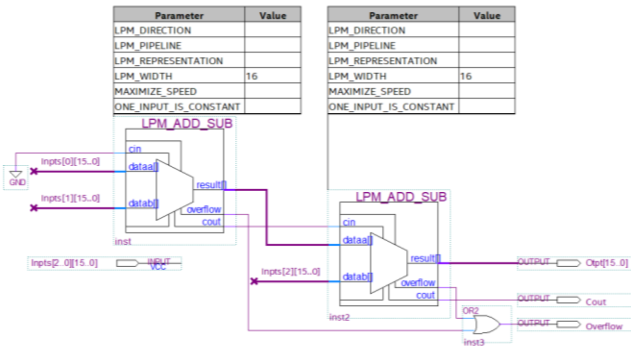

Figure 3. Structure of the summation module.

The block for implementing the activation function – *Trnsfr*, calculates the value of the activation function depending on the value of the total sum of the synaptic products applied to the input of this block. To implement different activation functions, several blocks have been developed for a series of classic functions such as: *step* (Figure 4), *linear*, etc.

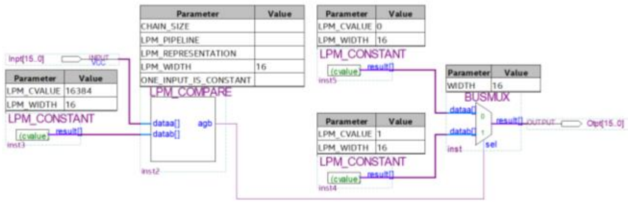

Figure 4. Structure of the step activatation function.

As a result of the synthesis of the structure of the neuron, the architecture presented in Figure 5 was obtained, in which the conceptual similarity with the model of the artificial neuron presented in Figure 1 can be noted.

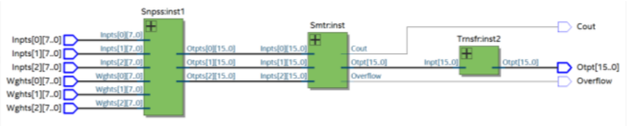

Figure 5. Architecture of the step activitation function.

Using the neuron model at the design stage of artificial neural networks significantly simplifies the process of their implementation in hardware. For the implementation of neural models in the automation of industrial processes, methods and tools for the synthesis of artificial neural networks based on programmable circuits were developed and implemented. The use of programmable circuits for the implementation of artificial neural networks presents remarkable engineering advantages because they essentially simplify the design stage and offer possibilities for the optimization of neural computations. An essential advantage of this architectural implementation method is the possibility of designing an entire system on a single circuit. The main advantage of implementing neural networks based on reconfigurable circuits can be fully exploited only in the case of using programmable circuits, a fact that offers the possibility of parallelizing the calculation processes carried out in the structure of each artificial neuron [5, 13].

III. Conclusion

Following the analysis, it was possible to identify the individual characteristics of the described method of architectural design of artificial neural networks. The essential advantages of hardware implementation of neural architectures have been determined. In the case of the implementation of intelligent systems for the automation of industrial processes based on neural architectures, the possibility of specialization of these architectures for the optimization through spatial parallelization of neural calculations was highlighted.

In the result, the specific computational features of the described architectures were identified. These achievements offer the possibility of implementing neural architectures based on programmable circuits based on the specifics and needs of the targeted problem.

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Multi-Objective Optimal Solution Search based on Genetic Algorithms

Silvia Munteanu [1], ORCID: 0000-0003-0749-8457
Ana Turcan [1], ORCID: 0000-0002-9334-7606
Victoria Alexei [1], ORCID: 0000-0003-4560-3131
Viorica Sudacevschi [1], ORCID: 0000-0003-0125-3491
Victor Ababii [1], ORCID: 0000-0002-0769-8144
Vioel Carbune [1], ORCID: 0000-0002-1556-4453
Dimitrie Bordian [1], ORCID: 0000-0003-1608-7553
[1] Technical University of Moldova, Chișinău, bd. Ștefan cel Mare 168, silvia.munteanu@calc.utm.md

***Abstract*— The paper presents the results of research carried out to solve complex problems aimed at the efficient use of natural and energy resources. The objectives of the paper are achieved by identifying the control process based on a Multi-Agent system with distributed data processing that implements a Multi-objective optimal solution search model based on the application of a Genetic Algorithm with Collective Computation. The set of Agents presents a computational architecture that forms a structured network topology based on a P-Systems model presented in the form of a Venn diagram. The Object diagram and the Venn diagram of the P-Systems model are presented in the paper. The correctness of the developed models was verified on the basis of a control system of the artificial lighting process that provides for the minimization of energy consumption, while ensuring the quality of the lighting process.**

Keywords*— Multi-Objective Optimization; Genetic Algorithms; P-Systems; Multi-Agent System; Sensor Network; Distributed Computing; Collective Computing.

I. Introduction

The application of optimization methods has expanded in recent decades in all fields of science, engineering and technologies. New generalized and specialized theoretical and algorithmic methods have been developed for application in certain fields. At the same time, a trend has been observed in the development of optimization methods oriented towards the interdisciplinary nature of the scope. Optimization has become a very useful tool for all fields of applied mathematics, engineering, medicine, and economics. Depending on the field of application and the solved problem are used approaches non-linear optimization (convex and non-convex), stochastic optimization, optimal control, discrete optimization, Multi-Objective optimization and heuristic [1].

Most real-world problems can be defined in terms of multi-objective functions, which are usually in the process of competition. In order to optimize these functions, it is necessary to adjust the functional description variables while also respecting the spatial constraints. This approach is considered efficient because computationally it requires a relatively simple implementation of the process of solving the individual objective functions [2]. However, the process of adjusting the functional description variables of the Multi-Objective model can be difficult because conflicts of interest may arise where an optimal solution for one objective function is unacceptable for the other functions. Solving the conflict of interest problem was worked it up with the application of genetic algorithms [3, 4] in combination with the weighted sum approach for solving Multi-Objective problems [5].

The Multi-Objective Decision-Making process is a very efficient modeling and methodological tool for solving complex problems in various fields [6, 7]. The Multi-Objective approach is also characteristic for cases when it is necessary to apply evolutionary algorithms in the modeling of knowledge-based systems, or where heuristic evaluations are required [8].

Solving complex problems defined on the basis of Multi-Objective models requires applying new methods of structural modeling and formal description. Analysis of structural modeling and formal description methods highlights membrane calculus (P-Systems). Membrane computing is a new paradigm in nature-inspired (biology) data interpretation and processing methodology in which distributed and parallel computing are modeled. At the same time, other computing models inspired by nature can be mentioned such as: evolutionary computing, molecular computing and neural computing, which can supplement the functionality of membrane computing [9, 10].

For the first time the idea of Membrane Computing was proposed by Gh. Paun [11, 12], who was inspired by the structure and behavior of the living cell. In Membrane Computing systems, the membrane is a separator that structures the evolutionary architecture of the rule-based computing system.

This paper proposes the design and research of a distributed decision-making system defined Multi-Objective oriented towards the search for the optimal solution based on the genetic algorithm. The stated objectives are achieved by identifying the decision-making system based on a Multi-Agent system [13] defined in a Multi-Objective optimization space [3, 5, 6]. The Multi-Agent system integrates a network of sensors and actuators [14] that act on the basis of collective intelligence models [15].

II. MULTI-OBJECTIVE PROBLEM FOR OPTIMAL SOLUTION SEARCH

Let be defined the Multi-Objective problem which describes the process dynamics $P(X) \in R^S$. The search for the optimal (minimal or maximal) Multi-Objective solution is characteristic for practically all fields of human activity (science, technology and economy) [8].

In this case, the Multi-Objective optimization problem can be defined based on the mathematical model (1):

$$F(X) \to \underset{X \in Q}{extr}, \tag{1}$$

where: $F(X) = \{f_1(X), f_2(X), ..., f_S(X)\}$ - are the set of target functions defined for each dimension S of the process $P(X)$;

$extr \in \{\min, \max\}$ - the set of solutions of the target functions defined in the space Q;

$F(X) = F_{\min}(X) \cup F_{\max}(X),$ - mode of formation the set $F_{\min}(X) \cap F_{\max}(X) = \varnothing.$ of target functions, where:

$F_{\min}(X) \to \min\limits_{X \in Q}$ - the set of target functions that ensure the condition of searching the minimum solution;

$F_{\max}(X) \to \max\limits_{X \in Q}$ - the set of target functions that ensure the condition of searching the maximum solution.

The minimum/maximum value search condition will be considered to be met if the values have been identified for $X^*_{\min} \in Q$ which ensures $F_{\min}(X^*_{\min}) \le F(X), \forall X \in Q$, or if the values have been identified for $X^*_{\max} \in Q$ which ensures $F_{\max}(X^*_{\max}) \ge F(X), \forall X \in Q$.

Thus the Multi-Objective search process will be defined based on the model (2):

$$\begin{cases} F_{\min}(X^*_{\min}) = \min\limits_{X \in Q}(F(X)), \\ F_{\max}(X^*_{\max}) = \max\limits_{X \in Q}(F(X)). \end{cases} \tag{2}$$

III. SYNTHESIS OF THE P-SYSTEMS MODEL

Multi-objective models have been observed to be specific for complex systems that consist of a spatially distributed structure of objects, mobile objects, or a combination of these. In the present paper, solving the problem of searching the optimal solution is carried out based on a set of Agents that respect the structure of the complex system. Figure 1 shows the diagram of an Object that includes: a *Agent* which activates in the environment *Environment*, environment perception system *Perceiver*, and the action system on the environment *Actuator*.

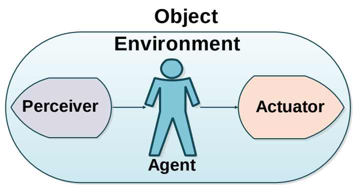

Figure 1. Object diagram.

The Venn diagram of the P-Systems model synthesis result is shown in Figure 2.

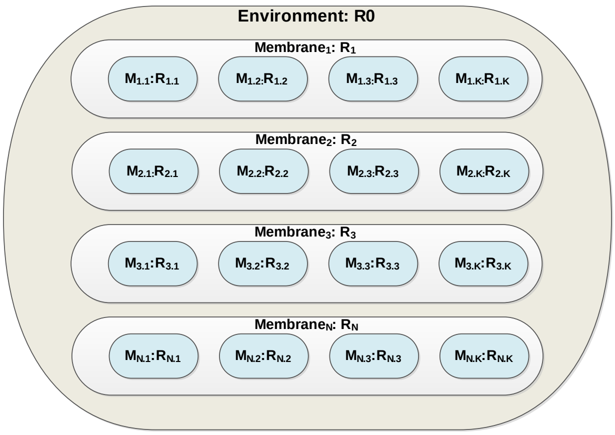

Figure 2. Venn diagram of the P-Systems.

Venn diagram of P-Systems includes:

- The activity environment of the Multi-Objective system *Environment* with the set of rules $R0$;

- The multitude of complex membranes $Membrane_i, \forall i = \overline{1, N}$ with the rule set $R_i, \forall = \overline{1, N}$;
- The multitude of elementary membranes $M_{i,j}, \forall i = \overline{1, N}, \forall j = \overline{1, K}$ with the rule set $R_{i,j}, \forall i = \overline{1, N}, \forall j = \overline{1, K}$.

Functionally, each complex membrane and elementary membrane presents an Agent that implements the set of rules defined for it. In turn, each complex membrane $Membrane_i, \forall i = \overline{1, N}$ groups the multitude of membranes $M_{i,j}, \forall i = \overline{1, N}, \forall j = \overline{1, K}$ in computational clusters, respectively, consolidating computing power in order to solve complex problems. This consolidation leads to the implementation of collective computing models [18, 19] made by the set of Agents involved in the process.

IV. Example for Multi-Objective Optimization

As an example of the application of the Multi-Objective optimal solution searching method, we will analyze a Multi-Agent system for controlling electricity consumption in the artificial lighting process [22].

Let be defined in the space $Q \in R^S$ artificial lighting process $P = F\left(t, X^M(t), X^L(t), U(t)\right)$, where: t - the evolution of the process over time; $X^M(t) = \left(x_i^M(t), \forall i = \overline{1, S}\right)$ - the set of motion sensors that identify the presence of the person in the space controlled by that Agent; S - the number of Agents to control the lighting process; $X^L(t) = \left(x_i^L(t), \forall i = \overline{1, S}\right)$ - the set of sensors for identifying the intensity of the light flow in the space controlled by that Agent; $U(t) = \left(u_i(t), \forall i = \overline{1, S}\right)$ - the multitude of command signals with the artificial lighting process; $F = \left(f_i, \forall i = \overline{1, S}\right)$ - the set of functions to ensure the condition defined in the model (1). The multitude of the functions F ensures control signals calculation $U(t)$:

$$F : X(t) \rightarrow U(t), \tag{3}$$

where $X(t) = X^M(t) \cup X^L(t)$ and $X^M(t) \cap X^L(t) = \varnothing$.

The energy consumed by an artificial lighting device $W_i(t)$ in the time interval $t \in [0:T]$ is calculated based on the formula (4):

$$W_i(t) = \int_{t=0}^{T} \left(w_i(t), u_i(t), \kappa_i\right) dt, \tag{4}$$

where: $w_i(t)$ - the control signal obtained as a result of the calculations in the model; $u_i(t)$ - the control signal obtained as a result of the calculations in the model (3); κ_i - the coordination coefficient.

To optimize the energy consumption, the Multi-Objective optimization problem is defined (5):

$$\begin{cases} F_{\min}\left(X^*_{\min}\right) = \min_{X \in Q}\left(F(X^M(t))\right), \\ F_{\max}\left(X^*_{\max}\right) = \max_{X \in Q}\left(F(X^L(t))\right). \end{cases} \tag{5}$$

where: $X^*_{\min}$ - are the values that ensure the minimum electricity consumption obtained as a result of the solution $\min_{X \in Q}\left(F\left(X^M(t)\right)\right)$; $X^*_{\max}$ - are the values that ensure the artificial lighting process of a satisfactory quality obtained as a result of the solution $\max_{X \in Q}\left(F\left(X^L(t)\right)\right)$.

Functional verification of the Multi-Agent system for Multi-Objective optimization of energy consumption used for artificial lighting was carried out based on *ESP-12E* devices (Figure 3). For data acquisition was used sensors: *PIR Sensor* – identification of the presence of people in the control area and a light sensor. The action element is made in the form of a relay that connects the *220V* power source to the artificial lighting *Lamp*.

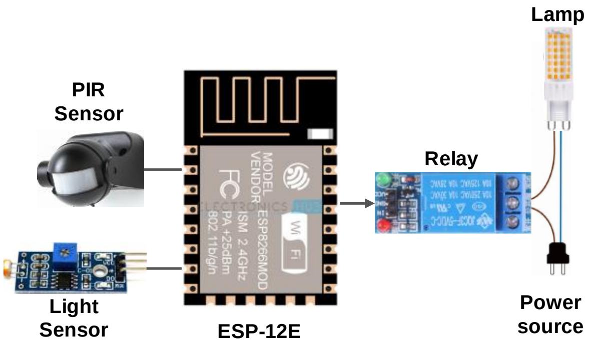

Figure 3. Functional diagram of the Agent.

The topology of the collective computing network is developed based on the P-Systems model and is presented in Figure 4. The collective computing network consists of wired LAN, and N Collective computing clusters consisting of Agents that are in the control space of the artificial lighting process. Communication between Agents is realized on the basis of $Wi-Fi\ Router$ which are connected to the network LAN.

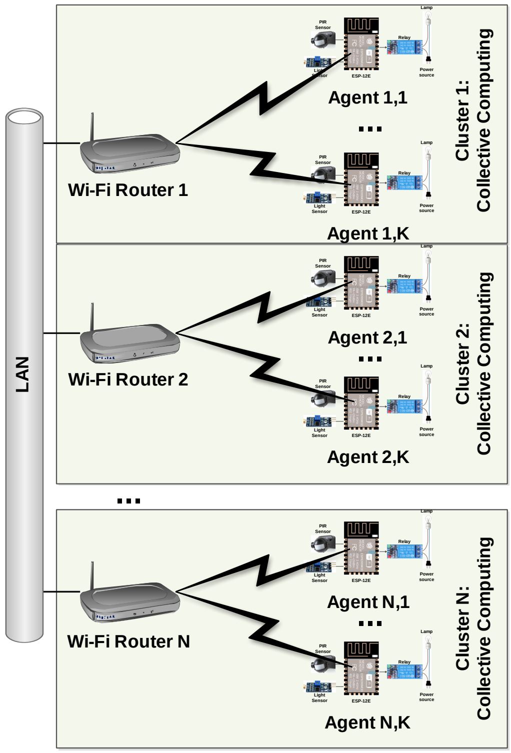

Figure 4. Functional diagram of the Multi-Agent collective computing.

V. Genetic Algorithm for Multi-Objective Optimization

The process of searching for the optimal solution is based on the application of a Multi-Objective Genetic Algorithm. For this purpose will be created the population A consisting of the multitude of Agents $A_{i,j}, \forall i=\overline{1,N} \,\&\, j=\overline{1,K}$ in which each Agent will be assigned a Chromosome $G_{i,j}, \forall i=\overline{1,N} \,\&\, j=\overline{1,K}$ made of K Genes $G_{i,j}=\left\{g_{i,j,k}, \forall i=\overline{1,N} \,\&\, j=\overline{1,K} \,\&\, k=\overline{1,K}\right\}$ [21].

Each gene $g_{i,j,k}$ each gene can receive one of the values $\{00,01,10,11\}$, where:

00 - passive state of the Agent $A_{i,j}$ in the Multi-Agent system architecture;

01 - identifies the position of the Agent $A_{i,j}$ in the Multi-Agent system architecture;

10 - identifies the direction of movement of the person in the space controlled by the Multi-Agent system;

11 - determines the active state of the Agent $A_{i,j}$ which identified the person's presence in the controlled space.

Examples of Chromosomes for the Agent $A_{1,3}$ from the architecture topology shown in Figure 4:

$A_{1,3}=[00 \quad 00 \quad 01 \quad 00 \quad 00 \quad 00 \quad 00 \quad 00]$ - identifies position 3 of the Agent in the Multi-Agent system architecture;

$A_{1,3}=[00 \quad 00 \quad 11 \quad 10 \quad 00 \quad 00 \quad 00 \quad 00]$ - identifies the direction of movement of the person in the space controlled by the Agent $A_{1,3}$ in the space controlled by the Agent $A_{1,4}$;

$A_{1,3}=[00 \quad 10 \quad 11 \quad 00 \quad 00 \quad 00 \quad 00 \quad 00]$ - identifies the direction of movement of the person in the space controlled by the Agent $A_{1,3}$ in the space controlled by the Agent $A_{1,2}$.

The sequence of operations of the process of searching for the optimal solution is shown in Figure 5.

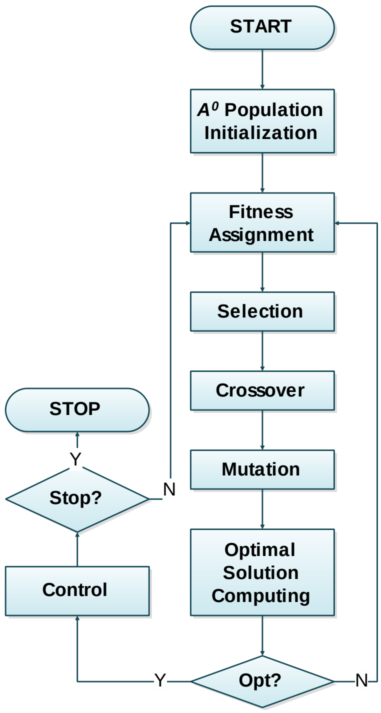

Figure 5. The sequence of operations of the optimal solution search process.

The sequence of operations includes:

Model-defined population initiation (5):

$$A^0=\begin{cases} A_{i,1}^0=\left[g_{i,1,1}^0 \quad g_{i,1,2}^0 \quad \dots \quad g_{i,1,K}^0\right], \\ A_{i,2}^0=\left[g_{i,2,1}^0 \quad g_{i,2,2}^0 \quad \dots \quad g_{i,2,K}^0\right], \\ \dots \\ A_{i,K}^0=\left[g_{i,K,1}^0 \quad g_{i,K,2}^0 \quad \dots \quad g_{i,K,K}^0\right]. \end{cases}, \qquad (5)$$

$\forall i=\overline{1,N}$

Fitness Assignment - The fitness function determines how fit an individual is. It gives a fitness score to each individual. The probability that an individual will be selected for control decision;

Selection - The idea of selection phase is to select the fittest individuals and let them pass their genes to the next generation. Two pairs of individuals (parents) are selected based on their fitness scores. Individuals with high fitness have more chance to be selected for control operation;

Crossover - Crossover is the most significant phase in a genetic algorithm. For each pair of parents to be mated, a crossover point is chosen at random from within the genes;

Mutation - In certain new offspring formed, some of their genes can be subjected to a mutation with a low random probability. This implies that some of the bits in the bit string can be flipped;

Optimal Solution Computing - Application of the mathematical model for the calculation of the optimization condition.

Opt? - The iteration terminates if the population has converged.

Control - Calculation and action on the controlled object.

VI. Conclusion

Optimization in Multi-Objective processes presents an important direction in the research and development of complex systems. These models are extensively described in numerous scientific papers in which their advantages and disadvantages are highlighted. Along with the advantages offered by the Multi-Objective optimization methods comes the main disadvantage which is expressed by the algorithmically and technological complexity of implementation. These disadvantages impose the need to develop new implementation methods and models based on the use of Genetic Algorithms, new methods of formal description based on P-Systems, the presentation of the system in the form of a Multi-Agent System with Distributed Data Processing and Collective Computing.

In the present work, the research results of a system for searching for the optimal Multi-Objective solution by using Genetic Algorithms are presented. The general problem of the Multi-Objective optimal solution search process was formulated. The synthesis of the topology of the Multi-Objective optimal solution search system was realized in the form of Venn diagram and P-Systems models. For the functional demonstration, an example of controlling the artificial lighting process was analyzed, which provides for the search for the minimum solutions for the consumption of electricity and the search for the maximum solutions for the quality of the lighting process. The process of searching for optimal solutions was carried out based on the Genetic Algorithm that is described in the paper.

Future research is planned in developing a set of operators to perform Fitness, Selection and Crossover functions to reduce algorithmic complexity and implementation costs.

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SMART LIFT – Intelligent lift service system

Maria Cernei [1], ORCID: 0000-0001-7595-5993
Andrei Dorogan [1], ORCID: 0000-0002-0518-035X
[1] Laboratory of Micro-Optoelectronics, Technical University of Moldova, Chisinau, Republic of Moldova,
maria.cernei@tse.utm.md

***Abstract.*— The paper presents the results of the development of an intelligent lift service software system that allows the detection of people and their numbers on each floor, the recognition of persons by assigning a conventional identity, the prediction of the destination floor for each user using facial detection applications and data forecasting based on the history of lift usage statistics.**

Keywords: software, intelligent systems, facial detection, data forecasting.

I. INTRODUCTION

Today's SMART systems and equipment enable the facilitation and automation of services in various industrial and public domains. The automation of public services contributes to more efficient equipment operation and optimized service costs. The development of a smart lift service system can help optimize service expenditure by minimizing electricity consumption. This aspect would facilitate the experience of lift users in offices or residential blocks.

To this end, the possibility of using existing facial detection and data forecasting applications to develop an intelligent lift service system was explored, which would allow the detection of persons on each floor of the elevator, their identification by assigning a conventional identity, the determination of the number of persons on each floor, and the forecasting of the destination floor for each user using data forecasting applications based on the history of lift usage statistics. The software system allows rapid processing of images received from the video cameras installed on each floor of the lift, the identification and registration in the database of the users of the system, determination of the number of users for each floor and the forecast of the destination floor for each user.

For system implementation purposes, it was developed a user interface to control, guide and monitor the intelligent software system. The system ensures the connection of the whole equipment to the Internet network for assuring e-mail and SMS alert messaging.

The 3 floor study block 1 of the Technical University of Moldova and the staff working at the Faculty of Electronics and Telecommunications, TUM were identified as a case study, in order to achieve these objectives.

II. DESIGN OF FACIAL DETECTION AND RECOGNITION ALGORITHM

Facial detection and recognition involves the usage of the most obvious facial features. Attempts have been made to measure the importance of certain intuitive features [1] (mouth, eyes, cheeks) and geometric measures (distance between eyes [2], width-to-length ratio). There are still some relevant human features that are taken into account such as skin color, location of human mouth and eyes, etc.

Facial recognition includes several subproblems. The input of a facial recognition system is always an image or a video stream. The result is an identification or verification of the subjects appearing in the image or video.

Facial detection is defined as the process of extracting faces from images. This procedure involves face tracking, position estimation, etc. Feature extraction involves obtaining relevant facial features from data such as certain facial regions, variations, angles or dimensions, which may or may not be relevant to the human (e.g. distance between eyes).

Facial detection faces several challenges such as:

- Position variation. The performance of face detection algorithms essentially decreases when there are large variations in face position. Position variation can happen due to subject movements or camera angle.
- Feature occlusion. The presence of features such as beards, glasses or hats introduces a complex component as faces may be partially covered by objects or other faces.
- Facial expression. Facial features vary due to different facial gestures.

• Image conditions. Camera and environmental conditions affect image quality, i.e. the appearance of the face.

Some face detection systems detect and locate faces at the same time, others perform a detection first and then, try to locate the face. Then, several tracking algorithms may be needed (Fig. 1).

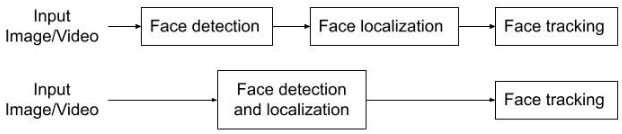

Figure 1. Facial detection process

Facial detection methods can be divided into four categories:

• Knowledge-based methods. Rule-based methods that encode knowledge about human faces.

• Methods based on invariant features. Algorithms that attempt to determine invariant features of the face, independent of its angle or position.

• Template matching methods. These algorithms compare input images with stored face templates or features.

• Appearance-based methods. A template matching method whose database of patterns is learned from a set of training images.

III. EQUIPMENT NEEDED TO IMPLEMENT THE SMARTLIFT SOFTWARE SYSTEM

To develop the software system, it is necessary to install a wireless IP camera, with a coverage angle of 110° - 120° , on each floor of the lift for capturing. To ensure connection and transmission of digital data over the Internet network, it is necessary to use a 5G Wi-Fi router and a medium-speed Internet connection with unlimited traffic. The processing and storage of information data is provided by a web server (VPS) with medium processing characteristics. The use of a VPS can ensure the operation of the system for one or more office or residential blocks. The small number of devices reduces the cost of the whole SmartLift system, which makes it easier to implement the smart system in practice.

IV. IMPLEMENTATION AND TESTING OF THE BETAFACE FACIAL DETECTION APPLICATION

To achieve facial detection and recognition, there had been identified several face detection and recognition applications (Face++, Luxand, and Betaface), each one with its selected algorithms (not known by us). After testing all these APIs, the BetaFace application (https://www.betafaceapi.com/) was identified and its possibilities were analyzed. It showed that this API provides best facial recognition. BetaFace API offers many facial recognition possibilities and features, such as face detection, face creation and search in own person databases, determination of age, gender, expression and ethnicity of faces, etc. For populating the person database of the system a user interface was developed (Fig. 2). Communication with the BetaFace application is provided by REST access methods and the transfer data is delivered as XML or JSON.


Added Betaface Persons DB

Nr.	Name	Person ID	Floor (etaj)	Phone	Gender	Send SMS	Face UUID
2	pavel_nistiriuc	pavel_nistiriuc@utmblockone	3	+37378479371	male	No	567fba53-b9fa-11ea-b153-0cc47a6c4dbd
3	serafima_sorochin	serafima_sorochin@utmblockone	3	+37369052017	female	No	0ba8bfb0-b9fb-11ea-b153-0cc47a6c4dbd
4	lilia_sava	lilia_sava@utmblockone	2	+37367594739	female	No	7c59593c-b9fb-11ea-b153-0cc47a6c4dbd

Figure 2. User data management interface for the BetaFace application

After processing the images with the BetaFace application, data about the user and the processed image, the person's name, the mobile phone number, the floor of the office where they work, the conventional identifier of the image and that of the detected face are recorded in the database.

Figure 3. Facial detection test interface using the BetaFace application

Several cases have been identified for testing, including the identification of a single or multiple individuals (persons). From the test results it was determined that BetaFace provides satisfactory results for the implementation of the system. The API proved to be quite reliable, detecting and identifying one, two and more persons from the captured image (Fig. 3). Additionally, a decrease in the time required for image processing was observed for the same test conditions.

Based on the test results it was decided to use this application for the next steps of the implementation of the SmartLift intelligent lift servicing system.

V. Creation of the Database for System Control and Monitoring

The operation of the software system, monitoring, user database registration, facial detection and floor forecasting for each person is provided by the database developed using the MariaDB/MySQL service installed on a medium capacity VPS. The MySQL database consists of tables populated with the data of persons using the lift, statistical data of lift activity for each person and tasks required to be performed at a given time. Accessing the database, insertion and updating the data in the tables is done through the PDO/MySQL (PHP Data Objects) interface, which provides a higher degree of security when accessing the database.

The statistical data table of the lift activity contains information about the day, date and time when a specific person accessed the lift from any floor and left to another floor. Since no real statistical data were available for testing and simulation of the system, simulated statistical data from a graph of the ordinary work of persons according to time and period of the day were used.

VI. Principles of Predictive Analysis and Development of Floor Forecasting Algorithm

Data Mining is an important aspect of predictive analytics and data forecasting, used to extract useful information from current data (usually large data sets) to predict trends. This aspect is the identification of relevant data to be analyzed and used in predictive models.

Machine learning (ML) and predictive analytics are both focused on efficient data processing. Machine learning can be taken as an extension of predictive analytics, which is responsible for self-learning and identification of data patterns, which are regularities, associations or relationships existing in the data).

There are several models of machine learning in time series data analysis. The most widely used are ARIMA, ARCH/GARCH, Vector AutoRegressive (VAR) model, Recurrent Neural Networks (RNN) for reading sequence dependencies, which create predictions based on previous data.

In order to realize the forecasting model, it is necessary to consider the time of access to the lift by the user, and the processed dataset must be consisted of days corresponding to the current day and/or even the current time. For this purpose an open-source API was used “Algorithmia”. Figure 4 shows the test results of the “Algorithmia” API. The processed dataset for the forecast (payload) was made up of statistical data selected independently of the time and day of the week they were recorded. Figure 4, A shows the number of statistical cases for changing Value 3 to Values 1, 2 or 3, and in Figure 4, B are shown the forecast result of the change of Value 3 to possible Values 1 or 2 (probability 0.2 and 0.8, respectively) for a given randomly selected day and time. The result obtained after testing the API “Algorithmia” is not quite satisfactory, as it does not reflect the desired statistical results.

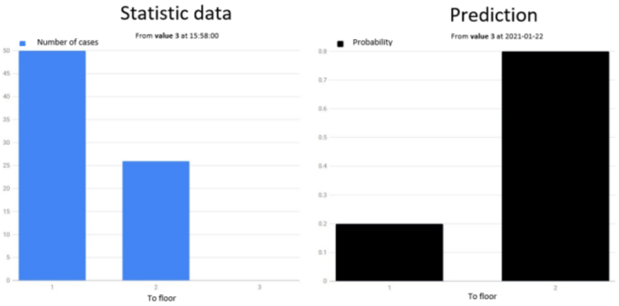

Figure 4. Number of statistical cases processed (A) and forecast result (B) for the “Algorithmia” API.

For our case of services or processes where statistical data are acquired at different points in time, time series forecasting models do not provide satisfactory results, because the statistical data used in this case are distributed with an equal step, and the most suitable are non-temporal forecasting models with linear regression, such as "Naive Forecast" or "Seasonal Naive Forecast". For the "Naive Forecast" model the forecast value is the value of the most recent observation. This method is often used to evaluate the performance of more sophisticated forecasts. The “Seasonal Naive Forecast” model is similar to the “Naive Forecast” model, but the forecast value represents the last observed value of the same season of the time period.

For improving the results an API in 2 versions (NA Predict v3 and NA Predict v3.1) has been developed and implemented, with some modifications and adjustments to increase the veracity of the forecast. The results obtained demonstrated the need to use a "Seasonal Naive Forecast" model in the API. The statistical data processed in this API (NA Predict v3.1) correspond to the randomly selected hour and day of the week and adjacent hours within a ±2 hour interval (Fig. 5).

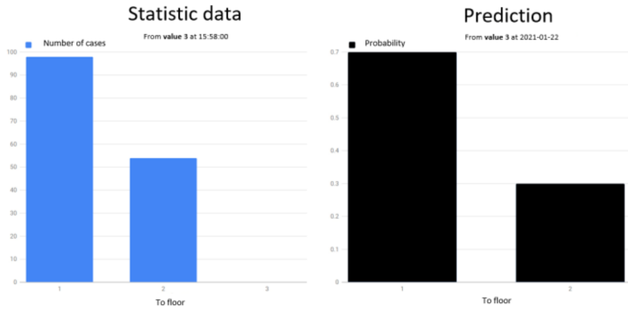

Figure 5. Number of statistical cases processed and forecast result for NA Predict API v.3.1

The obtained results match satisfactorily the processed statistical data with a probability of 0.7 and 0.3 for floors 1 and 2, respectively. For this API, a much more varied and extensive processed dataset (payload) was obtained, but also a much more essential difference between probabilities. The results of testing the NA Predict v3.1 application showed promise for use in automating the operation of the SmartLift system [3].

VII. SMARTLIFT SOFTWARE SYSTEM USER INTERFACE

For the convenience of testing the system and service functionalities, a simplistic user interface was developed using PHP/MySQL and HTML/CSS languages, with graphical representation of the office block floors (Fig. 6).

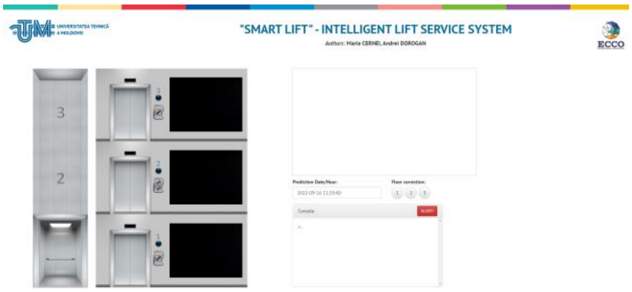

Figure 6. SmartLift user interface (https://smartlift.one/)

The interface shows the system console for monitoring lift tasks. Taking into account that the forecasting of destination floors is a probabilistic process, it is necessary to take into account the cases when the destination floor of the lift user is different from the forecast one. For these purposes, the floor correction option has been reserved in the interface.

VIII. INTEGRATION OF SMS ALERT SYSTEM FOR LIFT LOCKOUTS

The automation of the SmartLift operating process can additionally be supplemented with an alert module for lift service companies. Alert signals can be transmitted using the possibilities of the Internet and GSM network in tandem. Alert signals can be transmitted in cases of lift lockout or shutdown due to loss of mains connection.

For these purposes an alert system has been implemented that autonomously transmits short SMS messages over the GSM network using an already available application SmsGateway24, which can be installed on an Android or iOS mobile phone. The transmission of messages can be controlled automatically via a REST API.

Based on the capabilities of the developed software system, the identities of the persons in the blocked lift car can be recognized and transmitted at will, including the age of the persons (in case a child or adult is blocked).

IX. CONCLUSIONS

The implementation of the intelligent lift service software in offices and residential blocks can make a vital contribution to improving the quality of service provided to consumers by ensuring lower power consumption and subsequently lower servicing costs. At the same time, the implementation of the autonomous alert system increases the serviceability of the lifts by the responsible companies.

Automated operation of lifts is an important aspect in the case of servicing people with physiological and motor disabilities by minimizing the actions required when using the lift.

The statistical data accumulated in the system allows an analyzing the operating efficiency of the lifts and how the lift performs the tasks of raising and lowering the cabin according to the number of people inside.

The use of the implemented API "NA Predict v3.1" can provide forecasting, automation and optimization of the processes and activities of lift in offices and residential blocks by excluding the human component from the process.

The use of IP cameras within the system can serve as an additional utility in ensuring the security of office and apartment blocks. Considering all these aspects and the new possibilities offered, the SmartLift software system can be used as an additional option within existing SmartHouse systems.

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Decision Making System based on Collaborative Agents

Ana Turcan [1], ORCID: 0000-0002-9334-7606
Olesea Borozan 1, ORCID: 0000-0003-1091-5506
Victor Ababii [1], ORCID: 0000-0002-0769-8144
Viorica Sudacevschi [1], ORCID: 0000-0003-0125-3491
Silvia Munteanu [1] ORCID: 0000-0003-0749-8457
[1] Technical University of Moldova, Chișinău, bd. Ștefan cel Mare 168, ana.turcan@fcim.utm.md

***Abstract*— In this paper are presented the results of research done in the system projecting and research for making informed decisions based on the collaborative Agents. The mathematical model used in this research had the goal to find an optimal solution in a multi-objective space by using methods inspired by nature, especially evolutional calculus algorithms. The calculus system's architecture consists of two sets of Agents: agents that deliver data and information, and Agents that consume it. The interconnection process between Agents is a dynamic one which evolves in time and it determines the topology of the calculus system.**

Keywords*— collaborative; multi-agent; decision making; nature inspired algorithms; swarm intelligence; multi-objective optimal solution search; self-reconfigurable computing architecture; ESP8266.

I. INTRODUCTION

There has been a tendency in applying the optimization algorithms inspired by nature in the last couple of years. The majority of these algorithms are metaheuristic and are based on the swarm intelligence. Swarm-intelligence-based algorithms such as cuckoo search and firefly algorithms have been found to be very efficient [1]. The analysis of different sources pictures an evolution on all major algorithms inspired by nature, like the algorithms of ants and bees, algorithms of lilacs, fireflies and flowers, genetic algorithms, differential evolution, harmonic search, swarm optimization on particles and others. Also, there is a multitude of hybrid methods, multi-objective optimization and methods to cope with constraints.

Nowadays, distributed processing of data, based on computer networks, is one of the most efficient methods of using hardware and software resources. A computer network is a global integration of the different types of devices which allow for sharing and access from any distance: data, information, services and resources. A significant interest was developed in Grid Computing [2], which offers a detailed description of the modulus operandi and distributed processing of data based on the hierarchy with specific functions and communication protocols.

As an example of implementation of calculus models inspired by nature can be the IoT (Internet of Things) technology [3]. The IoT concept is used to define systems based on autonomous communication of a set of physical objects (sensors, devices for storing and processing date and actuators), with auto-adaptation and auto-organization capacities. The fields where IoT is applied are many, for example: smart houses and cities, industrial automation etc. IoT is based on the most innovative contributions in the projection of protocols, technologies, apps and architectures which imply intelligent things which are interconnected or they interoperate with the purpose of solving complex problems or multi-criterial optimization. An important role in the IoT technology is the fact that physical objects are virtualized which allows them to be omitted in the process of projection and development of applications.

II. COMPUTING ARCHITECTURE FOR DECISION MAKING

The decision-making calculus system based on collaborative Agents is a computing structure distributed and made out of three base components (Figure 1): set of Agents $PUBLISH\ Agent = \left\{PA_i, \forall i = \overline{1,N}\right\}$ which delivers data and information $TOPIC = \left\{topic_i, \forall i = \overline{1,N}\right\}$ for processing and decision-making; the set of Agents

$SUBSCRIBE\ Agent = \{SA_j, \forall j = \overline{1,M}\}$ which processes the data and the information $TOPICS = \{topics_j, \forall j = \overline{1,M}\}$ for generating a decision; a Server $MQTT\ Broker : List\ of\ TOPIC$ which gathers the data and information from $PUBLISH\ Agent$ and delivers them to $SUBSCRIBE\ Agent$ in relation to the list of requests generated by it.

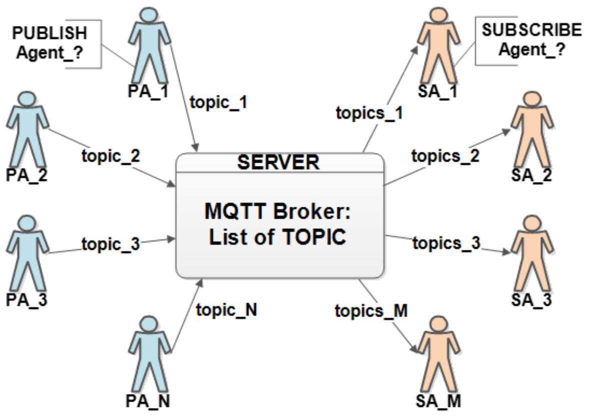

Figure 1. Computing Diagram for Decision Making.

The functionality of the decision-making system is based on the usage of the MQTT protocol [4] for the development of IoT applications. The protocol has been selected based on the analysis of the set of protocols on an application level (HTTP, MQTT, DDS, XMPP. AMQP and CoAP for IoT applications) shown in the research number [5].

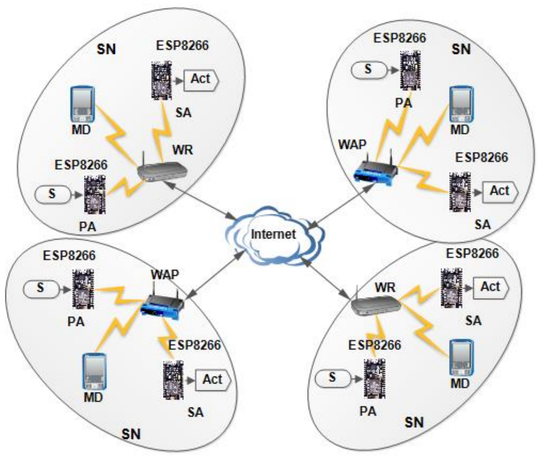

Figure 2. The Architecture of the Decision-Making System.

To implement the decision-making system based on the collaborative Agents, the devices *ESP8266* have been selected [6, 7] which give the user the following resources: communication based on the 802.11 standard b/g/n; integrated TCP/IP protocols; RAM and Flash memory; SDIO 1.1/2.0, I2C, SPI, UART, ADC and PWM standard interfaces. All of these grant unlimited possibilities for the user in the project development process.

In Figure 2 is presented the architecture of the decision-making system based on collaborative Agents which is formed by a set of subnetworks *SN* distributed in space and connected to the global network $Internet$ [8-11, 16].

Every SN subnetwork includes: a Wireless Router WR or a Wireless Access Point WAP which guarantee access for all devices Wi-Fi to the global network $Internet$. The set of mobile devices MD which will visualize data and automatically generate commands or through human operator's intervention; the set of Agents $PUBLISH\ Agent = \{PA_i, \forall i = \overline{1,N}\}$; and the set of Agents $SUBSCRIBE\ Agent = \{SA_j, \forall j = \overline{1,M}\}$.

$PUBLISH\ Agent$ is an autonomous computation system and it includes: the set of sensors S which perceive the state of the activity or event medium; and the device $ESP8266$ which performs the acquisition, processing, storing and communication algorithms in the given subnetwork.

$SUBSCRIBE\ Agent$ is an autonomous computation system and it includes: the device $ESP8266$ which communicates in the given subnetwork, stores and processes data, and generates decisions in accordance with the functionality algorithm; and the set of Actuators Act which acts on the activity medium.

III. MATHEMATICAL MODEL FOR DECISION MAKING SYSTEM

In the set $S \subset R^N$ is defined the distributed calculus process $P = \{PA, SA, X, Y, Q(X)\}$ which assures $P : S \rightarrow S$, where:

$PA = \{PA_i, \forall i = \overline{1,N}\}$ - the set of Agents which delivers data and information for the calculus process and works with other Agents;

$SA = \{SA_j, \forall j = \overline{1,M}\}$ - the set of Agents that consumes data and information to generate decisions and works with other Agents;

$PA \cap SA = \varnothing$ - the merging condition of the data and information delivering functions and their consumption for decision-making;

$X=\{x_i,\forall i=\overline{1,N}\}$ - is the state of S, which is the data and/or the information acquired from the set of sensors;

$Y=\{y_j,\forall j=\overline{1,M}\}$ - is the set of decisions to act upon the space S;

$Q(X)$ - is the function that ensures the optimization condition of the solutions in the space S.

The functionality of the decision-making system is defined by the mathematical model (1) [10, 11]:

$$\begin{cases} Q(X)=\underset{X\in S}{min/max}\left(f_j\left(X^j\right)\right),\forall j=\overline{1,M^j}, \\ g_i(X)\le 0,\forall i=\overline{1,N}, \\ h_j(X^j,y_j)=0,\forall j=\overline{1,M}. \end{cases} \quad (1)$$

where: min - searching for a minimal solution of the function f in the space S;

max - searching for a maximal solution of the function f in the space S;

f_j - the optimization function solved by the Agent SA_j;

X^j - the set of values of state X of the space S selected by the Agent j to solve the optimization function and to generate decisions;

M^j - the number of values of state X involved in data processing;

g_i - the system of constraints in the space S;

h_j - the set of functions for decision-making calculus y_j based on the values of X^j.

In order to solve the quality function $Q(X)$, which is a multi-objective optimization process, the genetic algorithm with N variables is being used.

The process of solving the constraint system $g_i,\forall i=\overline{1,N}$ is uniformly distributed between the set of Agents $PA=\{PA_i,\forall i=\overline{1,N}\}$. Solving the functions f_j and $h_j,\forall j=\overline{1,M}$ is uniformly distributed between the set of Agents $SA=\{SA_j,\forall j=\overline{1,M}\}$. The calculus process is collaborative, which provides for the exchange of data between Agents at every iteration of data processing.

The decision-making calculus $y_j,\forall j=\overline{1,M}$ is a collaborative process between the set of agents SA and PA. As a result of collaboration, self-reconfigurable computing architectures are created [9, 12-15]. The configuration of the calculus architecture is determined by the model (2):

$$\mathrm{H}_j(Y): X\rightarrow X^j,\forall j=\overline{1,M} \quad (2)$$

where $\mathrm{H}_j(Y)$ is the function that evaluates the influence of the status variables X on the decision y_j. Using this method, for every computation of the decision value y_j a virtual architecture for data processing is being created which ensures the achievement of the mathematical model (1).

IV. CONCLUSION

The Multi-Agent collaborative calculus is an efficient method of implementation of distributed and concurrent data processing algorithms. Furthermore, the Multi-Agent systems offer the possibility to implement calculus models inspired by nature, especially swarm intelligence.

The decision-making system based on collaborative Agents is an architecture for distributed calculus which implements a data processing model which ensures multi-objective optimal solution search. The architecture of the calculus system is auto-reconfigurable based on a model which determines the significance of the status values in the decision-making process.

In order to implement the system were selected the *ESP8266* devices which ensure the creation of Wireless networks and the implementation of the MQTT protocol for the organization of data exchange between Agents without considering their geolocation.

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Website performance analysis in relation to the Visibility indicator of the Webometrics ranking: case study TOP 5 universities from the Republic of Moldova & Romania

Dinu Ţurcanu [1], ORCID: 0000-0001-5540-4246
Rodica Siminiuc [2], ORCID: 0000-0003-4257-1840
Tatiana Ţurcanu [3], ORCID: 0000-0002-8972-8262
[1] Technical University of Moldova, Chişinău, Republic of Moldova, dinu.turcanu@adm.utm.md, https://utm.md/, rodica.siminiuc@adm.utm.md, https://utm.md/, tatiana.turcanu@srco.utm.md, https://utm.md/

***Abstract*—The Webometrics Ranking of World Universities periodically brings to the attention of mass media, but also to the society of the Republic of Moldova, information relevant for future students regarding the positions of higher education institutions in the country. A website is simply a prerequisite of online existence for a university. Most of the time, the university's webpage is the place where one can present detailed information about institution's activity, educational services provided, research activity, etc., this being the official source of information for future students, future graduates, but also university partners. The purpose of this paper is to analyze the webpages of the TOP 5 universities ranked by Webometrics from the Republic of Moldova and Romania, in terms of the visibility indicator of this university ranking. The paper has the task to make a comparative evaluation of the universities' webpages so that the conclusions formulated later could contribute to the improvement of the Moldovan universities' positions in the Impact Rank section of the Webometrics Ranking of World's Universities.**

Keywords—Webometrics, university ranking, visibility.

I. Introduction

University rankings provide future students and their families with information based on which they can make a better choice of the university they want. Therefore, the presence of the higher education institutions of the Republic of Moldova in the international rankings can become one of the factors that will allow them to continue to attract a sufficient number of students, including from abroad, thus helping the universities to survive financially in the conditions of decreased number of students, for demographic, but also for migration reasons.

Also, the university rankings allow better visibility at the international level, in order to attract international projects for the university, but also to establish viable partnerships with other educational or research institutions. And last but not least, the positioning of the university in the various international rankings, which reflect its performance, can also represent an indicator based on which the authorities will first be able to evaluate the efficiency of spending public funds allocated to state universities, and second, they will also be able to take measures aimed at increasing the quality of these universities, related to the pursuit of national interest.

Within some university rankings there are parameters that make these rankings seem extremely objective, but still the latter hide various subjective elements. Subjectivism comes from: the definition of indicators, which may not accurately reflect the missions of different universities and may not be adapted to all fields; the share given to various indicators when being added up or the inclusive errors resulting from the automatic collection and processing of an extremely large amount of data.

For example, the number of teaching staff of a higher education institution must be collected from various sources that do not, in most cases, provide this information accurately, completely or appropriately; the number of university students, in most cases it is not present in digital statistical reports on the web, or may be indicated with errors; gathering the number of publications of a university is sometimes subject to an erroneous process, because the name of a higher education institution can appear in various forms, etc.

The analysis of some methodologies of the university rankings can generate the misinterpretation made by their authors who choose those indicators depending on data accessibility. For example, considering that the primary mission of a university is education, from an economic point of view, this can be measured in the quantity and quality of graduates' preparation for labor market, and the most suitable indicator for ranking would be based on the average salary of this graduate, in the first years after the bachelor's degree graduation. Since these data practically present a complex problem of collection, in most cases, the authors of the university rankings, use specific tools, among which, for the education segment: employee opinions, the number of graduates with scientific awards, the number of graduates who have become administrators of top companies, development and positioning of a segment of the national economy compared to the university's field of study, the number of teaching staff per student, the number of international students, the number of academic mobilities, etc.

Currently, research represents another important mission of the university. The information used in the university rankings, regarding research results, is collected more simply, compared to those related to the education process, as a result of the existence of bibliometric databases and aggregated collections of scientific publications.

In this context, we can state that even if some university rankings use the academic collegiate evaluation in order to measure the quality of education, with a share of about 20-30% in the final result, the latter is mostly carried out still focusing on the research results. In other words, a professor from a university outside the country can find out information about a higher education institution from the Republic of Moldova, especially as a result of reading a scientific publication produced in that university, of attending a presentation at scientific conferences made by a representative of that university, of partnership relations with an academic or researcher from the university, the latter often results from the scientific collaborations, of discussions with Moldovan university graduates, in case they follow post-graduate studies, often focused on research.

In most cases, the international results of the research activity, but also the generation of the prestige of these activities, represent the most important component of the performance measured by rankings. However, performance in the field of research must not affect university performance in the teaching process, both objectives requiring the successful achievement of the other.

The hierarchization methodologies of higher education institutions cause controversial discussions and are evolving continuously. The latter are caused by the fact that it is very difficult to measure the level of performance of a complex higher education institution, and it is even more difficult, subsequently, to reflect it by a one-dimensional figure.

Since Webometrics is the only international ranking that includes most of universities from the Republic of Moldova, this paper will provide a comparative analysis of the web pages of the TOP 5 ranked higher education institutions from the Republic of Moldova and Romania, related to the Visibility parameter within the Webometrics ranking, while making some conclusions followed by recommendations aimed at improving the positions of Moldovan universities.

II. ANALYSIS OF VISIBILITY INDICATORS OF THE WEBOMETRICS RANKING OF THE TOP 5 UNIVERSITIES (REPUBLIC OF MOLDOVA & ROMANIA)

The Ranking Web or Webometrics is the largest academic ranking of Higher Education Institutions offering every six months an independent, objective, free, open scientific exercise for providing reliable, multidimensional, updated and useful information about the performance of universities from all over the world [1]. The Webometrics Ranking is not a ranking of the websites of Universities, it is a Ranking of Universities. It uses both webometric (all missions) and bibliometric (research mission) indicators. The primary objective of the Webometrics Ranking is to promote Open Access to the knowledge generated by the university. Established in 2004 by the Cybermetrics Lab from Spain (Spanish National Research Council, CSIC), Webometrics Ranking (current is the 18th year of publication) with the aim of offering full coverage of Higher Education Institutes whatever the country or discipline involved. Currently, 31000 HEIs from more than 200 countries are ranked according to a series of indicators.

Starting from January 2021, the ranking introduced new rules regarding the indicators used in the calculation. Thus, the web presence indicator was excluded (with a share of 5% representing online presence, directly proportional to the size of the institution's main web domain), and the current indicators taken into account by Webometrics are the following:

50% – Visibility – Number of external networks (subnets) linking to the institution's webpages (normalized and then the maximum value is chosen). Source: Ahrefs & Majestic;

10% – Transparency – Number of citations from Top 210 authors (excluding the top 20 outliers). Source: Google Scholar.

40% – Excellence – Number of papers amongst the top 10% most cited in each one of the all 27 disciplines of the full database. Data for the five year period: 2017-2021. Source: Scimago.

The methodology for calculating the transparency parameter is based on the collection of citations from the first top 210 public profiles of each university, in order to allow independent comparisons of the number of employees of the institution, with the subsequent exclusion of the first 20 top profiles of the list to improve representativeness. For the other 190 profiles per university, the number of citations is added up, and the institutions are listed in descending order.

The latest Webometrics ranking (July 2022) included 24 universities from the Republic of Moldova [2]. The best positioned university – the State University of Medicine and Pharmacy "Nicolae Testemitanu" (USMF), is on the 3875th place, followed by the Technical University of Moldova - UTM (the 3927th place), Moldova State University - USM (the 4026th), the Academy of Economic Studies of Moldova (ASEM) is ranked the 4th nationally and 7960 globally, and the 5th nationally and the 8456th globally out of over 31000 higher education institutions included in the ranking is the State University "Alecu Russo" from Balti (USARB).

Similarly, the July 2022 Webometrics ranking included 102 educational institutions from Romania [3], so the following universities are in the TOP 5 of this ranking: the 1st at the national level and the 823th at the global level - Babes-Bolyai University (UBB); position 2 nationally and 980 globally – "Alexandru Ioan Cuza" University from Iasi (UAIC); position 3 at national level and 1147 at global level - Polytechnic University of Bucharest (UPB); position 4 nationally and 1231 globally - Bucharest Academy of Economic Studies (ASE); position 5 nationally and 1451 globally - Transilvania University of Brasov (UNITBV).

Since both the transparency and excellence indicators in the ranking are tangential to the research activity within the university, we will analyze the values of the impact indicator (with a share of 50% in the final score of the ranking) for the universities mentioned above, but also the correlation of these values with the institutional webpages.

If we analyze the values of the impact indicator for the TOP 5 universities from the Republic of Moldova in the Webometrics ranking presented in fig.1 versus the values of this indicator for the Romanian universities ranked in the first 5 positions in Webometrics (fig.2), we will find out since this parameter has a share of 50% of the final score, none of the Moldovan university will be able to improve its position in the ranking if, in addition to research activity, it does not also improve the value of this indicator. It should be noted that the minimum value of the indices presented in the table indicates a higher position in the ranking.

Moldova, Republic of

ranking	World Rank	University	Det.	Impact Rank*	Openness Rank*	Excellence Rank*
1	3875	Nicolae Testemitanu State University of Medicine and Pharmacy / Universitatea de Stat de Medicina si Farmacie		8592	2386	4078
2	3927	Technical University of Moldova / Universitatea Tehnica a Moldovei		6741	2616	4558
3	4026	State University of Moldova / Universitatea de Stat din Moldova		3587	2785	5413
4	7960	Academy of Economic Studies from Moldova / Academia de Studii Economice din Moldova		8833	5015	7217
5	8456	Balti State University Alecu Russo / Universitatea de Stat Alecu Russo din Bălți		10599	4463	7217

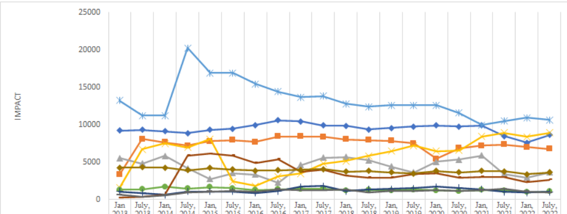
Figure 1. TOP 5 universities from the Republic of Moldova, ranked in Webometrics. July 2022 edition, source: Webometrics Ranking of World's Universities [2].

Romania

ranking	World Rank	University	Det.	Impact Rank*	Openness Rank*	Excellence Rank*
1	823	University Babes Bolyai		1066	864	1009
2	980	Alexandru Ioan Cuza University		995	1095	1379
3	1147	University Politehnica of Bucharest / Universitatea Politehnica din Bucuresti		2633	1137	1043
4	1231	Bucharest Academy of Economic Studies		899	1294	2098
5	1451	Transilvania University of Brasov		3619	1454	1258

Figure 2. TOP 5 universities from Romania, ranked in Webometrics. July 2022 edition, source: Webometrics Ranking of World's Universities [3].

Based on the public information provided by Webometrics, figure 3 presents the variation of the values of the impact indicator both for Moldova's and Romania's universities for the period January 2013 - July 2022. Although the value difference of the Impact parameter between the first university ranked in the TOP of the Republic of Moldova (USMF, with a value of 8592) and UBB, from Romania with a value of 1066 is quite high (about 8 times), the latter is not a value that could not be reached or at least reduced by the USMF within a reasonable period of time, which would allow to improve its position in the international ranking.



	Jan 2013	July, 2013	Jan, 2014	July, 2014	Jan, 2015	July, 2015	Jan, 2016	July, 2016	Jan, 2017	July, 2017	Jan, 2018	July, 2018	Jan, 2019	July, 2019	Jan, 2020	July, 2020	Jan, 2021	July, 2021	Jan, 2022	July, 2022
USMF (usmf.md)	9200	9317	9096	8867	9297	9438	9955	10569	10432	9902	9855	9339	9542	9721	9870	9748	9896	8462	7595	8592
UTM (utm.md)	3334	8076	7642	7192	7788	7930	7670	8411	8425	8361	8037	7940	7805	7469	5405	6844	7179	7348	6998	6741
USM (usm.md)	5517	4784	5805	4163	2707	3507	3336	2231	4591	5574	5666	5217	4376	3590	5037	5338	5839	3433	2943	3587
ASEM (ase.md)	1568	6689	7457	6934	8049	2400	1802	3068	3446	4804	5112	5790	6441	7181	6448	6544	8415	8890	8369	8883
USARB (usarb.md)	13224	11195	11195	20245	16876	16876	15437	14418	13677	13820	12777	12368	12599	12597	12601	11535	9954	10450	10901	10599
UBB (ubbcluj.ro)	1291	1362	1703	1443	1621	1478	1251	1345	1415	1468	1215	1244	1226	1284	1188	1112	1266	1207	980	1066
UAIC (uaic.ro)	1073	870	633	1048	1055	1031	880	1089	1669	1793	1107	1344	1419	1494	1679	1563	1369	1019	910	995
UPB (upb.ro)	212	312	597	5857	6109	5859	4893	5355	3681	3978	3162	2909	2901	3359	3494	2918	3021	2959	2327	2633
ASE (ase.ro)	627	325	589	972	1065	1167	1015	1369	1192	1185	1296	907	1154	1084	1210	1094	1269	1386	1057	899
UNITBV (unitbv.ro)	4234	4305	4239	3918	4212	4013	3831	3920	3943	4038	3688	3821	3616	3462	3806	3607	3811	3742	3368	3619

Figure 3. Value variation of the Impact indicator of the TOP 5 positioned universities both in the Republic of Moldova and Romania. Source: Webometrics Ranking of World's Universities.

III. CORRELATION OF THE IMPACT INDICATOR WITH DATA COLLECTED BY THE WEB ANALYZER OF THE TOP 5 UNIVERSITIES RANKED IN WEBOMETRICS (REPUBLIC OF MOLDOVA & ROMANIA)

Maintaining the performance of a website, especially for a higher education institution, is not a simple task at all. Improving the performance of an institution's website must be the result of serious decisions based on relevant and accurate data. In this regard, in addition to daily online activities, it is recommended to use reliable tools to check website traffic versus online pages of the competitor. Thus, monitoring your own university website and comparing the statistics of similar portals (national and international higher education institutions) has numerous benefits.

Currently, in the online environment, there are many website traffic checking tools available both for free and paid, but the purpose of this paper is not to compare the functionalities of these tools.

For the purpose of comparing the impact indicator values versus the information collected by the web analyzer for the webpages of the above-mentioned universities, we will use the tool SimilarWeb [4], which provides efficient information such as traffic sources, audience values, geolocation profiles and keyword performance. According to some tests [5], SimilarWeb ranks among the most accurate web analyzers, this being a free tool, but also having a paid version. With the help of the SimilarWeb tool, it is possible to collect information about the number of visitors, and it also enables us to see the traffic to the university website per country. Using this tool, it can significantly improve SEO (Search Engine Optimization) to bring more traffic to the university's webpage. The premium version of SimilarWeb offers various tools and complex options for comparing webpages against competing websites.

Analyzing the webpages of the universities selected in the research, with the help of the SimilarWeb tool, we obtained the following results, presented in Table I:

TABLE I. DATA COLLECTED BY THE WEB ANALYZER ON 14.09.2022 FOR THE UNIVERSITIES SELECTED IN THE RESEARCH. SOURCE: SIMILARWEB.

HEI	***Impact Rank***	***Total visits,***	***Bounce rate, %***	***Ave-rage pages per visit***	***Average duration of time spent on the site***
Republic of Moldova					
USMF	8592	234.5	47.17	4.43	00:02:22
UTM	6741	130.0	42.24	5.13	00:05:01
USM	3587	120.6	40.51	5.52	00:03:56
ASEM	8833	31.4	43.74	4.57	00:04:12
USARB	10599	23.0	59.36	2.78	00:02:17
Romania					
UBB	1066	462.8	41.81	4.92	00:03:11
UAIC	995	376.8	42.87	4.21	00:05:12
UPB	2633	487.1	33.45	5.88	00:05:31
ASE	899	282.7	47.52	6.37	00:04:37
UNITBV	3619	342.6	28.25	7.28	00:04:30

The indicators measured by the web analyzer and listed in Table I indicate the following parameters: Total visits - sum of all visits on desktop and mobile from the last month, expressed in thousands of users; Bounce rate - average percentage of visitors who view only one page before leaving the website, expressed in percentage. Total visited pages represent the total number of webpages that the user accesses on the site. The duration of the visit is the time spent by the user on the university website. Bounce rate is the ratio between the time the user opens the webpage and closes the page immediately. The results of the analysis of data collected highlight that the average time the user focuses on the webpages of the 5 universities included in the research in Romania exceeds the one spent on the webpages of the Moldovan universities. In this context, we can conclude that if the university's website shows a higher average visit duration than other competing institutions, this proves that the website has many interesting contents that attract various users (prospective students, current students, partners, etc.). Both the total number of pages visited by users in the case of Romanian universities and the bounce rate percentage (the percentage of visitors who enter the website and then leave the web domain, without continuing to view other pages from the same website) record values that allow them to be positioned ahead of the universities from the Republic of Moldova in the final score of the Impact Ranking. In the context in which Moldovan educational websites show a high percentage of bounce rate, they must take into account their websites content, language versions, but also the relevance of presented information for visitors both nationally and internationally.

Summing up the information presented in Table I, we can conclude that it is a priority in the next period „to fill” the webpages of Moldovan universities with accessible content that would be of interest to several service beneficiaries, not only to the internal academic community of the university or its potential students, thus increasing the number of reference subnets collected within the Ahrefs and Majestic ranking, and subsequently contribute to the improvement of the Impact Rank positions.

Regarding the increase in the impact rating for the TOP 5 Moldovan universities, it is recommended:

• to implement tools that will increase the social media presence of the university;

• to implement a greater number of academic mobility programs in the university, including internships, continuous training, professional retraining, partnerships with the business environment, development of joint research projects and programs, participation in international scientific conferences, other events of academic interest;

• to expand cooperation and interaction with international institutions, universities and research institutes;

• to increase the number of foreign students enrolled at university study programmes;

• to participate in international research, but also technology transfer, cross-border projects, etc.

In order to diversify, but also to increase the web domains, which refer to the webpages of Moldovan universities, in the next period, for each ongoing project, whether it is national, regional, international, or research, one should analyze and check if partners' website not only presents university's logo or mentions about it in the text, but also inserts a hyperlink to the university's webpage.

If the faculty or any university subdivision has any direct partnership with some institutions / companies, then partner's website can refer to the name of the faculty and the university's webpage, which will finally be counted in the Majestic and Ahrefs reports for the purpose of achieving Impact Rank.

An important role in the process of establishing the university's visibility on the web is played by language tags, which are extremely effective in SEO optimization. It is important to ensure that each language version is easily visible. It is advisable to keep content for each language on separate URLs, but also to place links on university pages to switch from one language to another. In such a way, an English surfer who opens the French version of the higher education institution's page could access the English version with a single click. It is recommended to use several languages in the organization of the website, but the translations must be of a high quality, professionally executed.

IV. Conclusions

With the purpose of improving the values of the Impact indicator and as a result of the analysis of the Moldovan universities' webpages, we propose the following short-term action-conclusions:

1. Deans of faculties, heads of departments, services and other university subdivisions should present truthful and up-to-date information that will later be professionally translated into English, French, and/or other languages of international communication and placed on the university website, with the aim of increasing its degree of visibility and attractiveness.
2. Completing the list of external links that the university domain receives from third parties with new links to various collaboration projects existing within the university.
3. The universities should join business directory listings, for example: http://www.umultirank.org, https://www.dnb.com/, https://www.google.com/business/, etc.
4. Increasing the total number of webpages hosted by the university websites.
5. Increasing the total number of *.pdf, *.ppt, *.doc, etc. type of files (didactic-scientific publications, regulations and instructions in force) of major interest to those who interact with the university, placed on the institution's webpage.

Medium term actions:

1. Boosting the promotion measures of the university image in the online environment.
2. Disseminating university events and activities within social networks and online media.
3. Centralizing and updating the webpages that currently use the web domains of the institution.
4. Don't focus on the number of backlinks in a particular domain. Focus on the number of different organizations referencing university web domains. Each independent organization (even with a single backlink to you) will add +1 to the number of referral subnets used in the calculation of the impact value.
5. Use the power of social media: motivate your academic staff and undergraduate / master's / PhD students to share the content of the higher education institution's website on all social networks: Facebook, LinkedIn, Twitter, Vimeo, YouTube, Reddit, etc. [6]
6. Motivate your academic staff and undergraduate / master's / PhD students to share university website content online: Wikipedia, SlideShare, GitHub / GitLab, Q&A websites, etc. [6]
7. Motivate your staff and undergraduate / master's / PhD students to share your website content (e.g. from an institutional repository) to all social networks: Mendeley, CiteULike, etc. [6]

8. Use the power of bibliometric catalogs – library staff to integrate the institutional repository with the variety of bibliometric catalogs. Register and be present in every online university database and catalog.

9. Increase the volume of english language content of the webpage - this will bring you immediate benefits by increasing the audience to the university website, including internationally.

10. Track the impact indicators of university departments and subdivisions: give certain bonuses or monthly increments to those who complete the above actions by counting them.

11. Motivate your staff to create valuable online projects for local and even international society (high-quality reviews, interviews with top graduates, your own internal rankings or other unique content that will increase your web citations).

12. When university partners write articles about a visit to you, or about a particular partnership, ask them to mention the university website or any other relevant sub-site of university subdivisions.

13. Develop reporting forms where university staff could indicate evidence or results of a business trip, internship or joint project, and in these forms, you can ask them to specify where the university field is mentioned on the hosting website, in the context of their activity.

As a result of implementing the above-mentioned recommendations, there is a strong possibility of reaching a critical mass for the purpose of general efficiency and increased competition, which could help propel Moldovan universities in the rankings. Universities should promote internal policies that support innovation, the application of research results and the development of start-ups. Also, universities must periodically ask for the opinion of students regarding the education they receive and other services provided by the higher education institution, in a way that ensures the sincerity of the answers, and take these opinions into account to improve the offered services.

Possible effects of the attempt to improve some complex indicators, for some university rankings, can have an effect only after time intervals between 3 - 5 years, period during which the indicators used by the most popular rankings can change. Therefore, the actions presented in the paper do not aim at measures that try to manipulate precisely defined parameters, such as the indicators of the current versions of the Webometrics ranking, but indicators that correspond to various results expected by the society following the development of the university activity and that can be collected quantitatively, under one form or another, so that they can be used in possible rankings. For example, universities that have focused on real growth in research performance will benefit from various subsequent evaluations, compared to higher education institutions that have focused only on indexing their own journals or only on encouraging publications in local journals. In other words, universities must not pursue artificial optimization of performance, but publish scientific articles that will be cited by other researchers, in international scientific journals; to prepare graduates that companies will hire and pay good salaries; to be visible nationally and internationally as educational institutions of academic excellence; to become more and more attractive for foreign students; to create real market value and applicability inventions both nationally and internationally; to recruit staff recording unbeatable results in research, recognized worldwide; to publish information of major interest on the webpages, not only in Romanian.

The universities that take seriously the improvement in international rankings, should proceed to a restructuring of human resources, and this action, depending on the university's budgets (which would allow it to make attractive offers to internationally recognized people), would allow a recruitment of some didactic staff from outside the country, with excellent results in research. In this context, the university management should be open to these competitive actions, even if this would overshadow or show a superiority over the current university's staff.

And last but not least, the candidates who apply for the occupation of vacant teaching and scientific-didactic positions must benefit from a real competition, in the context where, currently, there is often only one candidate per position, more precisely - the candidate for whom the position is being created. Without an imperative attitude towards these approaches, it will be impossible to talk about the entry of Moldovan universities into the top positions of the international rankings.

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Role of the University Management System in the digitalization of Technical University of Moldova

Dinu Ţurcanu [1], ORCID: 0000-0001-5540-4246
Rodica Siminiuc [1], ORCID: 0000-0003-4257-1840
Tatiana Ţurcanu [1], ORCID: 0000-0002-8972-8262
[1] Technical University of Moldova, Chişinău, Republic of Moldova, dinu.turcanu@adm.utm.md, https://utm.md/, rodica.siminiuc@adm.utm.md, https://utm.md/, tatiana.turcanu@srco.utm.md, https://utm.md/

***Abstract*—Digital transformation has radically transformed societies and economies, having an ever-increasing impact on everyday life. The COVID-19 pandemic has revealed certain challenges for education systems related to digital skills of the higher education institutions, the use of digital tools and general level of digital competences and digital literacy. Ideally, a University Management System should have several functionalities, such as: management of the professional guidance of students (prospective students), management of the admission process, student management, employee management, finance management, research management, graduate management, management of the university documents and processes, but also academic management. A successful university management system will ultimately ensure the quality of education, will maintain a high level of institution's image and academic integrity.**

Keywords*—university management system, digital transformation, digital literacy, quality of education.

I. INTRODUCTION

Digital technologies have already markedly transformed the media, commerce, entertainment sectors, and education, the higher education sector being the next on the list. In the future, university campuses will be kept as spaces for teaching, learning, research and innovation, but digital transformation will radically change the way knowledge is delivered, will enable real-time feedback from students, will boost distance learning and will enhance market diversification of the educational service providers.

According to the study on the economic and social impact of the COVID-19 pandemic, developed by UNDP (United Nations Development Programme) Moldova [1], about 150 thousand pupils and students did not have access to studies during the restrictions, due to the lack of the necessary equipment, knowledge or Internet connection of pupils/students or teaching staff; several small and medium enterprises, not being prepared for online commerce, stopped their activity, causing an economic decline of -7% of GDP in 2020; most of the employees of the local and central public authorities had to be physically present at work, exposing themselves to the risk of infection, due to the malfunctioning of some digital systems, etc.

Moldovan legal system in terms of public sector and its digital transformation has developed a lot lately. A series of recently published normative acts obliged public institutions to provide e-mail communication with citizens, but also to accept from them documents in electronic format. However, the public system still seems to be caught in the inertia of bureaucracy, and recent approaches to the subject by the mass media reiterate this inertia. The educational information systems are also fragmented, seized between the online and offline environments, also due to the lack of a unitary legal framework that would constitute the foundation for the architecture of digital public services. Some higher education institutions benefit from minimal or average functionalities of the University Management System (UMS), while others - of the same level, do not have sufficient resources to introduce such innovations in the service portfolio. One of the causes of this fragmentation lies in the lack of a previous prioritization of the digital transformation, an imperative of the institutional management too. This situation determined the emergence of an environment where some universities operate only on paper in the same inertia of bureaucracy.

Even though the Republic of Moldova has 98% of its territory under 4G coverage, several functional e-Gov services, an ICT (information and communication technology) sector with an accelerated development of about 7% contribution to the gross domestic product - GDP, the COVID-19 pandemic highlighted the lack not only of a university digitization strategy, but also of a national governance framework for digital public services.

II. DIGITALIZATION STRATEGY OF THE TECHNICAL UNIVERSITY OF MOLDOVA

Digital transformation strategy of the Technical University of Moldova (UTM) focuses on several documents that reveal the trends regarding the digitalization of the Republic of Moldova:

- 2030 Digital Compass: the European model for the digital decade proposed by the European Commission [2], which mentions the vision for the year 2030 regarding digital transformation at the European level. Four cardinal points are established and they should be considered by all national structures, and since Moldova was granted the status of a candidate country for accession to the European Union, these goals became national recommendations:

a. A digitally skilled population and highly skilled digital professionals;

b. Secure, high-performing and sustainable digital infrastructures;

c. Digital transformation of businesses;

d. Digitization of public services - providing all key public services in the online environment in proportion to 100%.

- The concept of the digital transformation strategy of the Republic of Moldova for the years 2023–2030 (STDM 2030) [3]. In this context, the document provides that the implementation of STDM 2030 will ensure the transformation of the Republic of Moldova into a country with an innovative and inclusive digital society, based on a modern infrastructure with digitally educated people, pro-digital governance, a business community that fully implements digital opportunities as well as a collaborative environment for stakeholders, which encourages the innovative work of all people and ensures sustainable human development.
- The digital education action plan of the European Union for the period 2020-2027 [4], which is grounded in two strategic priorities: Fostering the development of a high-performing digital educational ecosystem and Enhancing digital skills and competences for the digital transformation.
- The institutional strategic development plan of the Technical University of Moldova, 2021-2026 [5], which includes digital transformation activities in all university areas.

UTM identified during its existence the same issues highlighted by the previously mentioned documents, and on the other hand, during the period 2016-2022, it implemented several courageous digital transformation initiatives at the internal level.

Thus, throughout its existence, there were recorded a lot of achievements, facts and challenges at the university level:

- fragmentation of the infrastructure acquisition in some areas (accounting software, library resources, statistical analysis and planning software, etc.);
- digital transformation of the university components, such as teaching, research, the relationship with the business environment and the administration, was carried out fragmentedly, recording more dynamic and consistent steps only in the last 4 years, thus we can discuss about an average digitization of the university processes;
- taking into account that in the summer of 2022, Technical University of Moldova was reorganized as a result of the mergence (absorption) of the following public institutions: 1) Public Institution State Agrarian University of Moldova; 2) Public Institution Institute of Electronic Engineering and Nanotechnologies “D. Ghitu” 3) Public Institution the Institute of Power Engineering 4) Public Institution the Institute of Microbiology and Biotechnology, it is impossible to discuss the use and deep implementation of IT solutions in all fields of activity of the university. In some areas of the absorbed institutions, the institutional processes are not digitalized at all, and this causes the risk of slowing down the initiatives with an emphasis on digital transformation at the UTM level;
- students / didactic-scientific staff / researchers / administrative staff have benefited from training on digital solutions over time, but a human resource training strategy is now required, covering areas of skills related to digital literacy in order to better capitalize on the opportunities associated with the secure use at large-scale of the digital solutions within UTM;
- a major challenge for the university is associated with the process that involves stop using printed documents, holographic signatures and the full use of electronic documents, but also the certificate of the public key for the qualified advanced electronic signature [6]. University documents and information must be able to be created and exist originally in electronic format, being able to be archived by category, in order to be accessible, transparent and possible to be tracked. This challenge causes some important problems related to financing, but also to the identification of IT solutions, so that all documents created in the UTM have a visible digital history and can be archived / transmitted digitally to all interested users, but also comply with national legislation regarding archiving.

The following diagram was made according to the situation at the university level and presented in Table I, which describes the current organizational status based on the Strengths and Weaknesses, and respectively what we estimate will happen in the future in the external environment regarding digital transformation through the prism of Opportunities and Threats:

TABLE I. SWOT ANALYSIS OF UTM DIGITAL TRANSFORMATION

SWOT analysis	***Positive***	***Negative***
Current internal analysis	**Strenghts** 1. Previous investments in modern computer hardware and software at UTM; 2. Most of the university staff has a high level of technology acceptance; 3. UTM administration is willing to support a large-scale digital transformation process; 4. UTM's thourough understanding of the needs of external stakeholders regarding the university's services.	**Weaknesses** 1. Existence of fragmented information infrastructure within the UTM; 2. Various levels of digital skills among university's employees; 3. Insufficient financial resources the university can allocate them to digital transformation; 4. Insufficient human resources in order to achieve digital transformation at internal level.
Estimated evolution of the external environment	**Opportunities** 1. Existence of opportunities for digital transformation funding through external partners; 2. Establishing more valuable partnerships with companies interested in contributing to the digital transformation of UTM; 3. National and international legislation, along with various level strategies foster the digital transformation at UTM; 4. More and more national institutions are able to provide information in digital format.	**Threats** 1. Rapid change of digital solutions and requirements related to this transformation for various reasons; 2. Major and unpredictable variations in equipment prices as well as supply chain issues related to digital physical infrastructure; 3. Legislative inconsistency at the national level regarding digital transformation and the lack of funding for digital transformation processes.

Digital transformation should take place in a context defined by the university's peculiarities and also by the readiness level of processes. This type of context is determined by the indicators of the SWOT analysis presented above: strengths, weaknesses, opportunities and threats that modulate both the university environment and its evolution in the cultural, economic, political and social development paradigm of the region.

III. DIGITAL TRANSFORMATION OF TECHNICAL UNIVERSITY OF MOLDOVA IN 2018-2022 USING THE UNIVERSITY MANAGEMENT SYSTEM

One of the major objectives of the digital transformation strategy focuses on the development of the university management system, which enables: instant access of the administration to any university information; debureaucratization of the educational and administrative processes; increasing the satisfaction degree of the university environment; implementing modern methods of internal communication; enhanced UTM visibility at national and international level, but also a high level of university credibility, as a result of increasing transparency and access to information [7].

In March 2020, when the Parliament approved the Decision on declaring a state of emergency on the entire territory of the Republic of Moldova, caused by the COVID-19 pandemic, UTM, like other universities, faced a series of challenges. The litmus test was to provide exclusively online learning. A lot was done, various software applications were tested, a period of teachers' training followed. In this context, university's partnerships with various companies in the field greatly facilitated the process of transition to online education. Being one of the first universities in the Republic of Moldova to successfully implement Office 365 for Education, which has an impressive package of tools, which we used in the digitalization of courses, the creation of electronic registers and applications related to class attendance, but also the use modules of the university management system – all these tools represented a special opportunity during the period in which the study process was stopped. UTM was one of the few universities that went online not only for the examination session, but also for the defense of the final year projects, bachelor's and master's theses [8]-[9].

The evolution and modernization of UTM's information systems during the period 2018-2022 played a crucial role in institution's activity and increased its visibility in the online environment. The ICT services of UTM have been developed continuously, a wide range of tools being designed and implemented with the aim of facilitating the activity of the entire academic community:

1. The modules of the university management system of UTM, primarily the "Admitere" (Admission) module, were developed and adapted to the requirements imposed during the pandemic period, ensuring the continuity of university activities. Online registration and pre-admission were developed by the ICT department of UTM and later adapted to the requirements to register candidates for online education during the pandemic period. Therefore, these tools, shown in fig.1, allow the prior registration of candidates for both the first Bachelor's degree cycle and the second Master's degree cycle within the university admission committee. The

functionality of the developed tools enables the candidates to manage data, upload files and pay online all the required fees. The module also provides notifications to the registered candidates by e-mail concerning details about the stage of information verification of their files, as well as SMS notifications at any verification stage.

Figure 1. The interface of the module “Admitere online” (Online admission).

After creating the account, the candidate for studies can access the personal cabinet, presented in fig.2, which is intended to automate the process of making the admission within the UTM. This allows the candidate to complete the form, upload personal files, study documents and complete the corresponding fields corresponding of application form.

Figure 2. The personal cabinet of the candidate who uses the module “Admitere online” (Online admission)..

2. In order to fully digitalize the admission processes, the first „Achitare on-line” (Online payment) module was developed and implemented (see fig. 3), being initially applied for the payment of the admission fee, later being applied to other services provided by UTM.

Figure 3. The module „Achitare on-line” (Online payment) processes the admission fees paid by the applicants.

3. In the period 2018-2022, the University Management System was developed continuously by including new functionalities, as well as improving the existing ones. Annually, it is performed the analysis, redesign / design, implementation, installation and configuration of the functionalities that includes the following modules:

- Information system “Decanat” (Dean’s office)
- Information system “Departament academic ciclul I şi ciclul II“ (Academic department cycle I and cycle II)
- Information system “Evidenţa studenţi” (Student record)
- Information system “Fişa de lichidare” (Liquidation form)
- Unified System “Managementul resurselor umane” (Human resource management)
- Information system “Salarizare” (Payroll)
- Information system “Anti-plagiat UTM” (UTM anti-plagiarism)
- Information system “Universitatea Mea” (My university)

All these modules, as well as other digital tools that aim to facilitate university processes, can be selected by the operator, at the time of his/her authentication and authorization in the UMS interface of UTM, as shown in fig.4.

Figure 4. Selection by the operator of the mode required for the subdivision or university processes within the UMS of UTM.

Improving the functionality of the module “Managementul resurselor umane” (Human resource management), which aims to record the academic staff by using a wide range of functionalities. All the possibilities offered by the given system are due to the interconnection of a multitude of submodules: Planning, Orders, Reports, Staff Records, Salary Calculation, Time Attendance, etc. An important module that simplified and digitalized the nondigital or paper documents is “Pontaj” (Timesheet) information module – Timesheet Generation. This module collects the information at the level of orders issued on employees by the human resources records office, and based on them, it automatically generates the timesheets, which will be used later in the salary calculation. The interface of the automated timesheet generation system is shown in fig.5.

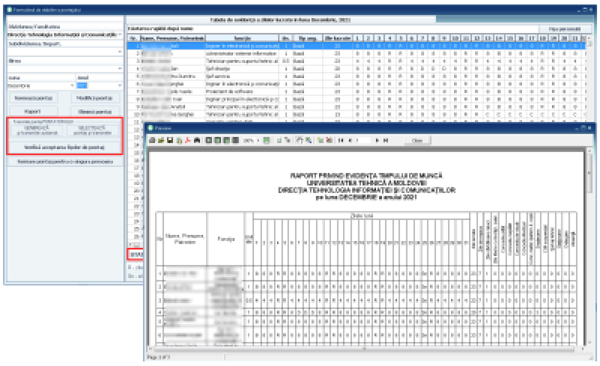


Figure 5. Automated generation of reports regarding the timesheets records of UTM employees.

The most important functionalities of this submodule include:

- setting the persons responsible for timesheets per faculty / subdivision / department, etc.,

- the possibility of automated transmission of the document generated in *.doc format to the timesheet managers for verification and approval,

- the possibility of sending a document with some changes made by the Human Resource Office after its generation to the timesheet managers for verification and approval,

- automatic notification of the timesheet managers via corporate mail about the generation of the timesheet document and the need to access the UMS for verification and approval,

- the possibility to establish a communication between the timesheet managers and the person who generated the timesheet through the online chat within the UMS.

Subsequently, the report on the record of the employees’ working time is used within the informational module also fully managed by the UTM - the informational module “Salarizare” (Payroll). It uses a set of regulations and mechanisms related to fixing the salary level, it differentiation (by branches, professions, positions, seniority, etc.). The interface of this tool is shown in fig.6.

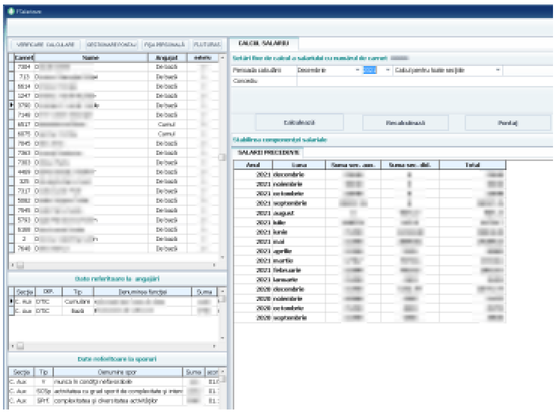


Figure 6. The operator interaction interface that manages the module “Salarizare” (Payroll).

4. Completion of the module „Arhiva ordine” (Order archive) with the module „Notificări” (Notifications), shown in fig.7, which carries out the notification process via the university corporate e-mail of each individual collaborator, with the possibility of direct access to the document in which he/she is being targeted.

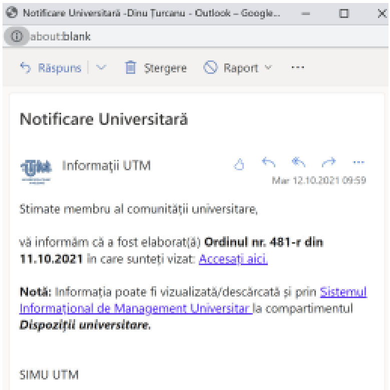
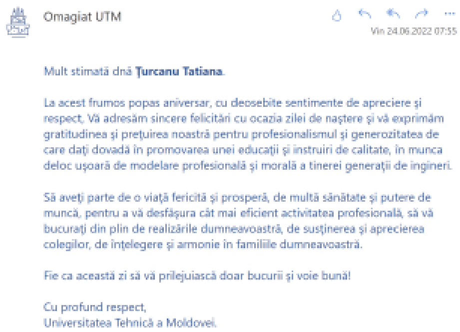


Figure 7. Example of notification received by the university collaborator in the corporate e-mail address.

5. The creation of the module „Omagiat”- (Celebrant), as a component of the university management information system, which performs a complex automated process of interaction of different data processing algorithms for the identification of celebrant university collaborators at an indicated period of time. Tool’s functionality focuses on 3 components: the module the module „Omagiat administrație” (Celebrant administration) - informing the rector and vice-rectors about the list of celebrants for a predetermined period via the university corporate e-mail; the module „Omagiat decan” (Celebrant dean) – informs the deans of the faculties about the list of celebrants from the

corresponding faculty; the module „Omagiat felicitare" (Celebrant birthday message) – sends a congratulatory message per celebrant as shown in the image in fig.8.


Omagiat UTM

Vin 24.06.2022 07:55

Mult stimată dnă Ţurcanu Tatiana,

La acest frumos popas aniversar, cu deosebite sentimente de apreciere și respect, Vă adresăm sincere felicitări cu ocazia zilei de naștere și vă exprimăm gratitudinea și prețuirea noastră pentru profesionalismul și generozitatea de care dați dovadă în promovarea unei educații și instruiri de calitate, în munca deloc ușoară de modelare profesională și morală a tinerei generații de ingineri.

Să aveți parte de o viață fericită și prosperă, de multă sănătate și putere de muncă, pentru a vă desfășura cât mai eficient activitatea profesională, să vă bucurați din plin de realizările dumneavoastră, de susținerea și aprecierea colegilor, de înțelegere și armonie în familiile dumneavoastră.

Fie ca această zi să vă prilejuiască doar bucurii și voie bună!

Cu profund respect,
Universitatea Tehnică a Moldovei.

Figure 8. Example of a birthday message sent to the corporate e-mail address of the celebrant university employee.

6. Starting from the projects on process digitalization within UTM, the purpose of which is to facilitate a series of work and/or study activities, in order to simplify the process of data collection at the electricity, drinking water and domestic water meters by the residents of the university dormitories, it was developed an informational management system that digitalizes the meter data and allows the issuance of automatic invoices in the online environment - the „Serviciul on-line de colectare a datelor" (Online data collection service), shown in fig. 9, which is currently being improved, through the establishment of automatic / remote reading and implementation of online payment based on Moldova Agroindbank and/or MPay - Government Electronic Payments Service.

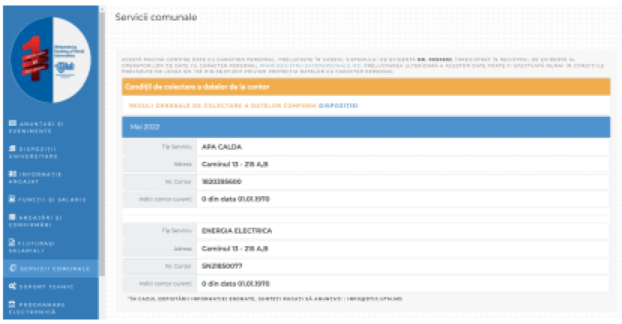


Figure 9. Data collection and issuance of online invoices for the services consumed by the residents of the UTM dormitories based on the "Serviciul on-line de colectare a datelor" (Online data collection service) module available in the university employee's personal cabinet.

7. Another very important digital tool of the university – the Online Platform "Universitatea mea" (My university), allows synchronization and quick access to the modules of the University Management System, which ensures transparency and access to information for any student or collaborator. The platform can be accessed from any location, from any device in real time, by accessing https://utm.md/universitatea-mea/. Based on this tool ("Universitatea mea – student" (My university – student"), UTM students can check online their academic situation and other information of university interest, as shown in fig. 10, and since the fall of 2019, the paper gradebook was excluded and is no longer used within the university. This tool, during 2021, was accessed by students 301,000 times.

Figure 10. The UTM student's digital notebook - the section "Academic Situation" of the module "My University – Student".

Also, through this tool, the annual agreement and the study contract can be accessed and signed. In order to confirm the consent regarding the extension of studies at UTM, the student has the opportunity to sign by pressing the „sign" button, as shown in fig. 11.

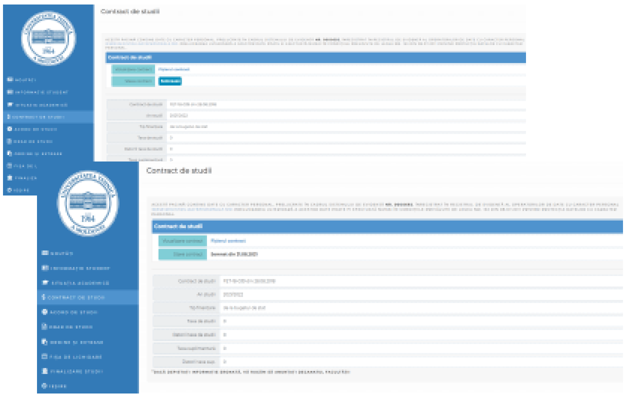


Figure 11. Accessing and signing the study agreement / study contract on the platform "Universitatea mea – student" (My university – student).

This agreement should also be signed using a holographic signature at the beginning of the academic year at the faculty's dean's office.

The digital tool ("Universitatea mea – angajat" (My university – staff) enables secure access of collaborators to the information related to university activity in real time as well as the automated notification of the persons targeted in some university documents (dispositions, orders, decisions, requests, etc.), as shown in fig.12. Also, employee's personal cabinet allows to check and request corrections of personal data, to access an aggregator of university news and announcements, etc. This tool, during 2021, was accessed by university employees 85,000 times.

Figure 12. Example of accessing the platform "Universitatea mea – angajat" (My university – staff) by the UTM collaborator.

8. Development of the module "Antiplagiat" (Anti-plagiarism), which is part of the University Management System and allows the academic departments to upload and validate through a friendly interface the final papers per student for the bachelor's and master's degree cycles, as presented in fig.13 and fig.14.

Figure 13. The uploading process of bachelor's theses and master's theses by the university academic departments for the generation of the similarity report.

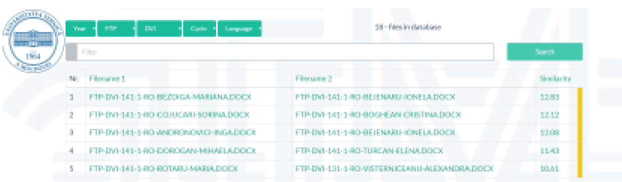


Figure 14. Generation of the similarity report within the module "Antiplagiat" (Anti-plagiarism) from the UMS of UTM.

9. Supplementing the online module „Universitatea Mea Student" (My university – student) with the tool that allows the graduate student of the first and second cycle to upload individually his/her bachelor's / master's degree thesis in order to check the similarity score, so that if the similarity score approved by the UTM is exceeded, the work can be edited until upon its final verification by the academic department, as shown in fig.15.

Figure 15. The tool enabling graduate students of the first and second cycle to check their bachelor's or master's degree thesis for the allowed similarity score.

10. In order to digitalize and secure access to the university dormitories, the ICT department of UTM implemented in the summer of 2022, an information system that will allow entry only based on a QR code generated by the application from the student personal cabinet on the platform ("Universitatea mea – student" (My university – student"). Thus, the university administration aims to limit the access of foreigners and increase the assurance of public order and safety in the university dormitories. It should be noted that a 24/7 video monitoring system, an access control system and a call system (intercom) with the possibility of opening the doors remotely, all of which can be accessed by the authorized staff (residents of the dormitories corresponding to their residential address) have been implemented. The possibility of generating the access code to open the dormitory door by the student is presented in fig. 16.

Figure 16. Generating the access code from the platform "Universitatea mea – student" (My university – student) by the residents of the UTM dormitories.

In the above-described and analyzed context, we found out that digital transformation refers to the fact that all university processes can be affected by information technologies and to the fact that all these processes can be improved / transformed due to the use of technologies. Digital transformation is not an end in itself, but it can contribute to achieving the university's strategy through an integrated approach that considers all areas of interest of the university and its processes.

IV. CONCLUSIONS

With the support of the university administration, but also due to available and effectively applied financial resources, digital technologies and the continuous development of the university management system will bring added value to education, improving and simplifying all academic and research activities at UTM and will offer a modern student-centered educational offer. Routine components will be automated, hence achieving financial and time efficiency, so that all those people involved in the life of the Technical University of Moldova can focus on really important aspects: knowledge, innovation, research and personal development.

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Activation of attraction processes of investments into national economy through capital market

Lilia Sava [1], ORCID: 0000-0002-4318-9486
Valentina Tîrșu [2], ORCID: 0000-0002-1726-792X
Daniel Cristișor [3], ORCID: 0000-0002-9192-7455
[1] PhD., Ass. Prof., Technical University of Moldova, lilia.sava@tse.utm.md, utm.md
[2] PhD., Ass. Prof., Moldova State University, valentina.tirsu@usm.md, usm.md
[3] PhD. Student, University of Suceava, Romania, dcristisor@gmail.com

***Abstract*— The globalization of the world economy and the integration of the Republic of Moldova into the European Community will require the state to create conditions for sustainable economic development, which is impossible without intensifying investment activity. The problem of attracting massive foreign investment requires improving the capital market in the country. The most important direction in solving this problem is the development of the internal stock market as the most efficient mechanism for redistributing financial resources. Therefore, the stock exchange should contribute at activation of attraction processes of investments in the national economy as a stimulus for future investment activity.**

Keywords — sustainable development, financial sustainability, stock exchange.

I. INTRODUCTION

The growth and economic development of a country are linked to the available funding opportunities of that society. These financial means can be secured both through the banking system and especially through the capital market, which is now a key element in attracting available capital. It is even appreciated that the modern stock exchange, as a result of having managed to substantially reduce the cost of operations, and as a result of carrying out transaction orders and providing real-time information, will soon overtake the banking system in terms of the ability to provide capital.

The attractiveness of a capital market in formation, such as that of the Republic of Moldova, is primarily due to the existence of solid economic foundations. A capital market cannot be analyzed separately from its national economy. The stock exchange cannot develop better than the real economy, after all, one of the functions of the stock exchange is precisely that of a barometer of the economic state of a country. Gaining credibility for these market economy institutions can only be done by creating an appropriate legal framework and regulating the activity [1].

Secondly, is assumed a state support for the development of the capital market, in a global assessment, the main mission of the state to support the development of the capital market is to support the development of the national economy. A convincing argument to invest in the capital markets in formation (the capital market of the Republic of Moldova) also depends on the performance of the economy, materialized in the growth rate. The link between stock market development and economic growth is strong. The economic growth rate should be the first criterion for assessing the performance of the capital market. So economic development can also entail the development of the capital market.

II. CONTENT

In the Republic of Moldova, the capital market is incipient, in formation, with little involvement in the real economy, that has been in evolution for a long time. As such, it has the characteristics of a non-performing emerging market: that it is a small market with low capitalization, illiquid market, with an attractiveness, efficiency, profitability and stability relatively low [2]. With the outbreak of the pandemic crisis COVID-19 in the spring 2020, which led to the imposition of restrictive measures and the reduction of economic activity by temporarily suspending or even closing the activity of some companies, dismissal of employees or sending them into technical unemployment, reduction of private consumption, restrictions on persons movement and goods transport, as well as disruptions in supply and distribution chains, as a result of the pandemic crisis exposed the primary market segment of the moldovan capital market to severe effects.

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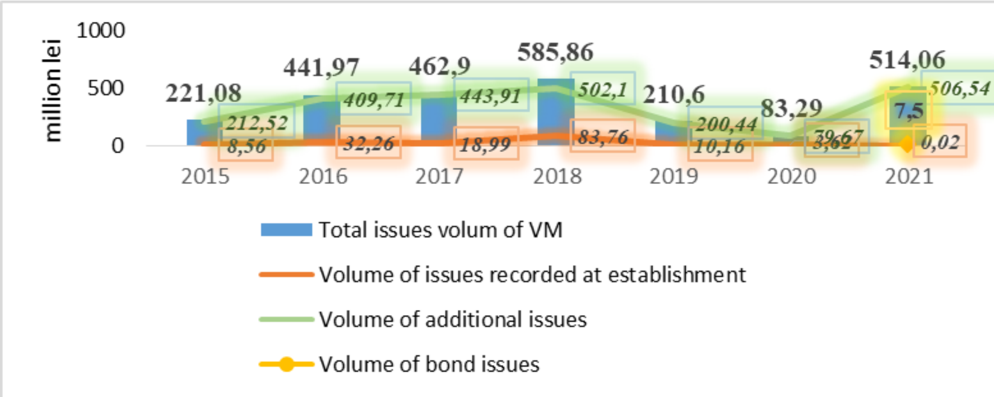

Figure 1. Volume of securities issues 2015-2021, Source: Developed by the authors based on the data from the BVM newsletters [3]

Viewed from the perspective of the issuers' capitalization of capital market instruments, it is noted that the years 2019-2021 were not exceptional, nor in these years these issuers, in order to ensure the production with new capital injections, they did not use capital market mechanisms to attract investment through public securities offerings. Thus, the shares were the only securities in circulation on the corporate capital market, the placements that were carried out exclusively in a limited circle of persons, through closed issues.

The repercussions of the pandemic crisis and the completion of legal procedures for shareholder quality adequacy in financial and banking institutions, initiated in previous periods, have led to even more severe cuts in the secondary capital market segment. Thus, after a significant jump of all relevant indicators, reaching a total trading volume of approximative 4693,1 million lei in 2018 and a historical maximum value of 5250,4 million lei, recorded in 2019, in 2020 an aggressive downward trend of this indicator was registered, the summary volume of transactions indicating values of only 1669,9 million lei (descending by 3580,5 million lei or by 68,2 percent compared to 2019).

In 2021, 7784 transactions were made with corporate securities in the volume of 2061,03 million lei, reported to 67,1 million lei of security issues, which shows an increase of 391,16 million lei or by 23,42% compared to the same period of the previous year (Table 1). Thus, transactions with securities were carried out, mainly on the OTC (over-the-counter) segment of the market, these being directly registered with the entities that keep track of the holders of shares (1,6 billion lei or 94 percent of the total volume of transactions carried out on the secondary market). At the same time, the most pronounced volume reductions occurred on the regulated segment of the secondary capital market, the summary volume recorded on this ransactionary platform being 69,5 million lei.As a total volume of securities traded outside the regulated market and MTF (OTC market), in 2021 registers an increase of 29 percent compared to 2020, where in 2020 there is a slight decrease (by 20 percent), compared to 2019, however, compared to the previous periods of 2015-2019, this indicator has an impressive rise.

This development was implicitly determined by the revision of the regulatory acts of the CNPF, according to which, in line with international practices, was established the liberalization of prices of securities traded on the non-organized segment of the secondary market.

The surveillance activity of the secondary capital market also includes monitoring the transactions that are carried out outside the regulated market and MTF (OTC market), with transactions in this market segment being recorded by the parties of this transactions either directly with the registry companies or with the investment companies, which have the right to carry out custodial activities, or in the Record System of the Central Securities Depository (CSD), depending on the person who actually keeps track of the traded securities.

The year 2021 was one of the most difficult years, with the lowest trading volume since the creation of the regulated market and of MTF (Figure 3). The low interest of investors is due to the changes that took place in the political sphere, also during this period the regulator of the capital market, the CNPF remained without management from september to the end of the year.

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Table 1. The evolution of stock market and over-the-counter market indicators, 2015-2021

Period	Stock Market		The OTC (over-the-counter) market Transactions outside the regulated market and MTF		**Total secondary market**	
	No. of transactions (units)	**Volume of transactions (million lei)**	No. of transactions (units)	**Volume of transactions (million lei)**	No. of transactions (units)	**Volume of transactions (million lei)**
2015	261	**193,97**	14270	**454,50**	14531	**648,47**
2016	748	**351,93**	11293	**785,41**	12041	**1137,34**
2017	407	**102,72**	20386	**461,19**	201793	**563,91**
2018	379	**1977,52**	7016	**2715,55**	7395	**4693,07**
2019	248	**3279,71**	5523	**1970,72**	5771	**5250,43**
2020	293	**103,16**	4524	**1566,71**	4817	**1669,87**
2021	170	**34,04**	7614	**2026,99**	7784	**2061,03**

Source: Developed by the authors based on the data from the BVM newsletters [3]

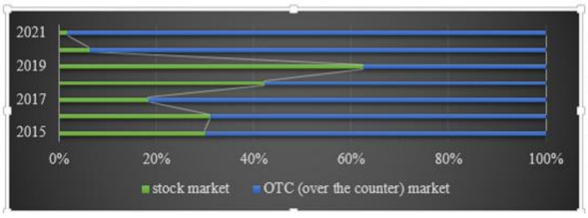

Figure 2. Volume of transactions on the stock and OTC market, million lei, Source: Developed by the authors based on the data from the BVM newsletters [3]

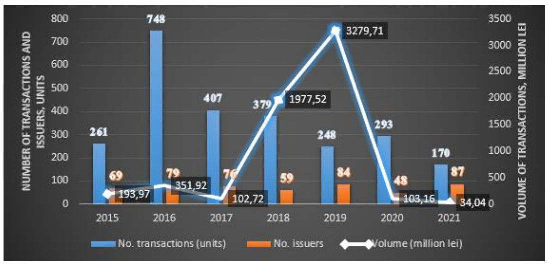

Figure 3. Evolution of BVM indicators, years 2015-2021, Source: Developed by the authors based on the data from the BVM newsletters [3]

It is worth noting that for the first time since the Exchange obtained the license of market operator, during the year of 2021 there were no transactions on the regulated market for a month, which led to equalizing the number of transactions on the regulated market (86 transactions) And in MTF (84 transactions). Transactions on PR took place between the period of January - April 2021, and may - November 2021, the volume of transactions had dropped sharply. The revival of the market begins in December 2021. On the other hand, the reverse is recorded in the MTF, where in the second half of 2021 takes place the market recovery, with registered transactions under the MTF of shares of issuers. Thus, the year 2021 was distinguished by diametrically opposed conjunctions for PR and MTF.

Analyzing the stock exchange structure for the last seven years, and despite the positive trend of volume growth within MTF in 2021, however, the volume recorded on PR remains to prevail. As a result of the activation of MTF transactions with securities that were not attractive in previous years, in 2021 we notice that over 30% of the total volume of exchange transactions is related to the MTF card. Public interest issuers are listed on PR and the frequency of market transactions is determined by the structure of the owners. Comparing the results of trading volumes on the stock and OTC market for issuers listed on PR, we note with regret the recording of significant volumes on the OTC market, on the background of a general decrease in the volume of transactions in 2021. However, at the end of 2021, a large-scale transaction was recorded on the OTC market, which led to the establishment of a historical maximum.

Finally, it is evident that there are positive moments on the stock market that inspire optimism for 2022, especially the trading of municipal bonds, which were admitted to trading under MTF in September 2021. It becomes an alternative to high-interest bank loans and intensifies securities transactions to issuers in other sectors of the economy, apart from those of the banking sector. The Moldovan capital market, viewed from this perspective, is full of contrasts. Market capitalization is high compared to the volume of transactions, market liquidity that is alarmingly low and volatility high. Although the capital market in Moldova is thirty years old, international standards remain a desideratum, a theoretical model, at least for now.

III. Conclusions

The low level of development of the national securities market is determined by the following factors: lack of public issues and liquid financial instruments, absence of institutional investors, insufficient application of advanced information technologies, low degree of confidence in investing in financial instruments and in the development of corporate relations. The normal functioning and development of the capital market ensure the reorientation and restructuring of the activity of companies according to market requirements, offer much faster financing methods both to the state, in the person of central and local public authorities, as well as to commercial companies. In this context, we can consider that the capital market must be not just a mere component of the market economy, but a barometer of the activity of each issuer and of the economy as a whole. As the capital market faces a number of described problems and impediments, the most suitable solutions for reanimating this sector need to be quantified for the coming years, including: stimulating the attractiveness of the capital market. In order to encourage investors and issuers of securities, fiscal measures are needed to redirect capital toward long-term investments in various attractive areas, stimulating public offerings; developing the bond market by: intensifying dialog with the institutions responsible for issuing state financial instruments, in particular bonds with a circulation term of more than one year, in order to admit them for trading on the regulated market; reviewing the regulatory framework for the development of the organized market (PR and MTF).

Considering that globally organized markets provide adequate protection for consumers involved in financial services through the creation of investment guarantee schemes, it becomes possible to develop this market segment through activities aimed for stimulating the attraction on the regulated market of large companies with significant trading values by highlighting the advantages of the presence on this segment compared to traditional financing methods.

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Microfinance organizations under conditions of crisis and uncertainty

Lilia Sava [1], ORCID: 0000-0002-4318-9486
Valentina Tîrșu [2], ORCID: 0000-0002-1726-792X
Anisoara Niculina Apetrii [3], ORCID: 0000-0002-8815-7111
[1] PhD., Ass. Prof., Technical University of Moldova, lilia.sava@tse.utm.md, utm.md
[2] PhD., Ass. Prof.,Moldova State University, valentina.tirsu@usm.md, usm.md
[3] PhD., Ass. Prof., Suceava University, România, anisoara.apetrii@usm.ro

***Abstract*— In conditions of deep global crisis, microfinance is considered to be one of the most adaptable financial instruments to the needs of small and medium-sized enterprises. This form of financial support for small enterprises in the form of microfinance organizations is highly relevant for the economy of the geographical region, the stability and scale of the activities of existing companies in this area. In this context, the authors, in addition to highlighting the momentary gaps in this segment of the economy activity, but also identify a number of proposals with regard to the management of credit risk and over-indebtedness risk, these are identified as the most urgent probable risks of the microfinance market, both in the Republic of Moldova and internationally.**

***Keywords*— microfinance, non-banking financial market, microcredit institutions**

I. INTRODUCTION

Microfinance has become an international phenomenon in recent decades, with continued growth in financial markets. In 2019, worldwide, this sector registered a portfolio of over 124 billion USD and over 98 million beneficiaries. As far as European countries are concerned, the microfinance sector is a relatively new one, starting to develop in the Western States since 2000, compared to 1990 in the eastern and central part of the old continent. As for Central and Eastern Europe, the microfinance sector gained popularity since 1990, initially as private initiatives, supported by international financiers. In other countries such as Romania and Bulgaria, microfinance organizations have a role as a non-bank intermediary, providing loans to the target segment. Currently Romania, microfinance is intensively supported by the European Investment Fund. In the Republic of Moldova, in recent years the sector continues to gain market share and become a visible competitor on the credit market. Considering this growth and the upward development trend of these organizations, a study of this sector is therefore necessary in order to determine the institutional capacities of these non-bank financial market players, as well as a determination of the degree of risk management capacity.

II. RESEARCH METHODOLOGY

The proposed objectives were achieved by applying several types of scientific research, of which is identified: *the documentary method, synthesis method, quantitative and qualitative analysis method, graphic method, etc.*

III. ANALYSIS AND DEBATE

The definition of micro-credit, being attributed to a relatively new and constantly changing sector, is not an ambiguous one, with different sources resorting to various statements. One reason would be the multitude of products and services offered by microfinance institutions, which take various forms: micro-credit, micro-insurance, each subcategory having its own services, its own operational costs, strategies and institutional contexts. According to the European Commission, microfinance consists, in particular, in granting small loans, necessary for entrepreneurs when starting a business, as well as SMEs for small investments or for regulating various cash flow problems. On the basis of the bibliographic analysis [3; 5; 6], we conclude that microfinance can be defined as that instrument for economic and social purposes, that put into action by non-formal organizations of the non-banking financial sector, by providing microcredit and other financial services to vulnerable rural populations, who want to start or develop their existing business and who do not have access to the necessary resources, thus achieving social goals of social and economic inclusion of the target segment.

Microfinance has an international spread, for this reason are found different interpretations of the concept, of the services offered, but also of the structure of the microfinance segment. Such a wide spread therefore leads to a multitude of organizational forms, ways and sources of funding, as well as services provided by the NBLOs (non-bank lending organizations). According to statistics published by the World Bank, in collaboration with MIX market, in 2018 there were 139,9 million beneficiaries of microfinance services, compared to 98 million in 2019 [7]. Of these 139,9 million, 80% of beneficiaries are women and 65% come from rural areas, proportions that have remained stable over the last decade, despite the increase in the number of beneficiaries of microfinance companies' products. Microfinance organizations (NBLOs) have provided billions of dollars in loans worldwide, with an average annual growth of 11,5% [7].

According to European statistics, most microfinance organizations take the form of non-governmental organizations (40%) and non-banking financial institutions (29%), followed by credit cooperatives and private banks. It is worth noting that the spread of organizations is different from state to state: for example, state-owned banks offer microcredit services predominantly in Germany, here the sector is traditionally based on the banking system. In other countries, the form of non-banking financial organizations prevails: Albania (100%), Montenegro (100%), Great Britain (71%) [3].

The microfinance sector is therefore very fragmented and differs significantly from one region to another, depending on the normative-legislative framework, but also on other economic, historical and cultural factors. In the Republic of Moldova, the microfinance sector is found in non-bank credit institutions (Figure 1):

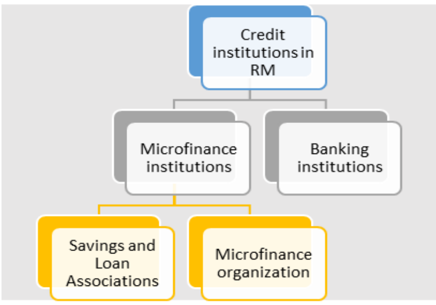

Figure 1. Financing sector structure in the Republic of Moldova

Source: Developed by authors

Savings and loan associations have a specific place in the non-bank credit market, targeting a certain category of beneficiaries, especially in rural areas, engaged in agricultural activities. This subsegment continues to be relevant, considering the importance of agricultural activities for the Republic of Moldova, which require an intensive investment and credit.

The European microfinance market is characterized by a diverse range of products and services offered, which can be largely divided into financial or non-financial products and services. The financial ones aim to directly contribute to the welfare of the target segment, by offering micro-credits for personal or entrepreneurial consumption, insurance services, deposits, etc. Non-financial services, on the other hand, are aimed at solving some managerial, strategy, and other types of problems within the client's business activity. Thus, the consultancy services aim to increase and/or maintain the financial profitability and sustainability of the beneficiaries of microfinance services. A common activity practiced by European NBLOs is to provide a combination of financial and non-financial services, thus ensuring both the profitability of the institution by ensuring the reimbursement of the amounts offered and the well-being of the client, on the other hand.

In the Republic of Moldova, lending predominates in terms of financing, but there are also several donors, such as the World Bank, the US Agency for International Development (USAID), the International Fund for Agricultural Development (IFAD), etc. We conclude that microfinance can take various forms at international level in terms of organization, types of services offered, institutional forms as well as funding sources. In order to determine the situation of the microfinance sector as a whole for the Republic of Moldova, as well as its dynamic trends in recent years, calculations will be made for dynamics indicators, which reflect the speed of integration and increase of the market share of microfinance organizations; capital quality; the ability of organizations to manage financial risks effectively, as well as market concentration indicators, in order to determine the existence of a monopoly on the microfinance market. Thus, overall, the evolution of the penetration rate of the sector before the pandemic shows a high and increasing demand for financial resources from the active population, while demonstrating the substantial growth of the sector and its relevance in the non-bank lending market (see Table 1).

Table 1. The penetration rate of Savings and Loan Association (SLA) in Moldova, at European and global level

	Republic of Moldova	Europe	Worldwide level
Number of associates	268	3 491	85 400
Number of members	137 860	9 103 706	274 227 022
Penetration rate	3,29 %	9,16 %	9,38 %

Source: Developed by the author on the basis of [8]

Analyzing the solvency indicators, we find from the National Commission of the Financial Market (NCFM) data that both types of microfinance organizations perform higher than the allowable values: In 2019, the solvency of the OCNs was 1,75 and the loan associations registered a considerable value of the indicator of 9,23. For NBLOs, this indicator has seen a modest growth trend of 5% compared to 2016. This shows a positive direction in the funding policy of these organizations. Referring to the solvency of savings and loan associations, such a high level is determined by the existence of a conservative financing policy and an undeveloped investment policy [1; 2].

We conclude that the indicators reflect a favorable situation of the profitability of the organizations of the microfinance sector, reassuring its profitability and importance overall in the non-banking financial market of the Republic of Moldova. Thus, participation in this sector can be seen as attractive to potential investors. However, the accessibility of the sector, especially for new participants as entities in the sector, can be considered as low. Thus, considering the specificity of the microfinance sector, but also the fact that the sector in question is relatively young and in the process of consolidation, the risk management policy for these organizations is still in the process of building up and requires a well-defined implementation, with the possibility of the contribution of certain regulatory rules by market surveillance bodies.

The country rating does not yet provide the level needed to attract other types of international investors, such as MIV (Microfinance Investment Vehicles) or other categories of investors that would allow for more notable growth. Another problem would be the dependence of remittances, the existence of increased risks of non-payment of loans and over-indebtedness. These issues involve the need to review investment, credit and risk policies within organizations. At present, the most relevant risks of the microfinance sector in the Republic of Moldova remain to be credit risk, over-indebtedness risk, and strategic risk. Good management of these risks would ensure a safe and continuous development of the sector and previous states experiences of risk reduction policies could strengthen this assurance.

In the Republic of Moldova, the most urgent risks identified for the microfinance sector remain to be credit risk and over-indebtedness risk. Considering the lack of transparency and limited reporting, as well as the decentralization of information on the credit history of beneficiaries, these risks have maximum exposure to the sector. Another issue would be determining the sector's dependence on remittance-based consumer lending and other sources that can be considered uncertain and unstable in terms of sustainability and security, which are also catalysts for the effects of credit risks.

However, future and stable growth must take into account the multitude of political, economic, social and technological factors that directly influence the activity of these organizations. It also identifies the need to pay more attention to borrowing risk, credit risk and the implementation of the costs of granted loans. Effective management of these risks would allow the growth based on sustainable and quality services, which would also lead to a strengthening of the loyalty and confidence of beneficiaries.

IV. Conclusions

. In order to limit exposure to risks, under conditions of major uncertainties in the region, several measures may be taken to be implemented by microfinance organizations, but also by the authority supervising the sector concerned, such as, for example, the ongoing assessment of geographical and economic areas prone to insolvency risks. In this context, an assessment of the economic sectors whose participating beneficiaries carry increased risks of default is welcome, limiting services to them thus reducing the degree of risk exposure.

A growth strategy for the sector will therefore have to address all the possibilities for expansion, whether it is to generate more potential beneficiaries, by continuously increasing the rate of market penetration, whether it’s about implementing new types of financial services and products. The development of new products can be an effective way to allow the sector to grow continuously and sustainably. This will involve the continuous study of the needs of the beneficiaries, their economic and social conditions, and the implementation, based on these determinations, of appropriate products. Such a strategy would ensure a high rate of return on the products offered. For these reasons, we conclude that the microfinance sector of the Republic of Moldova has real and feasible development prospects, and a correct management of all possible risks, accompanied by correct growth and diversification strategies are sufficient to create a well-built segment within the non-bank financial market.

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EdTech: Concept And Connections

Natalia Burlacu [1], ORCID: 0000-0003-3281-3834
[1] Technical University of Moldova, Department of Informatics and System Engineering, Faculty of Computers, Informatics and Microelectronics, 9/7 Studentilor street, Chișinau city, Republic of Moldova, MD-2045,
natalia.burlacu@iis.utm.md, https://fcim.utm.md/

***Abstract*— The present article turns out to be theoretical research in the field of Educational Sciences with an emphasis on educational technologies widely used in general didactic; and also specific didactics as instruments of interaction with the learner; of diversification and customization of the teaching-learning-evaluation process, bringing an added value in the transfer of knowledge to the new generation of learners, digital natives.**

The given paper includes the analysis of the scientific literature related to the EdTech theme; the presentation of the core domains in the development, and application of EdTech; the reflection on the typology of EdTech environments, as well as Hi-Tech components.

The author determines and describes the connections of the EdTech concept in the pedagogical, psychological, and technical context in this work, after which in the final phase he formulates recommendations regarding the possibilities of integrating and expanding EdTech in the educational process of local pre-university and university institutions. (Abstract).

Keywords*— *EdTech Concept; EdTech Connections; Hi-Tech Components, General Didactics; Specific Didactics

I. Introduction

For several decades, the technologies and digital environments have been ambassadors of a new innovative breath for several fields of human activity, including the field of education.

Currently, the organization and conduct of the didactic process but, in particular, of the didactic act in any discipline of studies, whether it runs in the form of a magisterial lecture, a practical seminar lesson and/or a laboratory, regardless of whether we are talking about hours of direct teacher-student contact or about the individual work of the learner, all of its is inconceivable without using of educational technologies/environments that add value in the teaching-learning-evaluation process.

Thanks to the possibility of diversifying teaching-learning-evaluation methods, but also the flexibility of presenting educational content, increasing the degree of comprehension of the subject matter studied through digital educational technologies and environments; these have become essential at all levels of education: from pre-university up to the university level.

The opportunity to implement digital educational technologies and environments exists for almost any discipline, form, and/or level of studies.

Thus, the idea of the current research emerges from the need to present, within a theoretical, analytical and descriptive study, the dynamics of the transfiguration of educational technologies, and also of teaching-learning-evaluation environments, determined by the technical-scientific progress of recent years, in accordance with the unique concept of EdTech.

The approach of the current investigation includes: (1). Analysis of the scientific literature regarding the key notions used in this article; (2). Staged and descriptive presentation (2.a). of the Basic Domains of EdTech Field for the EdTech development and application; (2.b). typology of EdTech environments, (2.c). the Hi-Tech component in the structure of the typology of EdTech environments; (3). Determining and describing the connections of the EdTech concept in a technical and psycho-pedagogical context; with (4). The final exposition of the recommendations and perspectives arrived at as a result of the research, but also of the conclusions related to the study at the current stage.

II. The Review of The Specialized Literature

A. *From the concept of educational technologies to EdTech*

There are actually a lot of studies comparing learning by “technology” (where “technology” normally means anything: some knowledge, facts, information, and skills acquired through experience or education which conduct to the theoretical or practical understanding of a subject, given in any format - printed, projected, electronic, and technological in a broad sense) and without, have (on average) revealed less or no significant difference in outcomes and in the field of educational researches (cronologicaly made by: Russell, 1999 [1]; Chen, Lambert, & Guidry, 2010 [2]; Tamim, Bernard, Borokhovski, Abrami, & Schmid, 2011 [3]; Means, Toyama, Murphy, & Baki, 2013 [4]; Pei & Wu, 2019 [5]).

Later, the semantics and content of the concept of **educational technology** were amplified by notions and educational phenomena such as *programed instruction and learning theories.*

Therefore, the initial dimension of educational technology has been expanded by introducing new approaches such as the systemic approach to the teaching process, micro-teaching, human-computer interaction analysis, and also computer-assisted training etc.

Without equivocation, we can affirm that in the last decade the extension of computer-assisted training to **technology-assisted training is already valid, where the computer is only the tool that presents itself as a single possibility or provides access to one or several of the options of interconnection with other technological products.**

B. Presentation of EdTech Core Domains

Being an acronym, EdTech represents a fusion of the lexemes Education and Technology; it retains the initial segments of the words from which it comes.

In our opinion, the **EdTech concept** refers to new technological implementations in the didactic process and *involves the adoption of* **hardware and software** *solutions with the aim of perfecting the teaching-learning-evaluation process and the didactic act, directly, for subjects in most scientific fields and curricular areas in various study levels.*

Thus, the innovative aspects of specific didactics originate at the intersection of EdTech with various school and/or academic study objects.

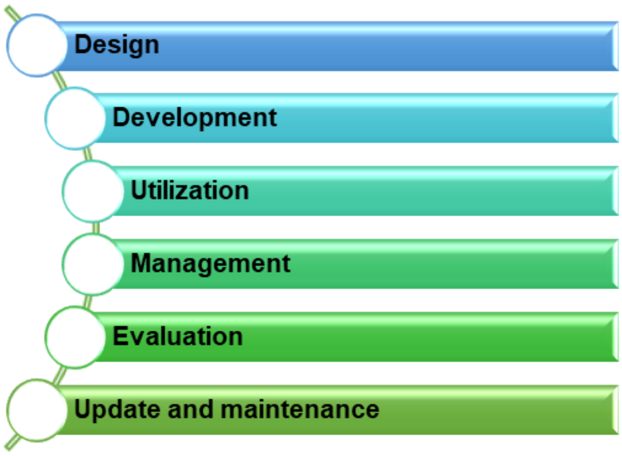

Figure 1. Core Domains of EdTech Field

EdTech profile specialists, either those who can be so called or those in the making, can be considered the people with completed university studies, at the bachelor's and master's cycle, in the field of Educational Sciences who, along with the knowledge of their field of specialization, (Computer Science & Mathematics; Chemistry & Biology, Physics & Mathematics; History & Geography, Linguistic & Literary Education, Primary Classes etc.) *have prominent digital skills that enable them to achieve educational goals, being assisted by digital/innovative technologies in their activity in accordance with the five basic EdTech directions,* which include the items shown in Figure 1.

The purpose of EdTech's core areas is to intervene and positively affect the efficiency of the didactic process; as well as facilitate and motivate learning; to transform the educational environment through original, creative, and innovative teaching-learning-evaluation methods and strategies into a stimulator of progress at the level of learning objectives, but also of the quality of the skills formed and developed.

Thus, the core EdTech domains (see Figure 1) can be described as follows:

- **Design** is the process of specifying learning conditions. The purpose of the design stage is to devise strategies and products to be applied at the macro level (for example, study programs, curriculum, and subject sheets) and at the micro level (for example: determining the approach of lessons and / or content and / or consecutive ness them in modules).
- **Development** is the process of transposing the content developed at the design stage into a tangible format that could have one of the following forms: hardware, software, visual (printed or digital), auditory and augmented materials, as well as programs or packages that integrate various types of formats. The form and/or degree of use of the technologies included in this field represent technological changes over time. At the given stage, in the context of EdTech, early technologies are updated by overlapping with new ones, predominantly, without excluding and completely replacing old technologies.
- **Utilization** is the stage that has the longest history that far exceeds humanity's concern for creating educational environments. In our opinion, using, by definition, is the act of implementing didactic processes and resources and being responsible for producing changes through educational innovation.
  At the given stage, the designer of the didactic act (set of actions planned and realized for the teaching-learning-evaluation process) with / or without his assistants deals with:

– creating educational materials; feedback (at various stages: initial, intermediate, and/or final);

- preparation of didactic instructions for students' interaction with the given materials (students will be taught how to use and how to practice and/or learn from the developed materials);
- outlining assessment strategies, measuring learning outcomes, marking, and providing feedback (at various stages: initial, intermediate, and/or final).

  Although not all teachers show the same level of enthusiasm, dexterity, and creativity in the integration of EdTech in the educational process, currently that field is also assisted by technologies.

- The stage of **Management** is meant to manage educational technologies. It should be noted that the content (programs, projects, even sometimes customized settings) to be managed may differ from case to case, while the basic skills required to manage EdTech remain constant. In the EdTech context, these skills should be accentuated by prominent digital skills and will consist of planning and organizing program products, work sessions, supervising assistants, trainees, planning administration activities etc. Depending on the specifics of the institution, even the management of the budget and other facilities can be included here; coordinating policies and/or procedures, and also ensuring EdTech management.
- The **Evaluation** stage is the process of determining the merit and/or didactic value of a project, action, or educational activity with the aim of issuing relevant judgments and conclusions for estimating the quality of the educational product as an object (educational offer, study program, discipline, lesson, etc.). At this phase, the focus is on the subject to be assessed and not on the learners and/or the project or final product from the learner's perspective. The evaluation of the teaching staff and auxiliary teaching staff can be taken into account in the evaluation stage made in the EdTech context, but, certainly, it is not decisive and primary at the given phase.
- The **Update and maintenance** is the act that involves the periodic rotation, but in the continuous mode, of the contents of all previous stages for the purpose of analysis, revision, modification, amplification, etc. of all of the processes provided for in the previous stages.

It is essential to note that the concept of EdTech itself, with the contents of the basic fields specified above, involves the didactic design of educational activities in various curricular areas and, subsequently, their application in the classroom, by assisting numerous types of environments, some of which were listed under domains 2 and 3 – Development & Utilization (see Figure 1) (which provide text, audio, images, animation and/or video streaming and include technological applications and processes such as audio or video tape (in the not-so-distant past), CD-ROM or DVD-ROM, satellite TV, computer-assisted learning, harnessing the potential of local Intranet / Extranet and Web-based learning, but not only).

III. EdTech Connections: Pedagogical, Psychological and Technical Aspects

In our view, today, the EdTech concept is a cumulative one that includes several components such as:

- ***Pedagogical approaches*** regarding teaching-learning media and innovative didactic methods - we refer to learning based on the learner; experiential learning, strategies such as problem-based learning, research-based, project-based; collaborative learning, etc. with the integration of digital and technological environments, but also their fusion for the skills training and development (key, specific, inter- and trans-disciplinary, transversal competences) and critical and creative thinking;
- Developed ***didactic resources*** to be used in various learning environments assisted by various technologies, starting from computational ones, up to Hi-Tech products;
- ***The appropriate digital support*** (hardware and/or software compatible with the technological educational environment) that is used in the teaching-learning-evaluation process depending on the teaching circumstances, but also the educational needs of the learner, aligned with the contents curricular (as the minimum required), but also extracurricular.

Talking about the hardware dimension and its possibilities for didactic integration, for several years now, in different areas of the world, we can follow experiences of incorporating Hi-Tech technologies into the educational process. These are the innovative practices of education in Estonia [6], Australia [7], Finland [8], Japan [9], and South Korea [10], where the equipment and design of modern classrooms allow them: (1). learners (pupils or students) to accumulate new educational-formative experiences, and (2.) teachers to train in the development and implementation of new teaching-learning-evaluation strategies, most special from a technological and didactic consideration, then in the digital classrooms.

We consider that if the didactic process calls for the integration of Hi-Tech technological products, it can be attested not only as a simple practical implementation of the EdTech concept but also as the involvement of **Hi-**

Tech EdTech in the didactic act. That is, the presence of an EdTech, assisted by cutting-edge technologies, descendants of the most advanced hardware and software technologies appearing on the market for technological products, confirms the integration of Hi-Tech EdTech in the educational process.

Digital classrooms have become less surprising and are currently already considered insufficient for quality learning for some schools and academic communities in different countries of the world. Thus, they are partially replaced either with smart classrooms or with trips to extra-curricular spaces (dedicated museums and/or specialized exhibitions and / enlivened laboratories) where online learning and e-learning methods are accompanied by augmented reality [6-10].

As a result, under the umbrella of the EdTech concept, typologies of digital and technological tools are included, some of which, being of the highest level of innovation and performance, respectively, form the Hi-Tech core of EdTech. In the author's view, the structure of the Hi-Tech EdTech concept can have the following graphic representation (see Figure 2).

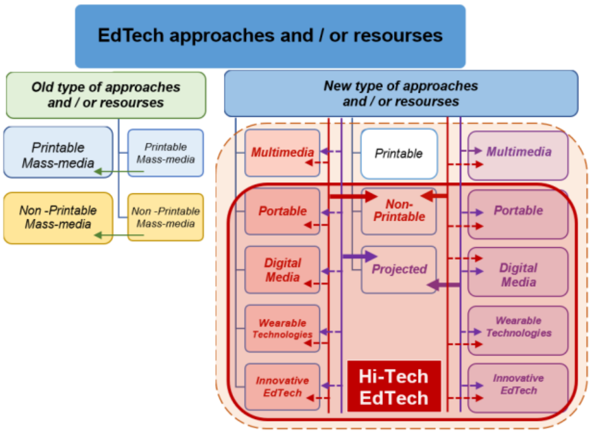

Figure 2. The Hi-Tech component (in red border) in the structure of the typology of EdTech environments (in orange border)

The efforts of researchers concerned with the theory of education and/or general didactics and/or specific didactics, engineers, trained in the development of software products intended for education, and also of those interested in the pedagogical, psychological, and technical effects of human-technology interaction are oriented toward measuring the efficiency of a wider range of Hi-Tech products intended to be applied in the teaching process and based on various learning environments (from multimedia and ICT (Information and Communications Technology) to augmented reality).

Regarding multimedia educational technologies, these can be defined as integrative technologies of several types, having a technical origin from different IT environments, such as text, graphics, animation, sound, and video - sometimes all are present, sometimes not; sometimes present in certain combinations.

Multimedia educational technologies, defined as integrative technologies of several types, are of technical origin from different computer media, such as text, graphics, animation, sound, and video - sometimes all present, sometimes not; sometimes present in certain combinations. Due to its complex structure, this kind of application brings a series of difficulties to the experimental research process; however, some observations can be made based on the attributes of the technologies with which they operate.

We consider it necessary to mention that when we are, apparently, dealing with the most complex combinations of technical media, we cannot necessarily classify them as innovative technological educational media, because of the trend of multimedia technologies, and also because the education supported by these media is already slightly outdated. At the moment, in the context of educational technologies, we cannot talk about educational innovation, limiting ourselves only to multimedia program products and/or multimedia systems and/or multimedia technologies, etc.

By Dron (2022) education is "the giving and receiving of systematic instruction, the process of facilitating learning, constituted from countless methods, tools, and structures, operated by teachers and many others – may usefully be seen as a technological phenomenon [...]" [p. 3, 11].

In this vein, there are several studies that investigate various dimensions of didactic human-technology interaction that we can classify as EdTech connections. In specific, regarding the interrelationship between education and technologies, we attest to a series of scholarly opinions with which, for the most part, we agree and which, emerging from their specificity, we can define in the categories described below.

- ***Connection with Educational Sciences.***

Although according to Dron, 2022, education itself boils down to “[…] the giving and receiving of systematic instruction, the process of facilitating learning, constituted from countless methods, tools, and structures, operated by teachers and many others – may usefully be seen as a technological phenomenon [...] some technologies are better designed, or more fit for purpose, than others” [pp. 24-25, 11].

An opinion that we also find at Dron and that we also share „Choice of technology does matter a lot, because of 1) how it affects other technologies in the assembly, 2) the adjacent possibles it provides, and 3) the avenues it closes. However, it is the orchestrated assembly that teaches, not any one component of it. Any effectiveness or otherwise of the assembly is a measure of emergent teaching skill among all the distributed teachers involved. This is equally true of methods of teaching (pedagogies) or learning designs” [p. 24, 11].

Also, there is research that attests to the easier understanding of abstract concepts, and also of some complex scientific phenomena by some students when the theoretical material is presented not only in the form of analytical text / verbal discourse but also in visual form.

- There is the eventual ***EdTech connection with Psychology and Specific Didactics*** emerging here.

Salomon (1979), which are study on the fact that the global definition of the average stimulus insufficiently reflects the difference between cognitive-psychological and educational goals, “A medium does not interact as an invariant system with a leamer's aptitudes so that learning is facilitated for some but not for others. Rather, something within the Interaction of Media, Cognition, and Learning mediated stimulus, possibly shared to some extent with other media, makes the presented information more comprehensible or better memorized by learners of particular characteristics” [pp. 5-6, 12].

- ***The connection with the Psychology of Learning,*** this being a sub-field of Psychology.

In this manner, according to Cowen (1984), empirical research demonstrates that visual environments help to understand concepts, making them more accessible to students by increasing the more qualitative and detailed recall of information related to the explained theoretical concept [13].

The scientific investigation presented in the doctoral thesis by Judy Williams (2010) has demonstrated that when comparing sensory learning styles and reading comprehension through tests (1). Chi-Square for Independence, (2). ANOVA and (3). Post-hoc tests [p. 3, 14] "[…] the results indicated that there was a relationship between kinesthetic, auditory, and visual learning styles and reading comprehension levels. When comparing the learning styles of struggling readers and on-grade-level readers, the results indicated that there was a significantly different distribution of kinesthetic, auditory, and visual learning styles" [14].

- Since the exploitation of EdTech in the classroom capitalizes on the digital competence, which, in turn, is defined as a key competence, but also a transversal one [15 - 17], the following ***EdTech connection concerns more areas such as Didactics of ICT*** [18-20; 22]***, other Specific Didactics*** [18 - 23], ***Educational Management*** [24 - 26].

IV. Conclusions

The concept of EdTech, but especially the conjunction of Hi-Tech, is a new one, while the scientific research of a pedagogical and psychological and pedagogical order - theoretical and applied - are insufficient and/or worn out morally and/or technologically, both from the perspective of didactics and of the methodological opportunities and technical assistance offered to educational actors: teachers, but also students. The activities of documentation, elaboration, delivery, etc. matter, but also their consecutiveness for the purpose of elaboration and subsequent implementation in lessons of different types in terms of subject, scientific area, complexity, level of study, and/or form of education. At the same level, all the upper enumerated activities matter for the qualitative and effective integration of **EdTech**, but especially **Hi-Tech EdTech** in the didactic process.

Given the fact that for now some EdTech technologies, especially those in the Hi-Tech category, are impossible to make widely available to learners due to the motivated high costs, and others being a bit archaic or outdated, already they cannot be found either because at the time, again, these were expensive, and now these are already unprofitable for long-term purchase and use, in order to implement EdTech, but also Hi-Tech EdTech we consider necessary:

- The development of extra-institutional / extra-university / extra-school spaces (dedicated museums and / or specialized exhibitions and / Enlivened Laboratories);
- The subsequent provision of these spaces to educational institutions for scheduled and/or unscheduled visits, lessons according to the study plan, etc. and not only;
- Implementation of actions and activities organized directly by the administrations/employees of these locations (which should have a staff as small as possible, but very competent from a technological point of view).

In the described way, practice places will also appear for students from study programs with a technical, technological, ICT profile, such as TUM (Technical University Of Moldova), but also of other types of universities. Such are universities with a pedagogical profile. These practice spaces could also be used to study some topics/modules within different university disciplines.

We also consider it beneficial to expand the technological possibilities at the level of local educational institutions (in the peripheral regions and/or extra-urban territories of our country) to ensure the implementation of educational experiences for both teachers and learners.

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Implementation of dual education at Technical University of Moldova

Viorica Sudacevschi [1], ORCID: 0000-0003-0125-3491
Larisa Bugaian [1], ORCID: 0000-0002-4478-5124
Dumitru Ciorbă [1], ORCID: 0000-0002-3157-5072,
Ion Fiodorov [1], ORCID: 0000-0003-0938-3442
Irina Cojuhari [1], ORCID: 0000-0003-2248-1338
Silvia Munteanu [1], ORCID; 0000-0003-0749-8457
[1] Technical University of Moldova, Chișinău, Republic of Moldova, http://www.utm.md,
viorica.sudacevschi@calc.utm.md, larisa.bugaian@adm.utm.md, dumitru.ciorba@fcim.utm.md,
ion.fiodorov@ati.utm.md, irina.cojuhari@ati.utm.md, silvia.munteanu@calc.utm.md

Abstract — **The article analyses the implementation of the dual study model for higher education at the Technical University of Moldova. This goal was one of the basic ones within the Erasmus+ COOPERA project "Integrating Dual Higher Education in Moldova and Ukraine". The development vision and needs of the national economy define the leading arguments for the pilot programs at the Technical University of Moldova. The faculty team proposes a Dual higher education model appropriate for students from two engineering programs. The model specifies the roles of the student, university and company in dual education and the benefits of all involved actors. In the designing phase of the project, the teaching staff consult students, company administrators and specialists to fit all interests into one joint model and curricula.**

Keywords—dual higher education; Dual Higher Education Model; study process, company tutor; university tutor; partner companies.

I. INTRODUCTION

Higher education has been under a detailed evaluation, and new principles have reconceptualised some teaching and learning processes during the last decades. The main reason, in many cases, was that the job requirements hadn't reached the expected level of competencies and skills of the graduated students.

Trying to cover company needs in specific skills, the Technical University of Moldova introduced innovative methods in the teaching and learning process in another Erasmus+ project, PBLMD. So, some COOPERA project team members implemented a complementary methodology to Dual education called PBL - problem-based learning. This experience defines an advantage in implementing Dual education at TUM [1-2].

Dual education was introduced to overcome this shift between labour expectations and the professional level of candidates. Dual education represents a form of study where the development of the abilities, skills and competencies is emphasised in the formation of practical skills based on the actual work environment, with a high degree of involvement in the work process [3-4].

There is a paradigmatic difference between practical and theoretical education. Practical education has a more specific context, focusing on functional knowledge and skills obtained by practising.

In the case of theoretical education, it tends to be more fundamental and universal. Dual education increases the acquisition and achievement of knowledge from practical learning in the work process. In this way, Dual studies offer two possibilities for acquiring professional abilities and competencies from academia and the workplace.

"Dual education" comes from vocational training in German-speaking countries. The first model was developed in the German region Baden-Württemberg at the beginning of the 1970s.

In 2009, it was launched the next step in the state of Baden-Württemberg, which supposed the transferring of all colleges of advanced vocational studies into a newly created Baden-Wuerttemberg Cooperative State University.

The CEDEFOP's glossary defines dual training as a form of alternating training that combines teaching periods at the educational institution with other periods of work stages in a workplace [3-4]. This alternation can keep different periods daily, weekly, and monthly, depending on the university regulation and study plans. In

2016, the CEDEFOP's glossary underlined that dual education supposes that students involved in the process of dual education should have the employee role and, due to this, should receive the salary for the work. These two facts make dual education complete in the sense of involving the students in the labour activities with a combination of fundamental theoretical studies at the education institution and supposes the contractual relationship between student, company and university, the actors involved in the dual education.

For the last decades, dual education has achieved its primary goal, increasing the employability of graduates with a lot of practical and theoretical skills. But as disadvantages, it can be mentioned that companies are often highly specialised and unable to train apprentices in all needed areas and offer all necessary skills and competitions [5].

The current social environment and high youth unemployment afflicting Europe have led European policy to favour education seeking to promote the employability of young people. The crisis and the effect it has on the high unemployment rates, especially among the youth, has led some countries to give great importance to dual education at all educational levels and to speed up policies and reforms for the development of this system of education [4].

The adjustment of higher education in the Republic of Moldova to the changes in modern society requires implementing innovative forms of education for the young generation.

At the Technical University of Moldova, dual education is implemented for the Bachelor's degree programs in *Robotics and Mechatronics* and *Automatics and Informatics*.

The paper analyses the opportunities dual higher education (DHE) offers for all actors involved: university, company and student. The dual education model approved at the Technical University of Moldova is described.

II. Erasmus + COOPERA Project

The introduction of dual education at a higher level of training in Moldovan universities is the most crucial goal of the Erasmus + COOPERA project "Integrating Dual Higher Education in Moldova and Ukraine", ref. No. 617490-EPP-1-2020-1-MDEPPKA2-CBHE-SP [5].

Implementing this concept in Moldova will allow practical knowledge, skills and attitudes development appropriate to each context by collaborating with the business environment and providing opportunities to capitalise on theoretical skills in the real sector. COOPERA is a project with national and regional impact. The Academy of Economic Studies of Moldova (ASEM) coordinates the project, having as partners other two institutions from the Republic of Moldova – Technical University of Moldova (TUM) and Free International University of Moldova (ULIM), the Ministry of Education and Research and ten institutions from the EU and Ukraine.

The project aims to integrate dual higher education in partner countries, in general, improve work capacity and individual development, increase compatibility and continuity between the requirements of the business environment and the initial training of university students and achieve a better high economic efficiency and social integration, in particular.

Specific project objectives are:

a) To identify the needs and specific requirements of companies in different industrial sectors and businesses for DHE and to find companies willing to participate in pilot implementations of DHE during the project;

b) To develop a flexible and generic Dual Higher Education Model (DHEM) to support the different needs and interests of employers, higher education institutions (HEIs) and students in various industries and business sectors and to provide recommendations to HEIs for the implementation of Dual Higher Education;

c) To test the specific DHE models generated from the developed generic DHEM by realising their pilot implementations during the project and to analyse achieved results;

d) To propose changes to legislation/regulations to adapt Dual Higher Education in the Partner countries.

III. Bachelor's Degree Programs with Dual Study at TUM

TUM selected two undergraduate study programs to implement dual education: *Robotics and Mechatronics* and *Automatics and Informatics*.

The *Robotics and Mechatronics* study program aims to train industrial and research engineers in robotics and mechatronics, stimulate creativity and innovation, adapt to new labour market conditions, and develop the necessary skills in four essential areas of engineering: automation, computers, electronics and mechanics.

The *Automatics and Informatics* study program is part of the general field of Engineering and Engineering Activities and provides training and education for specialists in Electronics and Automation. A specialist in Automatics intends to show an integrated set of knowledge, skills and abilities necessary to develop industrial equipment, control systems, communications and information systems for process management in different sectors of human activity.

The curriculum trains graduates to design automation systems, robotic and mechatronic equipment and systems, to use, operate, or integrate them into flexible manufacturing systems, to program and operate integrated computer production systems, and to solve application and research problems specific to the domain.

Both are bachelor's degree programs in interdisciplinary science and technology, which integrate with a systematic conception of such fields as Automation, Informatics, Electronics, Computers, Communications, Robotics, industrial, technological and manufacturing processes.

In previous decades, Robotics and Automatics were the prerogatives of the top industries (e.g., aerospace, aeronautics, military, and car manufacturers). In the recent period, based on advanced concepts and technology, both conventional and renewable energy production and distribution, intensive agriculture, food industry, light industry, pharmaceutical, chemical industry, management of biotechnological processes, constructions, transport systems, roads, and other can efficiently implement the most advanced approaches of technologies provided by Robotics and Automatics.

Several factors influenced the selection of these two undergraduate programs:

a) Continuous automation and robotisation of technological and production processes in the Republic of Moldova are based on the integration of engineering knowledge in computer systems, networks and information technologies, power electronics, mechanical devices, Etc, led to the need to train specialists who will acquire professional skills and abilities directly in the workspace of companies;

b) Different companies in the Republic of Moldova already have complex automation production systems based on the theoretical and practical concepts of state-of-the-art automatic, robotic and mechatronic systems. Thus, the internships at companies, the direct interaction with this equipment and the possibility to learn from professionals will allow the acquisition of the necessary competencies for future engineers;

c) The need to develop new methods and technologies for the design and production of automated, mini-, micro- and nano-robotic systems (that have found vast fields of application in technology, construction, medicine, Etc.) leads to the creation of favourable conditions for the development of dual education in the field of Automatics and Robotics.

IV. Dual Higher Education Model at TUM

The main goal of the Dual Higher Education Model is to improve work capacity and individual development, to increase compatibility and continuity between the requirements of the business environment and the initial training of university students, and to achieve a better high economic efficiency and social integration [6].

The particular scope of DHEM related to students is to become actively involved in the decision-making processes within the enterprise as their practical experience grows. The aim is to put students in a position from which they can develop and try their ways of solving problems during the practice phases [7].

TUM will follow an integrated model in existing programmes Robotics and Mechatronics and Automatics and Informatics, introducing changes in the study process.

The faculty team developed the dual education model in consultation with specialists in the fields of electrical and electronic engineering, computer science, information technology, automation and mechanical engineering: Arobs Software, Inther Software Development, Mechatronics Innovation Center, ICG Engineering, ElectroTehnoImport, Steinel Electronic, Bucuria, EFES Vitanta Moldova Brewery, Glass factory, Etc. to train the professional skills and abilities specific to the field and adapt to the requirements of the labour market. Also, teachers, graduates and students participated in various surveys. The implementation team studied their opinions and changed according to the curriculum.

According to the model approved at TUM after the discussions with representatives of the enterprises and industry organisations, students from these two programs, in the 2nd year of study, will have the possibility to select a free choice discipline/activity in-company training (120 hours), starting with 3rd year of study. They will have the opportunity to choose one of two ways to continue their studies: dual or classic. The model imposes the reorganisation of students into separate groups, in which they will study both traditional and Dual ways. It is essential to mention that students from both study forms will also have common disciplines they will attend during two days of study. Students who choose the classic form of study will continue with the courses according to the curriculum, and students who will select DHEM will leave for three days at the company, where they will have the opportunity to receive practice vocational training or work experience.

The distribution of the training hours (theoretical and practice) in the university and at the dual partner economic agent is specified in Table I.

TABLE I. Distribution of the Training Hours

	N. of weeks	Structure for the study in the university		Structure for the in-company training study		Total hours
		Hours/days per week	%	Hours/days per week	%	
1. Semester	15	15	100	0	0	900
2. Semester	15	15	100	0	0	900
3. Semester	15	15	100	0	0	900
4. Semester	15	15	100	0	0	900
5. Semester	15	300/2 days	33,3	600/3 days	66,7	900
6. Semester	15	355/2 days	39.4	545/3 days	60,6	900
7. Semester	15	310/2 days	34,4	590/3 days	65,6	900
8. Semester	15	100	11,1	800	88,9	900
Total		4565	62,7	2775	37,3	7680

The collaboration between TUM and the companies has to be dynamic and deep at all stages of the realisation of Dual higher education. Thus, the representatives of the economic agents will be involved in the development of curricula following the needs of the labour market; in the selection of potential students in the second year of study and the training of professional skills in the production environment; in ensuring the student's salary during the entire training process. The company will delegate a tutor, who will be responsible for training students and developing practical skills. The tutor will supervise the progress of studies, training plan, realised projects, issuing assignments to the students, examination of the practice students' reports, and drafting the competency of the student's profile for the company. Also, the company will be responsible for students' involvement in solving real problems; facilitating the employment of graduate students, who will carry out practical training in the partner company.

In the first year of testing the dual education within TUM, the program will use the existing curriculum for the study programs: Robotics and Mechatronics and Automatics and Informatics. Following years, the departments will adjust the curriculum to the demands of the labour market and the specifics of the study process of the dual format. These changes will require tight cooperation with company representatives to consider their needs for training future specialists in these fields. At the same time, the partner companies will offer teachers the opportunity to realise internships.

The university administration chose the "Computer Science and Systems Engineering" and "Software Engineering and Automatics" departments to pilot the dual education programmes. So, these departments are responsible for ensuring the educational process's quality in a Dual format. These departments are responsible for delegating the person who will coordinate the dual education and collaborate with the company's tutors.

The essential responsibilities of company and university tutors are:

a) to examine the learning process in the two places and to identify where the knowledge, skills and competencies envisaged in the curriculum can be acquired;

b) to monitor the student's learning progress. The aim is to stimulate the student to reflect on their learning and to be willing to share these reflections;

c) taking measures to reinforce learning and to correct failures in the process together with the university person-in-charge;

d) coordination of interaction between the student and the co-workers in the company.

V. Conclusions

Dual education in higher school represents an alternative form of study that places a significant emphasis on the formation of practical skills of students in the professional environment, with a high degree of involvement in this process by representatives of the business environment. Implementing dual education for the bachelor's degree programs in Robotics and Mechatronics and Automatics and Informatics at the Technical University of Moldova will increase interest in these two programs crucial for our country's economy.

The proposed dual education model imposes a close collaboration with the companies, which must be actively involved in this process.

Following the implementation of this form of education, both students and companies will benefit. The advantages for students are noticeable: an excellent opportunity to test their capabilities in the chosen career, financial independence (during the internship, the student receives a salary), trainers both from the university and from companies, and the experience gained during the training is helpful for the future career. Companies also benefit from this study method: partner companies can notice selected students' talent in advance, and the interaction with qualified employees can sharpen it.

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Comprehension, Possibility and Death. The Justification of the Ontological Understanding of Death

Lozovanu Ecaterina [1], ORCID: 0000-0002-5722-1600
Perciun Andrei [1], ORCID: 0000-0003-0401-0604
Lupușor Alexandru [1], ORCID: 0000-0002-4630-665X
[1] Technical University of Moldova, MD-2020, ecaterina.lozovanu@ssu.utm.md, andrei.perciun@ssu.utm.md, alexandru.lupusor@ssu.utm.md

***Abstract*— If death is revealed to us, in our human experience, as a certainty, one of the decisive questions of explaining our human condition aims at questioning and justifying this certainty.**

One of the authors who tackles this question is the German thinker, Martin Heidegger. According to him, death is understood and described, through a phenomenological and hermeneutical explanation, as an inner existential possibility as an ontological condition of the human being.

This understanding has received various criticisms from contemporary philosophers. One of these belongs to Bartrand Schumacher who sustains that the only ontological understanding of existence cannot provide a certainty of its own end. In this way, Schumacher opposes an ontic meaning to the Heideggerian ontological understanding of death.

In response to Schumacher's critics we propose to look more deeply at the concept of possibility as the key-concept in the Heidegger's ontological understanding of death.

Keywords—death; existential understanding; possibility

INTRODUCTION

The fact that our existence in this world has an end looks like an indisputable certainty. The real problem appears when we want to justify this certainty. The whole of Martin Heidegger's [1] reflection on death, as it is unfolded in his famous book *Being and Time* (1927), seems to arise within the horizon of the following question: *What gives me certainty that my existence has an end and that it is oriented to this end?* Through a laborious philosophical research, Heidegger attempts to provide an ontological solution for death's certainty. According to this, death is understood and described, through a phenomenological-hermeneutic explanation, as an inner existential possibility of the *Dasein* [2]: "As potentiality-for-Being, Dasein canpot outstrip the possibility of death. Death is the possibility of the absolute impossibility of Dasein. Thus death reveals itself as that possibility which is one's ownmost, which is non-relational, and which is not to be outstripped. As such, death is something distinctively impending. Its existential possibility is based on the fact that Dasein is essentially disclosed to itself, and disclosed, indeed, as ahead-of-itself." [1] Consequently, the ground for the certainty that Dasein is a dying being, should be found by Dasein itself in its own existential data. Heidegger says it expressly: "In the center of these considerations we have the task of characterizing ontologically Dasein's Being-at-an-end and of achieving an existential conception of death."[2]

[1] Martin Heidegger (1889–1976) was a German philosopher whose philosophical work is mostly associated with phenomenology and existentialism. His ideas have exerted a seminal influence on the development of contemporary European philosophy. They have also had an impact far beyond philosophy, for example in architectural theory, literary criticism, theology, psychotherapy, and cognitive sciences.

[2] *Dasein* is a German word that means "being there" or "presence". It is a fundamental concept in the existential ontology of Martin Heidegger. The German philosopher uses the expression *Dasein* to refer to the experience of being that is specific to human beings. Thus, *Dasein* is a form of being that is aware of and must confront such issues as personhood, mortality and the dilemma or paradox of living in relationship with other humans while being ultimately alone with oneself.

In others words, if we want to enlighten why we are dying, we have to question even our existence. Thus, we could emphasize Heidegger's ontological solution as following: The certainty of my death lies in my existence.

THE ONTICAL CERTAINTY OF THE DEATH

Namely this claim of Heidegger's becomes the object of Bernard Schumacher's critique presented in his work *Death and Mortality in Contemporary Philosophy*. Schumacher's commentary on Heidegger's understanding of death is focused on the definition of death as the possibility of impossibility of Being, as Heidegger developed it in *Being and Time.* Especially, Schumacher aims to discuss the certainty of this possibility[3]. More precisely, Schumacher attempts to put in question the ontological solution provided by Heidegger for obtaining the certainty of 'authentic dying' by which Heidegger designs the ontological meaning of death and tries to correct this Heideggerian ontological solution by referring to an ontical analysis in connection with the intersubjectival experience of the death. The aim of Schumacher's critics on Heidegger existential understanding of death is to ask whether Heidegger really succeeds in deducing Being-towards-death and the certainty of existential "dying", which he posits as fundamental principles of the ego, from the sole basis of his ontology of temporality, without having recourse to a provincial (narrow) ontical analysis of death.

In this perspectives, our approach of Schumacher's commentary aims to question the reasonability of his critics of Heidegger's ontological solution for certainty of dying and to verify the pertinence of his own solution for this certainty settled on an ontical and intersubjectival acknowledge of the death.

Schumacher disagrees with Heidegger's ontological solution on the account that the existence of Dasein unfolded as Being-ahead-of-itself does not logically imply its end [2]. In others words, Schumacher sustains that the only ontological understanding of existence cannot provide a certainty of its own end. In this regard, Schumacher affirms: "the impossibility of deducing Being-towards-the-end solely from an ontological analysis of Being-ahead-of-itself" [3].

Schumacher objects to Heidegger that his attempt to establish the certainty of 'authentic dying' is based solely upon his ontology of temporality (without having recourse to an ontical experience of another's death). Consequently, discussing Heidegger's ontological (onto-phenomenological) conception of the death, Schumacher arrives to affirm that the certainty of my own possibility of impossibility of being is conceivable only from experience of another's death.

In response, Schumacher insists that the certainty of my own death is conceivable only starting from the experience of another's death: "I maintain that this Being-towards-the-end is conceivable only starting from the experience of the Dasein's finitude, that is, from the experience of another's death" [4]. This solution can be recognized as an ontical one. The death of another human being provides the certainty of my own death. It should be mentioned that Schumacher's critique does not aim to surpass Heidegger's ontological standpoint opposing to it an ontical point of view, but rather to affirm the priority of the ontical certainty under the ontological certainty of human condition of mortality. In others words, Schumacher's claim is to ground the certainty of the possibility of my own death on the evidence of the reality of another's death. In this way, the ontical certitude seems to have the form of a logical necessity which can be expressed by the famous death's syllogism: "All human beings are mortal, I am a human being, therefore I am mortal". In this syllogism we encounter two certainties: "I am mortal" and "All human beings are mortal". The former correspond to the ontical certainty of my death and it is derived from the last. Thus, the ontical solution assumes the certainty of my death deducing its possibility from the evidence of the actuality of another's death.

On the other hand, Heidegger, in whose view the ontological level underlies the ontical level, intends to base the certainty of my possible death on the possibility as such. Precisely, Heidegger wants to find the certainty of Dasein's death not in the evidence of actuality of another's death, but rather even in the imminence of its own possibility of death. Thus, an ontical certainty appears as a mediate certainty: I acquire the certainty of the fact that I am a dying being through the evidence of the death of another being like me. Being mediate, the ontical certainty is the result of deduction. Contrary, the ontological certainty assumes the character of an immediate certainty. How is it possible to acquire immediate certainty of the possibility of death?

THE ONTOLOGICAL CERTAINTY OF THE DEATH

If we remember Heidegger's famous sentence from &7 of the book *Being and Time* that "Higher than actuality is possibility", the problem of Heideggerian

[3] Schumacher's critical approach concern the definition of death as the possibility of the impossibility of Being, as Martin Heidegger developed it in his work *Being and Time*. To do this, Schumacher introduces, first, the distinction between the ontical and the ontological levels; second, he shows that Heidegger maintains, along with Epicurus, that it is impossible to experience "my death" in the sense of "the state of death". In the third place, Schumacher describes how the philosopher of Freiburg affirms that one cannot know with certainty one's "authentic dying" through an analysis of someone else's death. Fourth, he discusses the solution that Heidegger had proposed for obtaining such certainty by referring to the notion of Being-towards-death.

certainty of Dasein’s death could be reformulated as follows: *higher than the actuality of death is the possibility of death.* The question which arises now is: *what makes the possibility of death something higher than the actuality of death?* If we want to clarify this point, we should question namely the way in which the Dasein refers to the possibility as possibility. According to Heidegger, the ontological relation with the possibility is assured by the *comprehension*. In this regard, Heidegger is as explicit as possible: “The kind of Being which Dasein has, as potentiality-tor-Being, lies existentially in understanding.” [5] Thus, while Heidegger defines death as possibility, the certainty of death should be described in terms of *existential comprehension*.

According to Heidegger’s ontological view, the certainty of the possibility of death is not something to be deduced from the actuality (in that case it would not be immediate) but rather something to be understood as possibility. The problem is not how can I logically deduce the certainty of my own death from the evidence of the others death, but how can I understand the certainty of my imminent death. In this way, we can say that the ontological certainty is not a certainty of “I know” (a formula proper to ontical certainty) but rather a certainty of “I understand”. Consequently, the immediate relation with the ontological possibility of the death should be justified as the fact of existential comprehension. The comprehension, as a mode of being constitutive to Dasein, provides an ontological certainty as non-mediated certainty of possible death, avoiding the fact of another’s death. Let’s try to explain it. I cannot understand an existence (a Dasein) without understanding at the same time its understanding of itself, because the self-comprehension is a constitutive part of its being. Thus, the certainty of death as understanding of its possibility could not involve the fact of another Dasein’s death, because it would furthermost need the self-comprehension of the dead Dasein, i.e. the comprehension of itself as a dead Dasein. Therefore, if we want to find a certainty of the death of one being we should understand the manner in which this being understand itself its own death. Consequently, the certainty of human condition of mortality depends essentially on the understanding of my own being as a Being-towards-death.

Although, we have to ask what it means to understand death? Following Heidegger’s thought we can say that to understand death means to assume it as an existential possibility, namely as the possibility of the impossibility of being: “Death, as possibility, gives Dasein nothing to be 'actualized', nothing which Dasein, as actual, could itself be. It is the possibility of the impossibility of every way of comporting oneself towards anything, of every way of existing” [6]. Heidegger designs this understanding of death in the mode of existential assuming of the possibility as ‘anticipation’ (*Vorlaufen*): “The ownmost, non-relational possibility, which is not to be outstripped, is certain. The way to be certain of it is determined by the kind of truth which corresponds to it (disclosedness). The certain possibility of death, however, discloses Dasein as a possibility, but does so only in such a way that, in anticipating this possibility, Dasein makes this possibility possible for itself as its ownmost potentiality-for-Being. The possibility is disclosed because it is made possible in anticipation” [7]. Thus, the ‘anticipation’ of death can be described as assuming the possibility of death through comprehension and as comprehension. In this sens we find the following words in Hedegger’s *Being and Time*: “Since anticipation of the possibility which is not to be outstripped discloses also all the possibilities which lie ahead of that possibility, yhis anticipation includes the possibility of taking the *whole* of Dasein in advance in an existetiell manner; that is to say, it includes the possibility of existing as a whole potentiality-for-being” [9]. Or, even more precisely in this way: “the authentic Being-towords-death is *anticipation*” [10].

If the possibility of death is found by comprehension as ‘anticipation’, we can continue to ask how we should understand the certainty of possibility? According to Heidegger, the certainty of possibility is the imminence. Thus, the certainty of possibility of death means that the death is an imminence for a Dasein. Precisely, Heidegger wants to find the certainty of Dasein’s death not in the evidence of actuality of death, but rather as the imminence of possibility of death. Moreovere, “when one has an understanding Being-towards-death - towards death as one's ownmost possibility-one's potentiality-for-Being becomes authentic and wholly transparent” [11]. In this perspective, the difference between evidence and imminence of death overlaps the difference between ontical and ontological certainty of our mortality.

Strictly speaking, the imminence is a possibility which cannot be surpassed by a Dasein. I can surpass the possibilities to travel through Asia, to have a child, to write a book. We can identify two kinds of the surpassing of possibilities: as accomplishment of possibility and as renunciation of possibility. But, death as the possibility which remains always ahead of Dasein is unsurpassable. This fact means that the surpassing of the death either in the form of accomplishment or in the mode of renunciation is impossible. It is easy to understand why the surpassing of the death as renunciation is impossible: we can renounce only to something in respect to which I can exert my will. But death does not lie within my power. More problematic seems to be the affirmation that the death is unsurpassable in the sense that it cannot be accomplished. If it is so, why does the death of another Dasein appear as something accomplished? The surpassing of the possibility of one trip is possible in the sense of its realization, because we can find ourselves after this realization. This is precisely that what is impossible in the case of death, namely this recovering of itself is missed. On the account of this impossibility of self-recovering, the character of unsurpassable can be attributed to death. Thus, death represents a kind of unsurpassable possibility because the fact of self-recovering after death is also impossible.

Consequently, besides the meaning of the possibility of the impossibility of being, death can be furthermore described in terms of the impossible possibility. Moreover, being understood in this way, this impossibility of death as unsurpassable possibility seems to unfold the certainty of the possibility of death. In others words, the certainty of possibility of death could be found even in its inner impossibility to be accomplished or canceled.

CONCLUSIONS

Shumacher bases his claim on Heidegger's characterization of Dasein as being ahead-of-itself, which accordingly does not logically imply the end of that being. One must then ground the certainty of the end of Dasein's being on the death of another person. Dasein then deduces the possibility of its own death from the deaths of others. This is problematic according to us for several reasons. First, according to Heidegger, the ontological level (or the level of general structures) underlies the ontic (or the level of the specific and particular), so the certainty of my possible death should be based on the possibility as such. For Heidegger, the ontological relation with the possibility is assured by the comprehension. Possibility is higher than actuality for Heidegger. The death of another, as ontic or particular, is known through deductions, as it is an actual death. But, if we want to find a certainty of the death of one being we should understand the manner in which this being understand itself its own death. We can never understand how another Dasein understands itself in its own death. So to understand the possibility of one's own death, the actual death of another is no help. The 'anticipation' of death can be described as assuming the possibility of death through comprehension and as comprehension." When we anticipate death we see it as the certainty of the possibility of death, which means it is a possibility which cannot be surpassed by Dasein either in the form of accomplishment or in renunciation. The death of another Dasein seems to be accomplished. The certainty of the possibility of death can be found in the impossibility of death being accomplished by my own Dasein as I will not be able to 'recover' myself after death.[5]

Ontologically speaking, though, just as Dasein is[6] never without a world, Dasein is also never without others. Our comportment towards, or the way we relate to, others can be 'authentic,' where we free others for their possibilities, or 'inauthentic,' where we leap in for the other, and take care of their possibilities for them. Heidegger bases his characterization of the authentic on the inauthentic – by seeing the inauthentic way people relate to one another and to death we can see the way authenticity lies latent in the everyday. In our ensnarement with the 'everyday' or the 'inauthentic' it is the very things we flee from and the way we cover them over that shows our concern. Being with others, or being with the 'they,' helps us flee from death, leading to the idea that 'one dies' or 'they' die, but it is really no one that dies. I would like to argue that this is inauthentic being-with-others, but being with others is not always a 'they.' In our most meaningful relationships it is rather a 'we.' Shumacher makes a point of saying that we can be shown the possibility of death by the loss of one of the people to whom we are closest. When one of the most integral people to us dies it is not a 'no one' who dies, or a 'they' who dies, but a very important someone, a someone we have a hard time conceiving of ourselves without. So in a sense, a 'we' which Dasein is part of, dies, and this seems to be part of Dasein's own experiential data. According to Heidegger, when we are authentically with others or with another, the other person frees Dasein for his or her possibilities. Death is a person's own-most possibility. So it seems that authentically being-with another in his or her death can free Dasein to the possibility of his or her death in a way that a strictly conceptual understanding of infinitude cannot, as we can conceptually know about death without really understanding or comprehending it. Authentic being-towards-death is a way of being that transcends the conceptual and completes Heidegger's project of finding the authentic from the inauthentic world of the everyday. Instead of assuming that we must have an authentic being-towards-death before we can have authentic being-with-others, perhaps we need to have authentic being-with-others before we can have authentic being-towards-death.

When we authentically anticipate death we see the possible as possible. An authentic being-with relationship with a person who dies can free us to that possibility.

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Improving the Informatics Competencies Through Assessment for Learning

Maria Gutu [1], ORCID: 0000-0002-2820-393X
[1] Technical University of Moldova, MD-2020, e-mail: maria.gutu@iis.utm.md, https://utm.md/

***Abstract*—This paper presents the impact of the assessment for learning on students' Informatics competencies. The paper has described the usage, advantages and disadvantages of the assessment for learning as self-assessment, peer assessment, and co-assessment. As a result, the survey method was applied to find out the students' opinions about the assessment for learning in general, and the self-assessment, peer assessment and co-assessment in particular.**

Keywords*—assessment; self-assessment; peer assessment; co-assessment; assessment for leaning

I. INTRODUCTION

The educational system in the Republic of Moldova has as its main outcome the development of a system of competencies, including knowledge, skills, attitudes and values, which allow for a person's active participation in social and economic life, and are based on the curricula of the educational disciplines. The education purposes to train the next key competencies[1]: (1) communication in the Romanian language, (2) communication in the native language, (3) communication in foreign languages, (4) skills in mathematics, science and technology, (5) digital skills, (6) capacity to learn how to learn, (7) social and civic competencies, (8) entrepreneurship and spirit of initiative competencies, (9) competencies of cultural expression and conscience of cultural values.

Therefore, the curriculum [2] for the Informatics discipline is focused on both key competencies and discipline-specific competencies. According to it, the high school education includes the next specific competencies:

1. The use of tools with digital action in order to improve the efficiency of learning and work processes, showing innovative approaches and practical spirit.
2. Interacting with members of virtual communities for learning and work purposes, showing interest in active learning, research and collaboration, respecting the ethics of virtual environments.
3. Promotion in digital environments of personal and collective elaborations and achievements, proving ingenuity, team spirit and conviction.
4. Development of graphic, audio and video digital products, demonstrating creativity and respect for national and universal cultural values.
5. Scientific perception of the role and impact of information technology phenomena in contemporary society, showing critical and positive thinking in the connection of different fields of study, activity and human values.
6. Processing the data of experiments in the field of real sciences and socio-human ones, showing critical thinking, clarity and correctness.
7. Algorithmization of analysis, synthesis and problem-solving methods, demonstrating creativity and perseverance.
8. Implementation of algorithms in programming environments, showing focus and resilience.
9. Exploring problem situations by modelling, planning and performing virtual experiments in digital environments, demonstrating analytical spirit, clarity and conciseness.

High school education in Moldova consists of three academic years: 10th grade, 11th grade and 12th grade. For each academic year, the Informatics discipline is organized into compulsory modules and optional modules. At the beginning of each academic year, the teaching staff will guide the students to select one of the proposed modules for choosing, taking into account the digital equipment and software products, necessary for studying the chosen module. Thus, the selected module becomes a mandatory one. The Table I shows for each high school level the compulsory learning units and the units that

[1] Education Code of The Republic of Moldova No. 152 dated July 17, 2014. https://mecc.gov.md/sites/default/files/education_code_final_version_0.pdf
[2] National Curriculum for Informatics Discipline, Grades X-XII, 2019. https://mecc.gov.md/sites/default/files/informatica_curriculum_liceu_rom.pdf

students need to choose one from. The learning units aim to achieve the competencies designed for the established learning unit and, respectively, aim to achieve the specific competencies of the discipline, as well as the key competencies.

TABLE I. COMPULSORY AND OPTIONAL UNITS

The compulsory and optional units for grade 10
The compulsory learning units: 1. Methods of describing natural languages and formal languages. 2. Vocabulary and syntax of a high-level programming language (HLPL). 3. The concept of date. Simple data types. 4. The concept of action. The instructions of HLPL.
The optional units: 1. Web design. 2. Computer Graphics. 3. Digital photography.
The compulsory and optional units for grade 11
The compulsory learning units: 1. Types of structured data. 2. The information. 3. Arithmetic bases of the calculation technique. 4. Boolean algebra. 5. Logic circuits. 6. Computers and networks.
The optional units: 1. Audio-video processing techniques. 2. Visual programming. 3. Hypertext markup languages.
The compulsory and optional units for grade 12
The compulsory learning units: 1. Subprograms. 2. Programming techniques. 3. Numerical modeling and computation. 4. Database.
The optional units: 1. Advanced processing of information from databases. 2. Experimental Methods in the Humanities. 3. Web programming. 4. Dynamic data structures.

The teachers have the freedom and responsibility to capitalize on significant contexts, methods, tools and techniques for the development of designed competencies in a personalized way according to the specifics of the students' class, the available resources, the number of academic hours allocated, etc. During the entire teaching-learning-evaluation process, the teacher connects the didactic approach of training and developing specific competencies to the development and consolidation of key competencies. Therefore, to improve Informatics competencies, an instructional design was applied focused on assessment for learning. It incorporated the assessment of the tasks done from the teacher and student perspectives. Such a framework was adapted to institutional contexts and students' needs. Whereas, a holistic approach was required in order to tackle general issues, for instance, the purpose and adequacy of assessment, its design and its impact on supporting students to become more self-managing in their own learning. Thus, assessment for learning (A4L) is an approach that helps students to become more involved in the learning process, develop judgement skills, and assess the student’s progress during the learning and teaching process. The Cambridge Assessment International Education define the concept of the (A4L as “an approach to teaching and learning that creates feedback which is then used to improve students’ performance” [1]. According to Carless, the A4L is “a crucial driver of student learning and that well-implemented assessment processes provide positive prospects for meaningful learning, whereas flawed assessment risks leading student learning in unproductive directions” [2, p. 3]. Black considers that assessment for lea A4L rning is “any assessment for which the first priority in its design and practice is to serve the purpose of promoting students’ learning” [3, p. 10,]. Thus, A4L is a way to improve the educational process for both students and teachers. The teachers have to plan tasks that help students to understand their actual own outcomes level, where they want to be in their learning, what the achievements to be gained are, and how to achieve them.

II. METHODOLOGY

This experiment was applied to the Informatics lessons in the lyceum “Spiru Haret” from Chisinau, the Republic of Moldova. The purpose of this experiment was to improve self-learning skills, ensure active engagement in deep learning, enhance students’ reflection on their learning and increase the students’ Informatics competencies.

Firstly, to enhance student’s achievements, the following active learning techniques were used: one-sentence summary, think-pair-share, one or five-minute paper, problem-based learning, case studies, jigsaw, misconception check, classroom opinion polls, infographic, pass the problem, jeopardy etc., thus encouraging the interactions between students and teacher, emphasizing time on task, developing reciprocity and cooperation among students, and respecting diverse ways of learning.

Secondly, for planning the steps of activities and assessments to achieve the goals, the students’ motivation was taken into account, i.e. what they hoped to gain from those activities, facilities for study, knowledge, skills, attitudes and their learning style. Thus, the teacher had to design and redesign instantly the lesson approach or teaching-learning strategies when necessary.

Finally, yet importantly, this experiment promoted an assessment culture, ensuring students’ involvement in setting the evaluation criteria and objectives. The A4L helped students to recognize their weaknesses and strengths, and to work on areas that needed improvement. Therefore, the next assessment methods have been implemented: self-assessment, peer assessment, and co-assessment.

A. Self-assessment

Self-assessment is a powerful learning strategy, which facilitates self-directed learning by students and enhances reflective learning. It allows students to reflect on their own work about what they have done well and what they could do better next time, and answer a few questions given by the teacher that would include both knowledge and feeling questions [4, p.153]. Therefore, they will be able to set new learnings goals for achievement.

Hence, it is important to discuss with students and to hold information sessions in order to "promote understanding, negotiate and decide upon assessment criteria, and to clarify the required standards and learning outcomes" [5, p.4]. In order to do this effectively, time has to be set aside for such activities at the expense of in-class content. The students have to know the criteria that need to be considered in their work for identifying success, which will result in deeper learning. The criteria may be designed by both the teacher and the students.

After the self-assessment task, the students have to answer the following questions: What are the things I learned? What is the most important thing I learned? What was the hardest part of the task? What was the easiest part of the task? What questions do I still have? What success did I achieve? What will I do differently next time? These questions will help students enhance learning and achieve better academic performance, remove misconceptions, and identify improvements whilst recognizing what they have done well yet.

The advantages of self-assessment are as follows: increase student engagement, improve learning results, improve motivation and encourage students to seek help in case of failure, develop self-judgment skills, and improve honest and critical reflection. This approach shows students that they are able to increase their achievements through their own efforts. It is also useful in preparing students for future professional development and life-long learning, increasing skills and competencies, including the capacity to be assessors of learning, not just knowledge.

However, this approach has also disadvantages. One of them would be the case when the assessment criteria are not clearly formulated and may be misunderstood by some students. There would be a risk that students would evaluate themselves incorrectly.

Another risk is that the student may not be honest with them and may over-assess their own achievements. The consuming time is also a detriment for students. They might not approve of this approach because of the extra time used to self-assess. This disagreement will be until they realize the effectiveness of this method on their own learning, afterward, they will realize that the performance doesn't depend on the number of done tasks but on their quality.

B. Peer assessment

Peer assessment is a student-centred approach that allows students to increase their working speed and improve critical reflection on the work of their peers. According to Topping, peer assessment is "an arrangement for learners to consider and specify the level, value, or quality of a product or performance of other equal-status learners, then learn further by giving elaborated feedback to and discussing their appraisals with those who were assessed to achieve a negotiated agreed outcome" [6, p. 1]. The students assess each other's achievements according to a set of performance criteria related to a learning goal and provide suggestion feedback on the quality of their peers' work. The peer may not agree with all of these ideas, though some cooperation based on improvement is to be expected. Peer review also helps students to identify their own strengths and weaknesses.

Similar to any other approach, peer assessment has advantages and disadvantages. The advantages are as follows: develop lifelong assessment skills to students by providing feedback on their work to each other; improve a higher understanding of assessment criteria; fortify students' responsibility for making constructive assessment judgement and descriptive feedback; encourage learning from each other's work; increase the students' cooperation; reduce the time and workload for teachers.

Next, the disadvantages of this approach will be pointed out. One of the weaknesses would be the students' inaccurate assessment of their peers' work. Therefore, fairness is not maintained. Even if the evaluation criteria will be well established, there will be students who will not assess critically for various reasons, either their friendship relationship or peer pressure, they do not have the necessary level of cognitive ability to evaluate, or they are not experienced in assessing each other. Another weakness is the learner's inability to meet deadlines. In the implementation of the peer assessment approach, the limit setting is one of the most important requirements otherwise, success cannot be ensured.

C. Co-assessment

Co-assessment is a collaborative assessment approach to collecting data on students' performances. It leads to deeper learning, enhances learning skills and stimulates to attain the needed competencies. Dochy emphasizes the term co-assessment as a collaborative assessment and cooperative assessment [7, p.17]. It can be any combination of self-assessment, peer assessment and assessment by the teacher, depending on the planned activity. In the co-assessment, the students and the teacher set the success criteria together. The teacher has to encourage a more democratic classroom and furthermore has to improve students' responsibility, taking a decision, leadership, communication, and conflict management. In this experiment, the co-teaching groups consisted of a small number of students. The groups were limited to three or four students. The co-assessment was done by all the students, including the teacher using performance criteria. For assessment, the Mentimeter platform was used, as it collects and processes the students' feedback or grades given to the assessed work instantly and they are displayed immediately on the teacher's computer. What is more, the feedback can be instantly shown to the whole class using the smartboard to discuss the assessed task. Therefore, every student would enhance their knowledge based on the feedback that everyone provides. The students may appreciate their classmates' work with a grade, however, the final decision belongs to the teacher.

The main advantages of the co-assessment are as follows: involvement of all the students in the given assessment task; active engagement in deep learning; encouraging learning from their classmates' feedback; learning through different teaching styles; promoting constructive assessment and descriptive feedback; increasing the students' collaboration and cooperation, creating friendships; creating a democratic classroom; greater intrinsic motivation, and developing enterprising competencies.

Similar to any other approach, co-assessment also has some disadvantages. A weakness of the co-assessment in the online format is that students need to have a connection to the internet and at least one smartphone/computer for each one. Another weakness is the increased risk of not maintaining fairness in the assessment of a student's work due to their friendships. The different speeds of assessment due to the varied work skills of students is also a disadvantage of co-assessment – students with a higher level of performance will assess/work faster than students with a lower level of performance, thus these students will get bored. If the evaluation is done in an oral format and the students have to argue the feedback provided, shy introvert students may struggle. The oral forms of assessment are also important and, according to Burlacu [8, p.70], these require an evaluation no less rigorous than the written tests/tasks.

According to Race [9, p.85], nothing affects students more than assessment, therefore involving students in self-assessment, peer assessment and co-assessment can let them in to the assessment culture and involve them more closely in their learning and its evaluation, and this one would help them to understand really what is required of them.

III. Results

As a result, in order to contextualize the findings regarding A4L, the survey method was used. The information was obtained on students' views about the value and importance of A4L in general, and about self-assessment, peer assessment and co-assessment in particular. Therefore, a survey has been conducted with the 186-targeted students. It contains 18 questions (see Table II) in order to establish the students' opinions regarding the A4L and which type of assessment is most embraced by the students.

TABLE II. Surveyed Questions

No	The surveyed question
1	Was self-assessment a useful assessment tool to achieve better academic performance?
2	Was peer assessment a useful assessment tool to achieve better academic performance?
3	Was co-assessment a useful assessment tool to achieve better academic performance?
4	Did self-assessment help you to set new learning goals for achievement?
5	Did peer assessment help you to set new learning goals for achievement?
6	Did co-assessment help you to set new learning goals for achievement?
7	Did self-assessment help you to remove misunderstanding?
8	Did peer assessment help you to remove misunderstanding?
9	Did co-assessment help you to remove misunderstanding?
10	Did self-assessment help you to develop your own assessment judgement skills?
11	Did peer assessment help you to develop your own assessment judgement skills?
12	Did co-assessment help you to develop your own assessment judgement skills?
13	Did peer assessment help you to cooperate and collaborate efficiently with your classmates?
14	Did co-assessment help you to cooperate and collaborate efficiently with your classmates?
15	Did peer assessment help you to become more responsible in providing feedback?
16	Did co-assessment help you to become more responsible in providing feedback?
17	Was the set of assessment performance criteria clearly formulated?
18	Did you maintain fairness in the assessment of the classmates' work?

The questionnaire was created to collect the opinions of the students, anonymously and voluntarily, in order to identify the strengths and weaknesses of the A4L. A five-point scale was used to answer all questions, with one being the lowest score and five being the highest score (one point for strong disagreement, two points for disagreement, three points – for weak agreement, four points – for agreement, and five points for strong agreement). After collecting the data, the results of the survey show that the majority of students displayed a positive view of assessing for learning.

The graphic processing (see Figures 1 - 8) of the survey results led to the following conclusions:

1. Most students confirm that A4L is a useful assessment tool to achieve better academic performance (see Figure 1), giving the highest score (5 points) to peer assessment (54.84%), followed by self-assessment (34.95%), and co-assessment (24.73%).

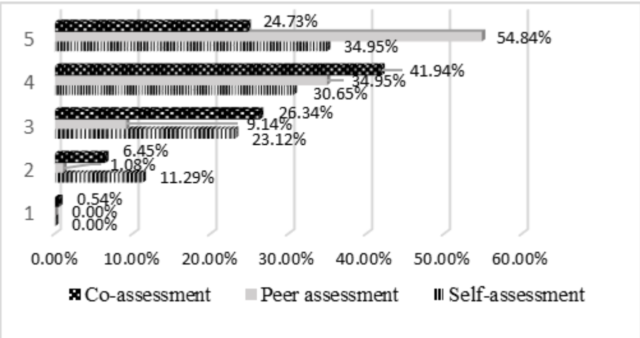

Figure 1. The students' answers in % for the following survey question: Was self-assessment/peer assessment/co-assessment a useful assessment tool to achieve better academic performance?

2. For the setting new learning goals for achievement, the results show that students are more supported by self-assessment with 56.45 %, followed by co-assessment (43.01%), and peer assessment (32.80%) (see Figure 2).

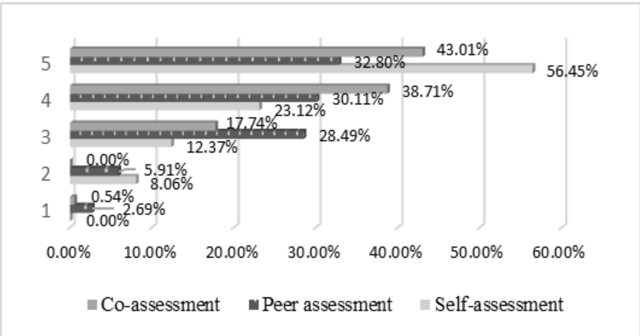

Figure 2. The students' answers in % for the following survey question: Did self-assessment/peer assessment/co-assessment help you to set new learning goals for achievement?

3. To determine the lack of learning and remove misunderstandings, the highest given percentage (48.92%) belongs to peer assessment according to students' results (see Figure 3).

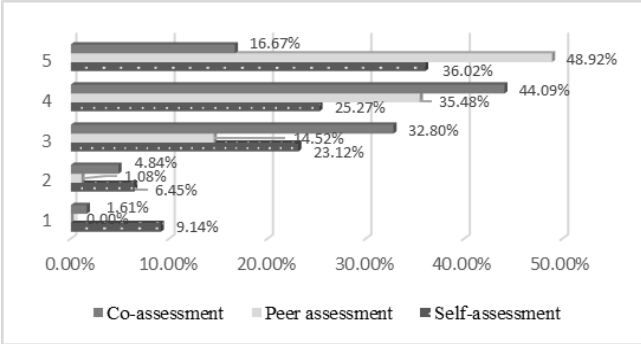

Figure 3. The students' answers in % for the question: Did self-assessment /peer assessment/co-assessment help you to remove misunderstanding?

4. The questionnaire results also show that co-assessment helps more students to develop their assessment judgement skills and to deal a constructive feedback, conferring a percentage of 60.22 (see Figure 4).

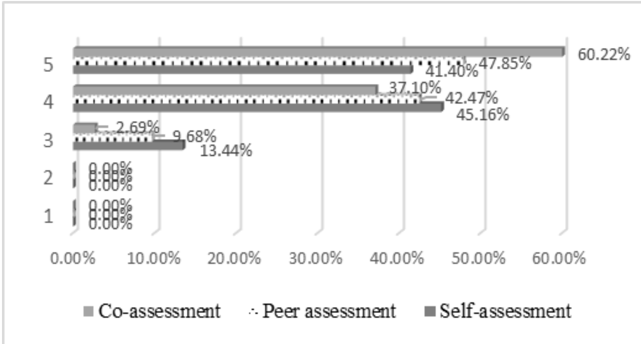

Figure 4. The students' answers in % for the question: Did self-assessment / peer assessment / co-assessment help you to develop your own assessment judgement skills?

5. About the efficient cooperation with their classmates, both the co-assessment (64.52%) and the peer assessment gained high score (58.06%), with a difference of 6.46% (see Figure 5).

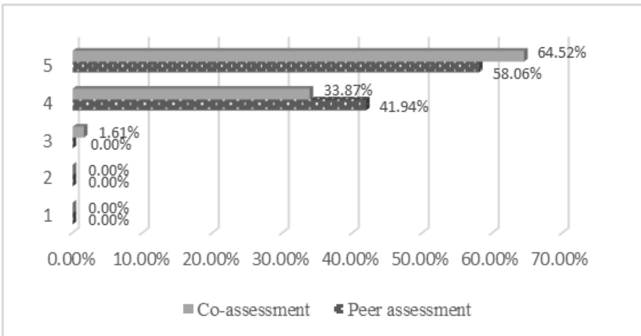

Figure 5. The students' answers in % for the question: Did peer assessment / co-assessment help you to cooperate efficiently with your classmates?

6. The students show through their survey answers (52.15 %) that they are more responsible in providing feedback when it is used co-assessment approach, offering the highest values, five points (see Figure 6).

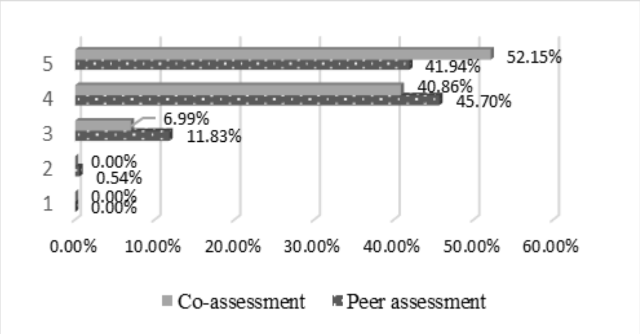

Figure 6. The students' answers in % for the following survey question: Did peer assessment/co-assessment help you to become more responsible in providing feedback?

7. To the survey question about the assessment performance criteria if they were clearly formulated, 2.69 % of students selected the lowest score (one point) and the 58.06 % of students selected the highest score (five points) (see Figure 7). This 2.69 % of students is assumed to be the students with lower-performing level that do not yet have the knowledge base to assess accurately and to understand well the assessment criteria. The findings are assumed because the survey was anonymous and voluntary.

8. Figure 7 interprets the data about the students maintaining fairness in the assessment of their classmates' work. It could be seen that never chose one and two points for it, three point was selected by 1.61 % of students, four points – 18.82 %, and the highest score was selected by large percentage of students, 79.57 %.

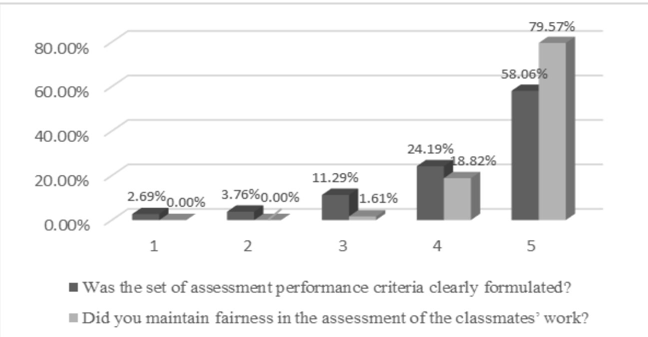

Figure 7. The students' answers in % for the survey questions.

The experiment results show that each type of assessment for learning contributes to improving the teaching-learning process depending on students' preferences. The lower-achieving students tend to need support to reflect on their learning and they often have to benefit from guidelines or instructions that they can follow. Higher-performing students tend to assess and give feedback more rapidly than lower-performing students therefore differentiated tasks have to be given.

IV. Conclusion

All assessments described in this paper are conducted with the goal of improving learning, involving discernment and occur best when students are accustomed to the assessment process, and when they receive and apply improvement suggestion feedback from both the teacher and their classmate. In all aspects of these assessments, students need to comprehend what is their level of current performance and how to improve their outcomes. Students' understanding of assessment criteria is an important point of reference for the success of self-assessment, peer assessment and co-assessment.

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Exploring PBL as a New Learning Context in Engineering Education

Elena GOGOI, ORCID: 0000-0002-4159-34771[1]
[1] Technical University of Moldova, Republic of Moldova, Chisinau, email: elena.gogoi@faf.utm.md

***Abstract* - This paper explores the experience of engineering students in an innovative context, namely, Problem-Based Learning (PBL). It first describes some particular details of PBL framework implementation at the BSc Degree in Software Engineering, an English-taught Honours Programme at the Faculty of Computers, Informatics, and Microelectronics (FCIM), Technical University of Moldova (TUM). The research also addresses some specific aspects of its implementation, preparation for collaboration, milestones, working processes, guiding sessions, etc. A comparative study between the 2022 and 2021 editions of BSc graduates in Software Engineering was conducted to identify the efficiency of several dimensions of PBL as one of the most recently adopted learning environments at TUM.**

Keywords – Problem-based Learning; mentoring; learning environment; educational context; engineering education; collaborative learning; teamwork; challenges.

I. INTRODUCTION

In the context of rapid technological progress, our society urges a vital interest in skilled employees who can easily update their knowledge, learn and relearn things and processes, to quickly adapt and be ready to recreate old technologies into new ones.

One of the principles of the Higher Education Learning Framework (HELP) states that: “A university education provides a learning experience that broadens students’ knowing and being for life beyond the classroom” [1, p. 1], which serves as a foundation for academic staff to focus on offering engaging learning experiences to prepare students for the world of work.

To keep up with these dynamic changes and to align with the needs of this digital society the Technical University of Moldova (TUM) strives to prepare future engineers fully equipped to analyze problems, find possible improvements and implement them in close collaboration with the industry.

Our university has been investing effort, support, and resources to enhance active participation and to create regular contacts and bonds that promote fruitful exchanges and efficient learning. It has also been making considerable efforts to provide innovative learning environments to transform learners’ educational experiences into more efficient, meaningful, and impactful ones.

Adapting the curriculum is among our priority objectives, which is why the academic staff from our University constantly works on expanding and redefining opportunities to improve it by adding new dimensions oriented to innovative learning contexts meant to enhance teamwork, collaboration, and hands-on activities aiming at better preparing engineering students to face this paradigm-shifting age.

II. PROBLEM-BASED LEARNING AT TUM: CONTEXT, BACKGROUND, FRAMEWORK

“Learning occurs in a context, and it can be used to enhance the learning experience”, another HELF principle aims to make the learning experience more relevant, meaningful, and engaging, so that students develop skills to apply learning to different contexts after graduation [1, p. 3]. It is a well-known fact that engineers do not work in isolation and TUM, in this regard, is in permanent search of favourable learning contexts. Also, many researchers claim that: “It is inconceivable to think that great engineering projects of high complexity can be conceived and created by an engineer in solitude. Consequently, collaborative learning is most suited and a natural must in preparing engineering students for the challenges that lie ahead” [2, p.175].

In this context, PBL, as a small group learning, was adopted at TUM as the driving key that can ensure collaboration and teamwork for future engineers. In 2017, the previously English-taught Honours Programme in Computer Science (FAF), was redesigned into English-taught Honours Programme in Software Engineering. Being complimented by Problem-Based Learning (PBL), a modern pedagogical framework, it has immediately become popular. This innovative collaborative approach was introduced in the curriculum of the Bachelor’s Degree in Software Engineering with the purpose of "enhancing students' competitiveness and employability" [3].

An interesting fact to mention is that the *collaborative learning strategy* is considered one of the oldest forms of group learning. The first attempt to address it began thousands of years ago when studying the Talmud, the Jews insisted on boys working in partnership with others to decode and facilitate the interpretation of sophisticated texts [4].

Quite often the concept associated with group learning varies from *cooperative learning*, *collaborative learning*, and *problem/project-based learning*, to *small-group learning*, *team-based learning*, *peer instruction/ mentoring*, etc., and it becomes difficult to distinguish among them. As it has been appreciated, these approaches share so much in common, that the terms are considered similar forms, often combined or used interchangeably or alternatively. Even researchers, argue about the term, accepting them as synonyms, as professor M. E. Weimer, in one of her public communications was insistently asking whether it matters what we call it [in 5].

Whatever the term of reference, it is extremely important to understand that all these philosophies or forms of small group learning promote active learning, active involvement in the learning process, a lot of interaction, and personal accountability leading to increased motivation and achievements, and development of critical and creative thinking skills.

The early 1960s are distinguished by an increased interest in small-group learning approaches both at the pre-university and university levels. The origin of PBL, as a form of cooperative learning, can be found in the medical program at McMaster University, gradually evolving into an educational methodology implemented by many other institutions around the world, being identified as "a learning method based on the principle of using problems as a starting point for the acquisition and integration of new knowledge" [6].

In our case, this pedagogical framework is always collaborative, encouraging students to engage actively in the learning process and skill acquisition. The PBL context model alludes to joining efforts in learning to achieve common educational goals. In this framework, disciples have the opportunity to identify and explore real-life problems, analyze them from different perspectives, apply knowledge to practice, collect relevant data, and discover and provide various viable solutions together with their fellows.

The PBL within the Faculty of Computers, Informatics, and Microelectronics, widely explores teamwork by addressing and developing multidisciplinary semester-wide projects as can be seen in Table 1 according to the *Study Plan for the Bachelor of Science in Software Engineering* approved in 2021 [7].

TABLE I. SEMESTER PROJECTS

Semester / Name of the Project	
1.	Conceptual Design of an IT Application
2.	Equivalent Models
3.	Basics of Application Development
4.	Development of Domain-Specific Languages
5.	Secure Application Development
6.	Internet of Things
7.	Information System Design
8.	Bachelor's Thesis

Teamwork, in a PBL environment at FCIM, TUM, means that students collaborate to enhance individual learning. This small-group learning can be translated into how group members actively support each other's learning processes. Teams shaped at the project start have to work out viable solutions for a proposed or identified challenge, problem, or real-life issue. Each team is expected to develop the vision of the challenge and propose an original IT solution to it. The students have to organize themselves to plan a roadmap, make decisions and find solutions decide, anticipate, adapt, and adopt different perspectives, and all actions needed to solve a problem which is turned into a project.

The PBL projects are always carried out in teams that are built at the beginning of a new semester. Usually, students are put together during the PBL take-off session in the first week of each semester. If in the first semester there are 5-6 students in a team, we move to smaller teams of 3 or even 2 students in the last semester (for the graduation project). The number of individuals assigned to a team depends on some factors rooted in hour distribution per academic staff. Moreover, in the first 2 years, the number of people is bigger (usually 90 students enrolled for the Software Engineering study programme), while in the 3rd and 4th years, the number decreases drastically because of dropouts (sometimes decreasing to 60-70 students for the same programme).

Of course, the most challenging, in terms of group formation, is the first semester because students hardly know each other and the rationale beyond the criteria used to set up the teams focuses on heterogeneity (male/female, ethnicity, knowledge, skill backgrounds, and many others). The MBTI personality type indicator has been recently adopted as one of the tools suggested by psychologists for teamwork and one that helped us build balanced teams in terms of personality and character, commitment, leadership, etc.

In the context of PBL, team-building activities are carried out to engage students in discussions, interaction, and knowledge sharing. Also, some hours usually focus on teamwork issues: teamwork objectives, team formation and team development stages (forming, storming, norming, performing, and adjourning) according to Bruce

Tuckman's model, Meredith Belbin's team roles, the importance and the need of synchronizing hard and soft skills, assertive communication, conflict management, time management, project management, etc.

Each team is randomly assigned a teacher-supervisor. During both PBL editions a group of teachers, mainly from the Department of Software Engineering and Automation, has been steadily guiding the teams.

It is important to emphasize that in PBL, a crucial transformation in both teachers' and students' roles should be considered. The teachers move from the traditional knowledge imparting and sharing, to facilitating, guiding, and supervising students' learning. The student, in this paradigm, is no more passively absorbing the information but moves to self-directed learning, focusing on a learning-by-doing approach.

Broadly speaking, the teacher in a collaborative PBL setting will guide, notice, observe and intervene only when s/he considers it necessary, so that, students do not deviate from the right path to knowledge acquisition and learning objectives attainment. Furthermore, s/he becomes *a mentor*, *a supervisor*, and *a facilitator* of the educational process. In our academic community, colleagues, working in the PBL context, are known as *mentors*.

Another important point to make is that PBL mentors are occasionally recruited from IT companies on a voluntary scheme. This form of collaboration has only forged the partnership between industry and university, aiming to get constant feedback from the labour market, a helpful tool meant to guarantee permanent optimization of study programmes and future-oriented technologies.

The PBL mentoring/supervising process normally involves a mandatory weekly one-hour-and-half-session between the mentor and his/her team. These meetings are held in the team-assigned project room or online, at a pre-scheduled date and time. During this meeting, the mentor discusses the progress and project management issues with his students. The other meetings without the mentor, are not included in the faculty schedule because they are held in extra-curricular time.

Of course, implementing Problem-Based Learning as a collaborative context for engineers doesn't mean a new curriculum adoption and content change only, but also adequate infrastructure aimed to simulate the world of work. The meeting point, called the *PBL area*, was designed to offer more interaction, and it was configured to pursue ideas and creative solutions to real-world problems, providing opportunities to explore new technologies and to engage with peers giving a meaningful impact on their studies.

Several classrooms, large lobbies, recreation spaces, mobile furniture, and collaborative open spaces have been designed to support small group learning and also engage the active minds of students and mentors. To fulfil course and programme requirements, this environment is meant to immerse students in deep learning.

III. Methodology

In this article, we tried to explore teamwork challenges faced by the 2022 and 2021 graduates of BSc in Software Engineering at the end of their degree. The responses were collected by an individual survey and also in small and academic group open discussions within several PBL follow-up sessions. The discussions were meant to highlight several aspects related to the PBL framework and environment to improve the level of satisfaction and the learning outcomes in the next editions, and also to reinforce the positive dimensions pointed out by our graduates. The results are shared among the faculty staff, students, and PBL mentors, of course.

The survey was applied at the end of BSc, which means 8 semesters of teamwork in PBL. The overview of the survey consists of several sections: PBL dimensions, mentor's roles in PBL, collaborative principles, etc. For this specific paper, we have focused on the dimensions of PBL as a new learning context, the optimal number of team members, the level of satisfaction with the PBL experience, challenges faced and, of course, suggestions to improve this new learning context to increase the learning efficiency.

Small group discussions with students were organized after the survey was completed. The discussions were facilitated by the faculty staff and aimed at collecting students' opinions more openly. Some of the topics discussed included the project themes, the assessment methods, and the PBL as a learning methodology.

As previously mentioned, the study is focused on exploring the elements of a new learning environment based on teamwork and problem-solving. Also, the methodology uses a quantitative and a qualitative instrument to collect the opinions and perceptions of students about PBL elements, giving them the opportunity to both write and discuss in an open and informal environment, and to express themselves freely and honestly.

IV. Results and Analysis

We explored the effectiveness of several elements of PBL as a new learning context, applied to undergraduates from the English-taught Honours Programme in Software Engineering, Faculty of Computers, Informatics, and Microelectronics, Technical University of Moldova.

After 8 semesters in a collaborative environment, we have chosen to compare the results of the first 2 editions of graduates with an equal number of respondents: the 2022 edition (41 respondents out of 46 graduates) and the 2021 edition (41 respondents out of 43 graduates).

The following tools have been analyzed: the size of the most efficient group work, level of satisfaction, elements, challenges faced, things to be improved, etc in the PBL context.

From the figure below, it is clear that there is no significant difference between the number of females and males entering the Software Engineering (SE) field. This representation leads us to the idea that women get more and more interested in domains, previously chosen, mainly, by males.

Figure 1. The number of male vs female students in SE: a) 2022 edition, b) 2021 edition. (figure caption)

In the table below, we present the collected data for each question of the survey.

Q 1. Teamwork will help me be more marketable in the workforce.

TABLE II. IMPORTANCE OF TEAMWORK SKILLS

	2022 graduates	2021 graduates
Yes	30	36
No	1	1
Maybe	10	4

When asked about *the importance of teamwork skills* after graduation, the vast majority of graduates from both editions have positively appreciated it; the figures reveal that the young people entering the IT world are already familiar with the requirements of the labour market. Interestingly that one person from each edition denies the importance of teamwork as being an unimportant skill on the job. We have also identified 10% of indecisive individuals from the 2021 edition, while the number doubles in the 2022 edition.

Another important element of a collaborative environment is the optimal number of teammates for a more efficient working process.

Q 2. What is the optimal team size?

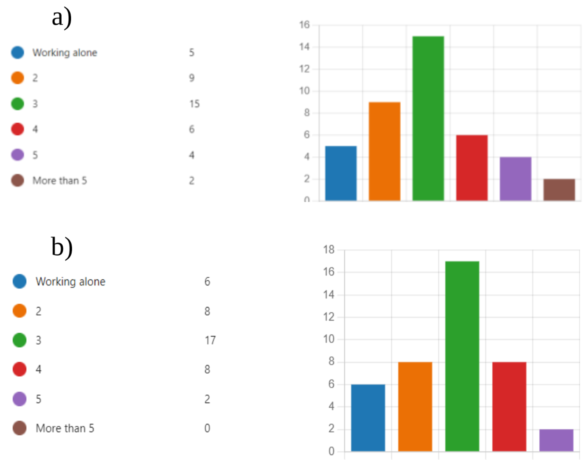

Figure 2. The number of team members in an efficient team: a) 2022 edition, b) 2021 edition. (figure caption)

During their degree, Software Engineering students worked on their PBL projects being assigned to 8 different teams, having the possibility to interact with new teammates every semester (from 6 members to 2). The data would seem to suggest that the optimal number for the most efficient teamwork is 3. As they have explained further, the fewer people, the easier the working process, and task delegation and the more individual responsibility assumed. We cannot ignore the fact that more than 10% of respondents dislike working in teams preferring to work alone. It might happen that an eight-semester period is not enough to adapt to a collaborative working environment or to develop teamwork skills. Or, this happens because they are introverts, finding it difficult to collaborate with others. On the opposite end, just a couple of students feel comfortable working in a bigger team.

Q 3. Which PBL element(s) did you enjoy most?

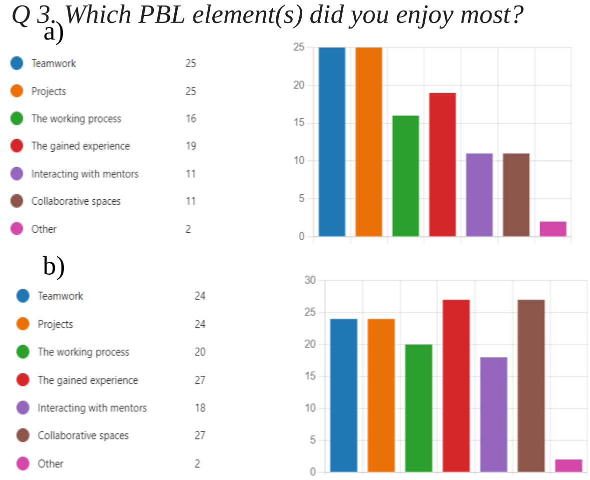

Figure 3. PBL elements students enjoyed most: a) 2022 edition, b) 2021 edition. (figure caption)

Working in a new context like PBL means dealing with several elements meant to enhance the learning process, knowledge acquisition, and efficiency. Since respondents have suggested several elements like teamwork, projects, collaboration, collaborative spaces, interacting with mentors, and gaining experience, we can't say that they have highlighted their preferences more for some elements, and less for others. One distinct difference between the two editions is that the 2022 graduates enjoyed less the collaborative spaces and interaction with mentors than their 2021 peers. The explanation is quite simple in this dimension: the 2019 pandemic and the transition to online education led to less human interaction and of course the lack of possibilities to learn and work in a physical collaborative space for students enrolled in 2018.

Q 4. On a scale from 1 to 5, how would you appreciate your level of satisfaction with your 4-year PBL experience?

TABLE III. AVERAGE RATING NUMBER WHEN APPRECIATING THE LEVEL OF SATISFACTION IN A NEW ENVIRONMENT, PBL

2022 edition	*2021 edition*
3.63	**3.68**

When asked to appreciate the level of satisfaction with a four-year PBL experience, on a scale from 1 to 5, the average rate represents 3.63 points for the current year, 2022 graduates, and 3.68 points for the previous year, 2021 graduates. These data seem to suggest that our graduates faced a similar number of challenges. On the one hand, these results are encouraging for our institution since we have managed to get above the average with the first 2 editions of graduates who experienced learning and knowledge acquisition in a new setting like PBL. On the other hand, these data must be considered as a signal that we have to continually work on improving the elements constituting the new learning context to get to a higher level of satisfaction.

Q 5. Would you advise other students to join a study programme based on the PBL framework?

TABLE IV. ADVISING SCHOOL GRADUATES TO JOIN PBL

	2022 edition	2021 edition
Yes	21	23
No	1	2
Maybe	19	16

To see how enthusiastic about encouraging other school graduates to join a study programme that aims at a collaborative paradigm oriented to PBL 51% of 2022 graduates and pretty the same number, 56% of 2021 edition reported their desire and openness to advise others to join this degree.

Q 6. Would you like to become a part of our PBL Mentoring Team?

A big discrepancy between the two editions of graduates concerning their desire to join our team of mentors was discovered. While more than two-thirds of the 2021 graduates, right after graduation accepted to become part of our PBL mentoring team, actually only one graduate has joined our team. In the 2022 edition, the number of those enthusiastic about supervising a PBL project decreases drastically to less than one-third, thus, 3 of them have joined our team. Further research needs to be conducted to identify the reasons for refusing to work in an academic environment.

Of course, students working in a collaborative context oriented to PBL have faced a lot of challenges common for both editions: free riding and difficulties to convince every member to contribute, task delegation, tight deadlines, conflicts among peers, difficult milestones, etc. They have also complained about the tough bureaucratic process, including writing meeting notes and meeting agendas with the current status of the project for every single team meeting.

The graduates' insights below serve as a window to an understanding of the challenges they faced while working under the PBL framework.

"Teamworking process ... so complicated to work in a team when everyone has his point of view", anonymous 2022 graduate.

"Some team members know that other team members will work on the project and don't contribute until the last week before the deadline", an anonymous 2022 graduate.

"Not all the teammates are interested in working on the project. Feedback is not understood properly", anonymous 2021 graduate.

"Learning a new programming language in 3 weeks, and writing meeting notes, that I didn't do before", anonymous 2021 graduate.

While some of our graduates faced a lot of challenges, some others felt positive about their 4-year of PBL experience and fully enjoyed learning in this new context.

Learning in a collaborative environment helped our graduates grow and develop soft skills and improve their hard ones as can be seen from their insights:

"I didn't face many specific challenges; every new project was a challenge but it was interesting to work on them", anonymous 2022 graduate.

"It was a challenge for me to get out of my comfort zone and to speak in front of a public, this was a problem for me and PBL context helped me to overcome it", an anonymous 2022 graduate.

"The biggest challenge was to socialize. PBL requires teamwork and social interaction. Throughout the school period, all the students are taught to face all their issues alone, and PBL is the exact opposite of that. It was

difficult to adjust, but the more I studied in the PBL environment, the easier it became, and I didn't even notice how much more enjoyable the teamwork and social interactions became …", an anonymous 2021 graduate.

"I wouldn't say there were exactly challenges, I would rather call them opportunities; when you do not know a specific programming language, our mentors' timely answers and resources provided the exact help I needed. Besides that, our professor XY's homework, at the beginning was so terrible that everyone wanted to finish his course, but later you understand how important the assignments were and what happiness was to have him as a teacher.", an anonymous 2021 graduate.

In the end, they were invited to suggest aspects to be improved in the teaching-learning process. The most common suggestions were oriented toward the organizational process of project development, clear assessment criteria, clear deadlines for the checkpoints, and less bureaucratic stuff, like writing weekly meeting notes, and others.

"To work in smaller teams, 2-3 people for each project", anonymous 2021 graduate.

"To have more interactions with the mentor", anonymous 2021 graduate.

"Let students choose their mentors, teammates, projects … ", anonymous, 2022 graduate.

"PBL framework should be applied for all students at the Technical University of Moldova", anonymous 2022 graduate.

CONCLUSIONS

This paper explored the elements of a new learning context, Project-Based Learning in the Bachelor of Science degree in Software Engineering within the Faculty of Computers, Informatics, and Microelectronics, Technical University of Moldova. The study was grounded on the first 2 editions of graduates (2022 and 2021). The answers were collected at the end of their 4-year degree using questionnaires, small group open discussions, and individual feedback. The results show that in both editions students have a more than average level of satisfaction with their experience with teamwork. Students also acknowledge that PBL, as a collaborative tool, will help them be more marketable in the workforce market. The results of the present study demonstrate that 3-4 individuals in a team are the optimal number for a more efficient working process Additionally, students consider teamwork as a valuable asset to their personal and professional development.

The respondents also point out that they prefer to learn by working in teams. While a lot of them have acknowledged their desire to become part of our mentoring team, only a few have joined us.

The small group and individual discussions reinforced the idea that working with free riders is time-consuming and should be immediately addressed requiring an official reaction.

It is now clear that future work should also focus on promoting a culture of reflections in PBL, requirements for formal meetings, and strategies for wider adoption within teams. Moreover, research should be conducted on the assessment process analysis: peer evaluation, group project, and individual interviews and the weighing of each for the final grade. system of teamwork and group project along with the reflection processes.

Of course, future work will be aimed at improving the whole process which will include more guidance from mentors, addressing the free-riding phenomenon, giving penalty points for those who do not contribute to the project work or, in the worst scenario, to be eliminated from the initial team and be assigned an individual project of lower complexity.

All of this points to the fact that the most important dimension requiring improvements is the planning process, especially for the teachers joining the PBL mentoring team for the first time. This can be achieved through continuing teacher training where new teachers will be initiated on how to act in a new educational context, the one oriented to small group learning and identifying real-life issues like PBL.

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Non-linguistic Thinking as an Effective Tool for Innovation in Education

Leon Brânzan [1], ORCID: 0000-0003-0049-6176
[1] Dept. of Informatics and System Engineering, Faculty of Computers, Informatics and Microelectronics, Technical University of Moldova, str. Studenţilor, 9/7, b. 3, MD-2045, Chişinau, Republic of Moldova, leon.brinzan@iis.utm.md, https://fcim.utm.md/

Abstract—**In higher education subjects are traditionally taught in the form of lectures, where teachers are required by the curriculum to cover a certain amount of content in order to prepare their students for subsequent courses or examinations. It has been observed that people struggle when they are required to memorize a lot of new information, this phenomenon is explained by the working memory theory [1], and the negative effect is amplified when teaching subjects like programming, with the links between categories of information that has to be memorized not clearly identifiable by beginners. Lecture material for programming courses often mixes language-specific information (keywords, syntactical rules, ready solutions), mathematical basis for a given solution (type theory, algorithm theory), hardware-specific limitations (computer memory management) etc. This often has drastic consequences for students' success in later courses that rely on material from previous courses [2].**

This paper argues, that the process of learning is not simply about transferring knowledge from teacher to student. In fact, knowledge does not have to be "existing in an objective manner" for subsequent transmission, it can also be "built in a constructive manner by the learner" [3]. Within a traditional educational process software engineering students find themselves in situations where text is used to reason about other forms of text: typically code examples are shown first, then the code's structure and syntax are explained. While there is intrinsic value in reading code written by experts, reading explanations of that code is much less effective than trying to reason about the structure and function of a program, and various features of a programming language. This paper will attempt to showcase several teaching techniques that don't utilize textual explanations (either partially or completely), putting forward the argument that non-linguistic presentations can be more effective in teaching, under certain conditions. Several methods of achieving this effect will be described, with the main goal of appealing to the student's ability for computational thinking.

Keywords—non-linguistic learning; software engineering; cognitive load theory; computational thinking

I. CONTENT DELIVERY

Software engineering is a multifaceted discipline. Mastering it requires memorizing a lot of factual information, knowledge of at least one programming language, and learning a particular set of skills that enable the learner to tackle complex engineering tasks. Programming can only be learned by solving problems specifically designed to develop these kinds of skills. This makes efficiently teaching software engineering difficult. The traditional way of teaching programming heavily relies on content delivery. Subsequent memorization of information delivered in this way requires development of multiple neural links in the corresponding neural networks, ergo – active interaction with a given piece of information and deliberate dwelling on the result of that interaction are needed [4]. Designing and writing software is one of the most complex problems students can be tasked with. Software itself is often on the leading edge of any given industry's advancement. It follows that software engineering courses should be on the bleeding edge of education. In actuality, the opposite is true. High-profile courses, like Harvard University's CS50 program, while claiming to be designed "with the aims of making the content of the course more widely available and contributing to public understanding of innovative learning"[1], do not go too far from the traditional lecture form in their attempts to innovate learning, only supplementing information delivered during lectures with various visualization techniques, and only sporadically. They do not illustrate the relations between different concepts presented to students from one lecture to the next, leaving it up to students to infer those connections.

Lecture is a process of deconstructing knowledge by the teacher, negotiating between teacher and learner, and subsequently reconstructing it by the learner. The same applies to learning via textbooks which inherits all of the

[1] CS50 Syllabus, Harvard College, https://cs50.harvard.edu/college/2021/fall/syllabus/

drawbacks of the lecture-form with the added detriment of having no ability to appeal to the author for clarification. Lectures are becoming less and less effective [5]. The ideas and skills required to master programming cannot be learned by listening to a lecture or by reading a book (though they are learned about, which has its own value). However, methods of doing it using software solutions which take into account how the human brain actualizes abstract concepts and processes code have existed for decades but are rarely used in education.

This paper will provide several concrete examples of how software enables students to learn the "spirit of engineering and problem solving" in order to support its main claim, that non-linguistic forms of learning can be extremely effective, especially for disciplines like programming.

II. Text and meta-text

While it has been noted, that "relationship between code and language may be ontogenetic as well as phylogenetic", and that "[it] is hard to imagine how code in its current form could have been invented in the absence of language" [6], learning programming as an activity is not based solely on learning a programming language. It is primarily about solving logical tasks and then applying a programming language to recording resulting solutions in text form for subsequent reuse. Programming languages are primarily a tool for formalizing generalized solutions.

The process of thinking itself does not directly correlate with speech, only overlapping with it in some areas [7]. More specifically, instrumental thinking – the ability to understand mechanical joints and devise mechanical solutions for problems that are mechanical in their nature – is linked to concepts and speech to a much lesser degree. Actions become subjectively comprehended before being manifested in speech. The primary function of instrumental thinking does not lie in transferring of knowledge but in applying accumulated knowledge to problem solving [8]. It is this kind of thinking that educators in engineering need to foster among their students.

When text or speech is used in a learning environment, three of its functions must be considered. First, the writer/speaker's intention is to communicate thoughts and ideas using language. Second, his intention is to be understood exactly. Third, "[...]beyond the linguistic code, communication entails a special structure of embedded intentions (the intention that others understand one's intentions) and is based on cooperative principles by which interlocutors work together toward understanding each other" [9]. This last function can never be guaranteed to apply when communicating through text or speech, because when the source of information encodes ideas into natural language the ideation process of the person(s) receiving that information is intruded upon. It is for these reasons that lectures and books for the most part fail to efficiently teach complex concepts, of which programming is a primary example. A question then arises: is there an alternative, more efficient way to teach the aforementioned "spirit of programming"; can students be taught to think like software engineers before learning a programming language and writing a single line of code?

III. Computational thinking

The term "instrumental thinking" borrowed from psychology, while it applies to programming, is not directly linked to it because it had been in use before programming as activity fully emerged. Computational thinking – "the thought process involved in formulating a problem and expressing its solution(s) in such a way that a computer—human or machine—can effectively carry out" [10] – will be used in this paper to refer to the kind of thinking that should be developed in engineering students. Computational thinking as a concept does not describe a new kind of thinking process in a neuro-biological sense, it is a specialized term substituting "instrumental thinking" that implies understanding of objective processes specific to the problem at hand. However, it has been stated that "computational thinking is conceptualizing, not programming. It describes a way of thinking at multiple levels of abstraction, not only the ability to program" [11][emphasis added]. Thus, programming is a subset of computational thinking, since computational thinking involves solution expression, at the same time contrasting itself with programming. That has other implications as well. Firstly, that "programming" as an activity is separated into several distinct stages: formulating a problem, expressing a solution (in mathematical notation, programming language etc.), executing, evaluating – some or all of which go under the aegis of computational thinking, which "complements and combines mathematical and engineering thinking" [12]. Each of these stages requires different strategies, concepts, and forms of knowledge; this would mean that learning to do each of them would require different approaches as well. Secondly, expressing a solution – recording a set of steps using natural or formal languages – itself requires a specific form of thinking. The nature of this process is more easily understood since it involves mapping ready instructions to a specific language's grammatical and syntactic rules. The thought processes behind the remaining two activities are not as easily defined.

What's important to point out is, it is not hands-on (empirical) experience that is responsible for developing knowledge but the nature of the experienced activity, because the human brain develops new pathways in response to acquiring new information [13]. Therefore, the chosen learning strategy bears the most importance in regards to the effectiveness of learning processes.

IV. NON-LINGUISTIC METHODS OF TEACHING

While it remains to be empirically confirmed whether non-linguistic forms of learning are more efficient than traditional forms, there are several important benefits of using non-linguistic methods of teaching which could be leveraged for an overall more efficient learning process, regardless of the medium: language agnostic learning solutions, conformity with the multimedia principle of delivering information, cognitive load theory-aware methods of teaching, reflection-based learning, reactive learning environments, inference-inductive activities. This is by no means an exhaustive list, and these characteristics are not exclusive or inherent to non-linguistic learning methods but all of them can be tapped into using non-linguistic forms of learning with the help of proper tools to enhance the learning process.

Using non-linguistic methods of transferring information has two immediate consequences. First, students are not limited by the need to have prior knowledge of a specialized language or notation, or the need to dedicate time to getting acquainted with a notation/language. Second, it could also be beneficial to transfer information without the use of text, instead planting ideas into the respective areas of the brain directly (similarly to how code does it, appealing to the multiple-demand system [14]). Working memory is limited in how much information it can hold onto at any one time. That amount can be looked at as cognitive load, "the cognitive effort (or amount of information processing) required by a person to perform [a] task" [15]. It can be associated with a specific topic, the way information or tasks are presented to a learner, or the work put into creating a permanent store of knowledge (a *schema*). Non-linguistic forms of learning reduce the amount of extraneous information students must sift through while performing a learning task, which enables them to focus on the information relevant to learning, reducing cognitive load.

Cognitive theory of multimedia learning (*CTML*) assumes that "the working memory processes verbalized and visual pictorial information in two separate channels" [16]. To leverage that inherent characteristic of working memory it is advised to use multimedia instructions to "maximize the amount of available mental resources" [16]. It has been empirically shown that "people learn more deeply from a multimedia message when extraneous material is excluded rather than included" [1]. Tools that conform to CTML limit the use of text and guide the learner's focus by other means (for example, communicating essential information and relations about information via spatial arrangement) [17].

Reflection is another powerful teaching tool. "When learners reflect, the otherwise implicit knowledge becomes digested through active interpretation, questioning, and exploration" [18]. It is worth pointing out that reflection is widely used in modern-day programming for incrementally improving software features (analysis) and diagnosing problems in software products (debugging). It is a crucial skill for a software developer. Yet very little time is dedicated to teaching core concepts of debugging, analysis, and profiling[2] to beginners. Purpose-built non-linguistic learning tools could and should incorporate reflection into the learning process, since "it is essential to increase learning outcomes and the learner's awareness of their own learning" [18].

Reactivity is omnipresent in computer games because it is one of the primary tools designers and programmers use to guide users during the gaming process. Consider this simple example: playing a tabletop version of Solitaire for the first time. If the player does not have a good grasp of the game's rules and makes a mistake (places a card in an invalid position) he will not be aware of his mistake unless someone else points it out. Now replace the tabletop version with a software version of the same game. The rules did not change, but now if the player makes the same mistake, the game can react to it by notifying the player of that. In fact, developers can have checks for all possible invalid game states in place to prevent players from making any kind of mistakes. This is a great teaching tool because it does not require prior experience with the game from players. The game can be successfully completed by trial and error, simultaneously teaching players its rules. This principle could be utilized in educational software to teach certain aspects without requiring learners to read large volumes of text.

Inference is one of the primary functions by which humans receive information, especially in cases where "sensory data are scanty or ambiguous, or incongruities occur in perceptual situation" [19]. Naturally, inference plays a major part in the process of non-linguistic learning. Human communication is characterized by its "intentionality and cooperative processes, not by language alone" [9]. A structure of such intentions embedded into communication "makes it possible to infer meanings beyond explicitly conveyed language" [9]. There is a plethora of research data supporting the idea of the effectiveness of visual "displays" in promoting learning. Cognitive processing has several forms (Mayer's "select-organize-integrate" model) that can be leveraged "to

[2] The process of gauging the amount of resources software applications require to run, usually employed to detect deficiencies in resource management.

afford different kinds of inferences" by using visual displays [17].

In this context selection refers to focusing on specific information in an instruction. It can be promoted by driving attention to one part of a message and omitting non-critical information. Organization refers to inferring relations between pieces of information. It is especially important for memorization since associations between new data and prior knowledge "facilitates retrieval from long-term memory", this process is guided by integration.

To summarize, significantly reducing or completely eliminating the reliance on text should be the primary objective of computer science educators, as this paper argues, and the methods described above can be used for that with great effectiveness.

V. EXISTING RESEARCH

There are several academic examples of note that show work being done on the subject of teaching programming to children using visual media. Experiments conducted with middle school children by Adele Goldberg et al. at Stanford showed promise initially [20]. Using early implementations of the Smalltalk programming language scientists attempted to ingrain basic programming concepts into children's minds. In 1973 Alan Kay, the original author of Smalltalk, joined Goldberg's team of researchers to develop new approaches to children's computer education using bleeding edge computer software technology. He proposed Smalltalk as the basis for further educational experiments. To Kay it was apparent that "the children could [...] draw pictures on the screen, but there seemed to be little happening beyond surface effects" [20]. At the same time he recognized that teaching concepts of object-oriented design to children would be a dead end, since it was still a fresh idea alien even to seasoned programmers. An alternative approach that utilized a visual language for communicating concepts had to be developed. Kay called it *literacy*, "the content of this new kind of authoring literacy should be the creation of interactive tools by the children" [20].

During the experiment each group of students consistently had a few children that excelled at their tasks and managed to produce working software prototypes (albeit very limited in scope and features): a painting application, object-oriented illustration system, music score capture system, circuit design system, to name a few [20]. After several groups of children had gone through the training, researchers made a discovery that each group's progress didn't generalize well at all. That is to say, only a small number of children would produce something significant at the end of the course, while 80% of the children would struggle, because the knowledge wouldn't come to them naturally. Another compounding effect was the children's background, "children were chosen from the Palo Alto schools (hardly an average background) and we tended to be much more excited about the successes than the difficulties" [20]. The overall success of any given child wouldn't "extend into the future as strongly" as Kay and Goldberg had hoped [20].

What had been happening was Kay using his existing knowledge to generate ideas that were far from intuitive for beginners, in actuality students were struggling to see the links between going from one set of instructions to the next in Kay's examples. Kay later concluded, "[it] isn't enough to just learn to read and write. There is also a literature that renders ideas. Language is used to read and write about them, but at some point the organization of ideas starts to dominate mere language abilities. And it helps greatly to have some powerful ideas under one's belt to better acquire more powerful ideas" [20]. This is where he agrees with Elliot Soloway [21] in that the success for most students depends not on any particular features of a programming language, but on how easy it is for a beginner to *be able to think in the same way that good programmers think*. Programming concepts should be learned gradually over a prolonged period of time in order to build up the structures that provide forward-thinking capabilities required to design software solutions. Kay calls this ability *fluency* – the process of building mental structures that hide "the interpretation of the representations" [20], similar to how people that know how to read don't perceive written text as symbols but rather as the direct meaning behind the text.

VI. EXAMPLES

This part will describe a software product that conforms to the characteristics and methods listed above, very effectively employing them to promote non-linguistic learning. It is worth noting that this example was not built as dedicated educational software, which is interesting in itself. The best work on promoting computational thinking using innovative approaches is being done outside of education[3], while the opposite would be expected.

Baba Is You[4] is a computer puzzle game in which puzzles are solved using linguistics. The rules of the game are not explained through textual descriptions, instead they are presented for each puzzle as objects that form short phrases that define the relations between objects on the screen, and are a part of the playing space (see fig. 1).

3 https://www.zachtronics.com/zachademics/
4 https://hempuli.com/baba/

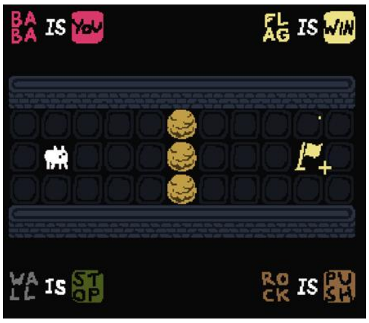

Figure 1. First puzzle in the series, all basic elements on screen

The text “BABA IS YOU” in the upper left corner indicates to the user that an entity named Baba is under his control, it is the player’s means of interacting with the world. “FLAG IS WIN” hints at the winning condition (get Baba to the flag to win), “WALL IS STOP” informs the player that the playable character cannot go through wall tiles. “ROCK IS PUSH” indicates to the player that tiles that look like rocks can be pushed away. But it is not until the second puzzle that the players realize, there is a lot more to the problems presented by the game to them (see fig. 2).

Figure 2. Starting conditions (left); winning condition satisfied (right)

Baba is surrounded by walls. The phrase “WALL IS STOP” is placed right next to the player’s character. This is a subtle hint at how subsequent puzzles are designed. Baba can interact with everything on the screen including phrases that describe the rules. And those phrases can be changed by using Baba to push parts of them away. Altering the phrase in such a way will change the rules governing the current puzzle. For example, pushing either “wall”, “is” or “stop” in that phrase will make all the walls on the screen non-corporeal allowing Baba to reach the flag on the other side of the wall. Since there is no limitation on where you can push different elements within the confines of the screen, it is possible to push “win” in order to form the phrase “WALL IS WIN” (see fig. 3).

Figure 3. Changing rules to make “wall” the winning condition by spelling “wall is win”

This will expectedly allow the level to be completed by placing Baba on top of any wall tile, revealing an alternative solution to this puzzle. Players are taught another important skill in this instance: thinking “outside the box”, which is a particularly important skill for a programmer to have, because every problem in programming has multiple viable solutions. Some solutions are more effective, while other solutions – cheaper etc. But all of them are valid. The way *Baba is You* teaches this and other aspects of computational thinking without saying as much as an entire sentence, is ingenious.

Games are inherently suited for use in education. All higher animals engage in some form of games for learning purposes in the early stages of their lives [22]. Experience gained during such activities is applicable in real life. However, the same cannot be said about most computer gaming software. Games are well suited for learning in context of specific forms of knowledge, where games fare much better than other forms of media. Knowledge that is inherently hard to verbalize makes a good use case for educational software. Software that models systems is particularly good at teaching computational thinking, and excels at teaching programming. It enhances acquisition of skills like empirical validation, technical intuition etc.

VII. CONCLUSIONS

Before an engineering student can learn complex abstract concepts, he must learn a programming language and how to write a simple program in that language. The traditional approach to training using text is much less effective because the student is hindered by his lack of knowledge of: the relation between hardware and software, programming languages, basic constructs (algorithms), core paradigms etc. The use of specialized software allows for teaching those concepts to students without any prior knowledge, in parallel to other established methods.

Interactivity is one of the most important properties of computer software. It enables software to react to the actions of the user in ways that allow the user to gain experience and knowledge non-linguistically. Each interaction can be viewed as a self-contained experiment: the user thinks of a desirable outcome, tries an action, looks at the reaction, evaluates the outcome and repeats the loop if necessary. Coincidentally this mirrors thought processes that occur when completing programming tasks. Contemplating an idea, implementing it in code, launching it on a computer, the computer instantly reacting to it. If it reacts in an unexpected way it is seldom not a teaching moment, it enables *learning from expertise*. The user learns something new about the programming language being used, about the way the computer processes information, about their own thought process. These characteristic properties of computer software could be harnessed for educational purposes.

Software engineering is an applied science. It requires expertise in multiple domains. “Expertise is an ability acquired mostly by experience” [3]. However, it is worth noting that this effect is not uniform with learners across all levels of experience. “When assessing which agent, either the instructor or the learner, was most effective, we observed mixed results in the literature, [...] novice students may learn better under instructor-managed conditions, whereas more expert students may learn more under learner-managed conditions” [23]. Software has the means to provide education with the tools required for enabling a richer learning experience, circumventing traditional text-heavy forms of teaching, providing more effective methods of learning concepts that are essential for developing computational thinking, that at the same time are hard to verbalize. However, it is unclear to what extent non-linguistic new forms of teaching would be more effective. There is still need to accumulate empirical proof to quantify the assumed positive effects of non-linguistic learning, but that would have to be the subject of a future study.

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The impact of the COVID-19 pandemic on the financial education of primary school students

Lidia Sabău [1,2,3], ORCID: 0000-0002-2858-7232
[1] „Ion Creangă" State Pedagogical University of Chișinău, PhD School „Education Science", Chișinău city, Ion Creangă 1 street, MD-2069, www.upsc.md
[2] „Vasile Alecsandri" University, Calea Mărășești 157 street, Bacău, Romania, www.ub.ro
[3] „Mihai Drăgan" Secondary School, Logofăt Tăutu 7 street, Bacău, Romania, www.scoalamihaidraganbacau.com

***Abstract*— The global COVID-19 pandemic of 2020 has exposed both the underdevelopment of education systems around the world and the level of financial literacy – both of the population and students. This aspect brought back to the fore the importance of using ICT in school, in the actual act of teaching financial education, as education systems were preparing for the transition to online education due to school closures. This critical research provides an overview of the challenges brought by the pandemic: the problems faced by teachers in schools in the form of online teaching, the fundamental change in teaching methods during the pandemic, and the adaptation that both teachers and students must adopt, alike. This article will also provide some recommendations for integrating digital technology into financial education learning environments in the post-pandemic era.**

Keywords*— *COVID-19 pandemic, financial education, digital technology, teaching and learning, global pandemic

I. Introduction

Regarding the application of information and communication technology (ICT) in the field of education, much research has been carried out, especially in the last two decades, since the Internet has taken on greater importance, with the rapid advancement of technology, but also the presence of the virtual in the real.

Information and communication technologies have had a major impact on the teaching of compulsory and optional subjects - such as financial education in primary education, which is the subject of our research. Thanks to technology, learning financial concepts takes a new dimension, arouses more interest among students, and stimulates learning, memory, thinking, and language skills, especially in management, money management, savings, expenses, wants, and needs.

In recent years, digital technologies have facilitated active and interactive learning, promoted access to information, and brought to the attention of the entire educational community their potential to make learning an easier, faster, but also more dynamic process. Nowadays, the use of digital technology is present not only in education but also in many other aspects of our social life, especially in the financial sector, due to the new global coronavirus pandemic (COVID-19).

Under certain conditions, the presence of social sites (social web) can create the conditions for a good collaboration between teachers and students, who simultaneously form active social and learning environments, as well as new opportunities for interaction based on a diversity of opinions [1].

In teaching and learning, the use of digital technologies has made it possible to teach and deliver financial programs to students even when schools have been closed. However, since teachers have had to deliver their lessons online, the question is their adaptability, their ability to deliver the curriculum in a pedagogically relevant way, to continue to promote quality learning during times of general society, such as a pandemic.

We emphasize the importance of teachers' teaching methods and tools and their impact on student education, but also the adaptation of teachers and their tools to online education because there has been a transformation in the act of delivering financial education due to the COVID-19. The key challenges teachers face in teaching are precisely the most effective ways and methods to adopt to maintain students' interest and curiosity in learning, especially choosing an effective way to convey simpler and more complex concepts to students or abstract (such as those in the field of economics).

Finally, the document makes recommendations on integrating digital technology in the post-pandemic learning environment for the financial education of elementary school students.

II. DIGITAL TECHNOLOGY IN FINANCIAL EDUCATION

In this article, the author notes that digital can be seen as an extension of information and communication technology (ICT). Digital technologies are computerized electronic devices that generate, store, or process data from a variety of sectors, including finance, to facilitate and facilitate the operation of people more efficiently.

The world of finance today is mainly done in the online sphere: databases, financial transactions, payments, purchases, digital documents, virtual currencies, online transfers, etc. Mobile phones, tablets, and the Internet are common examples of digital technologies, all of which serve society, but all require prior training to use them effectively.

The use of digital in education in general and financial education, in particular, is not new. Research on the impact of digital technology in education, especially teaching and learning, has been conducted since the internet became more widespread and accessible to educational institutions and the general public. There have been and continue to be discussions about the effectiveness of technology in transforming instruction, as well as in improving student learning at all levels and in all disciplines. Thus, in 2018 it was stated that „digital technologies succeed in recreating an ecology, learning conditions close to natural ones, those that normally predispose to authentic learning experiences" [2], following as in 2020, amid the pandemic of COVID-19, the Council of the European Union to conclude that „in the long term, artificial intelligence will amplify the effects of the digital transformation of societies, potentially offering new promising opportunities for learning, teaching and training in the future" [3].

Therefore, the pandemic facilitated the wider use of online financial instruments: online purchases and payments, money transfers, financial information over the Internet, and access to banking products without going through a bank. Digital technology is involved in the conversion of methods teaching methods by eliminating the disadvantages caused by different teaching styles [3]. Several researchers, including Utami et al. [4] found that digital technology as an application is effective in improving learning in some subjects. Financial education has made great strides in this respect: more physical activities have been moved online, more students can participate in real-life financial education activities, a wide range of Educational apps available, and more. Digital financial education has been launched, the teaching-learning-assessment process has been digitized - thus saving physical resources. Financial education is therefore more accessible to students.

Thanks to technology, they no longer need physics textbooks or special notebooks, and the transmission of information and the lessons themselves become much more interactive. However, published reports show less promising results. For example, in 2015, before the pandemic, the Organization for Economic Co-operation and Development (OECD) reported that it had evidence that digital technology had no impact on improving educational outcomes in partner countries. Even researcher Manfred Spitzer disagrees with the digital version of education because of the „increasing inability to use and control mental abilities to their fullest extent", leading to a loss of consciousness control [5]. Here, supporting the use of digital for an effective teaching action is always controversial. In contrast, in March 2020, education expert Andreas Schleicher said that „those from privileged backgrounds will find their way through closed school doors to alternative, subsidized learning opportunities parents are supportive and willing to learn; disadvantaged people will remain excluded if schools close" [6], meaning they prioritize financial resources when implementing digital in education. Instead, let's remember that technology involves both spending and investment.

Contrary to all sound arguments for or against the effectiveness of technology in education, the global pandemic of 2020 has forced all education systems around the world, at all levels, to adopt technology as an alternative to traditional teaching-learning methods, so that education does not become interrupts, to have a continuity, by maintaining educational activities, including for financial education in primary school.

Regardless of the will of the actors involved in shaping student behavior, the 2020 pandemic has mobilized resources from and within education, so that the educational process can continue. Financial education was available to elementary students even before the pandemic, in physical form, with handouts, textbooks, workbooks, and file support. Online schools have used presentations, digital media, and meetings with experts - digital technology makes accessing this type of education easier.

A. *The impact of the pandemic on financial education*

The global COVID-19 pandemic in 2020 has changed the world, leading to the collapse of state-owned economies, the collapse of entire industries, and tremendous transformations in society, and within the family, but there are also significant changes in education. People's lifestyles have changed dramatically, regardless of their nationality, education level, income, or gender. New ways of living in society have emerged - social/physical distancing, distance learning, significantly higher use of food delivery, and video products. Financial education has changed in terms digitized and made available online, can access this education for many people at the same time. Some educational activities in the financial sector are even carried out with multiple classes at the same time.

The way the education system delivers education at all levels has also undergone dramatic changes. School closures due to COVID-19 have caused significant disruption to education in general schools. According to the United Nations Educational, Scientific and Cultural Organization (UNESCO) (2020), approximately 1,6 billion children in 194 countries have been affected by these disruptions. Schools at all levels have quickly switched to online education using digital technology, which has had a great impact on the education industry [7].

Having digital devices for all students is a big challenge from a financial point of view, but this detail is very important because it thus offers the possibility that education can be accessed by all subjects of the training activities. The pandemic forced school systems in many countries around the world, even if they were not prepared or had the financial resources to do so, to act financially urgently to find viable alternatives to the traditional curriculum that was no longer being carried out. So, the use of distance learning alternatives using the online environment and digital devices have emerged as viable options in order not to be obstacles in the way of students' training.

Quickly, the use of digital technologies such as video conferencing tools (such as Zoom and MS Teams), learning management systems, and online learning materials became the new standard in education. Thus, the use of the term „digital learning" has become a topic of discussion in the educational community.

According to studies carried out by various world organizations, access to digital learning was conditioned by various factors: access to electricity, access to the Internet, the existence of electronic devices in a household so that every member of the family has access to education (Figure 1) [8].

To these are added the inevitable dangers of the online environment: the decrease in the quantity, quality and yield of learning, the discrepancy between the lack of digital equipment and skills and what can be achieved in reality, discrimination in the digital world, students' access to the virtual world through the Internet [9].

The society was not prepared for such a challenge, being forced to adapt quickly, on the fly, so that the training of the students would not be endangered.

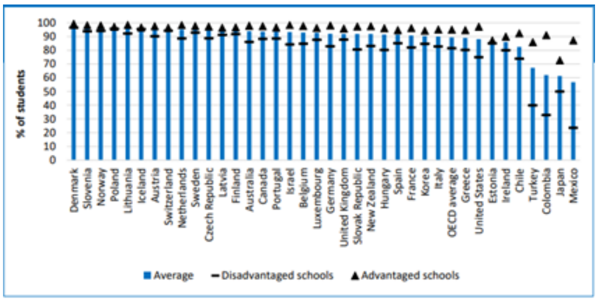

Figure 1. Access to access. Percentage of students who have access to a computer that they can use for schoolwork

Pandemic times have affected the financial education of adults and children by the unpredictability of various and unexpected situations from day to day. The imposition of security restrictions has certainly led to better thinking about how to spend money, a financial balance has been applied to the unpredictable, and unknown online payment tools have been introduced is used, a critical reflection process has taken place and an analysis of personal financial circumstances, family priorities, financial /investment costs have been taken into account, a clearer distinction between needs wants and needs. In addition to the impact on formal education, the COVID-19 pandemic has also had a major impact on informal family education.

Because education is done online using existing technology, parents have a certain role to play in their children's learning at home. Parents will need a mentor for non-formal education programs, the main needs of these parents are related to the need for knowledge to help their child learn at home, their numbers accounted for 80,43% [10]. Since parents are financial role models for their children, children learn from their parents about family spending, savings, shopping lists, and a clear distinction between wants and needs. The results of existing financial education in training people before the pandemic can be seen in the organization of individual households throughout the pandemic.

B. Financial education teaching practices during the COVID-19 pandemic

During the pandemic, to avoid interruptions, educational institutions had to keep education running, so they had to adapt quickly to the situation [11]. As social distancing became imperative, teachers adapted their teaching methods and replaced them with pre-scheduled online meetings to teach the school curriculum. Later, morning reports were conducted in the virtual classroom, inviting expert speakers to join via video conference [12]. It was easier to invite specialists from the economic environment to the classroom, as physical travel was no longer necessary. So, at the heart of all this is the use of digital technology. Thus, teachers had to adapt quickly to the use of online digital technology, whether they liked it or not. In other words, they had to do this action, to adapt to new concepts and pedagogical ways of teaching, for which they may not have been trained. This, then, raises several questions about the digital utility and effectiveness of the technologies: How have they been implemented by teachers? How prepared were teachers to move from face-to-face to fully online delivery? What are some of the challenges found? What kind of solutions were adopted?

In other words, COVID-19 has exposed many inadequacies and inequities in our education systems [13], but also the fact that some financial education activities can take place more easily in the virtual environment.

It can be easily anticipated that teachers could not comfortably carry out their regular daily teaching activities in an online environment. It was a huge challenge to maintain established relationships with students in the classroom due to the loss of direct contact and lead time that students would have had in their physical learning activities. It is not just about delivering the program using an online platform, but significant challenges. The biggest challenge, acknowledged by teachers, was keeping students interested and motivated.

Students from marginalized groups who do not have access to digital learning resources or lack resilience and commitment to learning on their own are at risk of falling behind [Idem]. Lacks or inadequacies in digital technology have hindered learning more or less. However, the educational resources in the online environment meet the students, helping them to go through the subject at their own pace. Even so, many teachers found themselves in a situation where they had to redesign their learning activities so that they fit the learning needs of their students. However, they did not feel they had the training to do this effectively. According to the OECD, around 60% of teachers surveyed in partner countries reported a high need for training in the use of ICT / digital technologies. Certainly, this requires calling in professionals as well as continuing professional development programs in teaching through digital technologies.

III. POST COVID-19 CONSIDERATIONS REGARDING FINANCIAL EDUCATION

The COVID-19 pandemic has exposed deficiencies in education systems, one of which is preparing teachers to use fully online curriculum delivery at any grade level, in any subject, including financial education. With the pandemic, it has been established how important digital technologies are in the teaching-learning process. Digital technology is not only changing the teaching and learning methods of education in general and financial education in particular, but it can also change the role of teachers from transmitters of knowledge to coaches, mentors, and evaluators [6]. Thus, teachers need school- and system-level support as well as professional training in this area more than ever.

Teachers must participate in continuous training courses constantly to be able to innovate in educational activities, as well as to adapt to unexpected changes or transformations. Therefore, teachers and institutions need to prepare and improve their skills to cope with the changes in the education system after the COVID-19 pandemic. As it was done, for example, in one of the universities in Vietnam, in terms of e-learning infrastructure, „we are preparing for technological advances in our modern global development, and individuals will also remain resilient to social challenges, as is COVID-19” [14].

This is to ensure that the design of teaching and learning through the use of digital technologies is in line with pedagogical practices. Teachers must avoid what Teräs et al. [11] pointed out in their paper, that „some forms of online learning are criticized for not following pedagogical principles and good practices”. In other words, teachers should think first about the best pedagogy, especially when planning the online delivery of educational activities. Support in the home learning environment is also important.

Within the family, a certain working atmosphere must be created to ensure at home an environment conducive to the online education process, and to facilitate the development of a more intelligent generation with good character, both in the eyes of parents and in the eyes of society [15]. Parents and homeschoolers need to be familiar with technology, and electronic devices to help children in the learning process. It wouldn't be bad if the schools got involved in initiating some community development programs, programs that would involve the „home teachers”.

This is to provide effective guidance if the student is stuck in learning due to various reasons related to the technology they are using. Indeed, success in student education can be achieved if the three responsible persons work together in this process. The three responsible persons are the family, the school, and the community [16]. The pandemic has heightened the importance of schools and communities working together to maintain student well-being and engagement in learning.

Schools need to actively engage in research to continue to develop, improve, and establish effective practices in using digital technology for teaching and learning. With that, a school should focus its efforts on developing its online and distance learning infrastructure to improve system accessibility and reliability. The process of developing the capacity of students and teachers to learn and teach in different ways, to enhance the online learning experience similar to face-to-face communication, should continue. It can be said that learning is largely a social enterprise. Therefore, teachers need to emphasize the priority of developing and maintaining relationships in the online environment. Not only knowledge, and skills but also attitudes and character development must also be developed during the learning process, especially during the COVID-19 pandemic and post-pandemic.

Intania & Sutama [17] explain that: (1) the purpose of education in training students is concerned with promoting the good, an achievable aspect of their social life; and (2) in the age of the COVID-19 pandemic, the mission of education is to motivate students to learn the subject independently, but also to develop in students a responsible attitude towards the tasks assigned to them by the teacher received in online training activities. If teachers are not trained in ethics, character, or values education, they will not be prepared to teach these areas themselves [18]. This can be achieved with pedagogies that promote connectivity (relationship teaching), inclusion (filial teaching), equity (cognitive and reflective teaching), and voice (teaching dialogue) [19].

It should be noted that the considerations presented above are based on the assumption that online digital technologies are available to all teachers and students. For systems that are not minimally equipped to make digital technology available to all in the education system, they must reflect the role of the education system in promoting societies capable of progress, especially technological progress.

Furthermore, an effective future response depends on foresight and preparation. The following set of recommendations are designed for possible contexts of unlimited access to digital technology:

- During the financial education classes, it is good to take into account the physical size of the class, both for the safe conduct of activities and the organization of a „financial zone” essential for safety (depending on the availability of staff, the size of the class and the availability general);
- In the case of larger collectives, they can be divided into smaller groups, and team activity is recommended in practical financial organization activities: expenses, investments, financial specialists, etc.;
- Applying the role-play method in the classroom, both face-to-face and online, so that, through play and disguise, students have various tasks in financial education learning contexts;
- Use existing open educational resources or improve existing ones so that they are useful in teaching financial concepts and achieving the objectives proposed in the didactic activity;
- Updating owned digital devices to facilitate teaching-learning activity;
- Giving priority to pedagogy, regardless of the variant of the teaching-learning activity of financial education - the curriculum, methods and pedagogical strategies are permanently applied;
- The use of physical materials, even if the activity is carried out online, because it offers concrete learning support, regardless of the Internet connection;
- The involvement of parents and "home teachers" because they can provide the necessary support to the training activity in the absence of the school teacher and can motivate the student to learn, but also to participate actively in the lessons;
- It is advisable for the teacher to have an education focused on equal opportunities, this means adapting the activities according to the limited access to technology of some students or their access to electricity (requires devices);
- Constantly getting feedback from students, so that the financial education being taught is a subject that students can understand, with appropriate language, age-appropriate concepts, but also with concrete real-life examples of the world of money;
- Due to unforeseen changes, vigilance, verticality, and adaptability, but also innovation and improvisation are valued in a teacher - all to create learning plans for students.

IV. CONCLUSIONS

The COVID-19 pandemic represented a challenge for the whole society, in all aspects of life, with a significant impact on education and the training process of students. Financial education must continue, face-to-face or online, with physical or digital resources, so that key student skills remain a priority in instruction, regardless of its form. The teachers who found solutions, who adapted quickly, who always saw the child's supreme interest, despite the vicissitudes of the time, are to be appreciated. The students were supported, motivated, and encouraged not to give up school, even if it was conducted online.

Therefore, education systems need to provide teachers with the necessary training and support for the use of digital technologies, especially online platforms, to ensure that they can adhere to pedagogical principles and best practices for effectively engaging students in learning.

Digital technologies have proven their importance during the COVID-19 pandemic, especially in education. Thus, there is a need to rethink good pedagogies, as well as how digital technologies could be integrated into supporting students and motivating them to learn. Since learning is a social endeavor, it must be considered to involve a change in the social aspect of learning through digital learning environments. Therefore, teachers are challenged to think about how, in an online environment, **connection**, **inclusion**, the facility to maintain **awareness** and **reflection**, and **dialogue** could be maintained in providing students with experiences or even learning contexts that -would achieve in traditional face-to-face learning environments. When this is achieved, we could guarantee that teachers will have the ability to support the well-being of the student, to support their involvement in the act of instruction, and motivate the student in learning - both during pandemic times and similar ones.

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