Abstracts

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The beginnings of cybernetic modeling of biological systems in the 1970s

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The paper will be a subjective description of what happened in the 1970s, because the author did not search for publications by other authors, but presented what he was either doing himself or with which he had direct contact. Perhaps someone had dealt with cybernetic modeling of biological systems in Poland before - but for me it started with my thesis, prepared in 1970 and defended in early 1971. The first models were built as electronic systems from separate components, but then it was time for computer simulations. The paper describes the difficulties that initially arose when trying to develop cybernetic modeling of biological systems at AGH as a technical university. Later, however, these difficulties were overcome and numerous publications were published on modeling the human auditory system (in order to build a system for robotic voice control) and then also other biological systems. Images of many publications that were created in the 1970s will be presented, and the first MCSB conference, which was of great importance in the development of cybernetic modeling of biological systems in the Krakow scientific community and throughout Poland, will be discussed. The presentation of the paper will be in Polish, because all the presented publications from the 70s are in Polish, but the essential elements of the presented issues will also be commented in English.

Sensors and Systems for Health and Behavior Tracking in Daily Living Environment

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The lecture presents concepts and paradigms of physiological and behavioral sensing in human daily living environment. It starts with specifying benefits and challenges the daily tracking may have to the human and specifies the potential target users of such systems. Next it reviews sensors and their characteristics and sensor networks to track selected physiological parameters and behavior of the subject. It provides background for services based on 'Internet of Medical Things' taking in consideration all requirements concerning medical devices such as information safety and integrity. In the second part the lecture presents behavioral record types and forms and provide examples of approaches to identification and prediction of human actions. This is considered in aspect of potential risk factors in everyday living, lifestyle control and profiling and behavior-based diagnostics of functional health. The lecture also presents selected own achiekomendavements of the author's group in the field and examples of topics for further research.

Computer modelling of medical and healthcare curricula: building, analysis, mapping and optimisation in practice

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The lecture will summarise current experience, the most important activities and results together with identified pitfalls in the area of medical and healthcare curriculum mapping. Many of the achieved outputs have also had a positive influence on both technological and methodological toolkit of the MEFANET educational network covering all Czech and Slovak medical and healthcare faculties as well as other involved partners academic institutions in Europe. Future prospects of possible cooperation in terms of strategic international projects will also be presented and discussed. One particular European project called BCIME (Building Curriculum Infrastructure in Medical Education) will be emphasised. The main attention will be focused on delivering methodologies and a unified ICT platform developed for optimisation of

curricula in medical study programmes. Some of the achieved results like need analysis, methodological and technical manual, implementation of standard-compliant curriculum management system, and curriculum mapping will be presented in detail.

From Simulation to Action, from Heart to Robin Heart - short story

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Surgery is a specific type of medical activity, assuming the use of direct physical methods of intervention, in a place damaged by illness or injury. In 1997, the team of Foundation of Cardiac Surgery Development FRK (Fundacja Rozwoju Kardiochirugrii im prof. Zbigniewa Religi) led by the author started the first project in Poland (financed by National Science Commitee), a program of **simulation** of cardiac surgery procedures to optimize the operation effect. The surgeon often makes decisions in conditions of external uncertainty (lack of sufficient knowledge about the operating environment) and internal (lack of knowledge and experience). The area of uncertainty can be reduced by using advisory and training systems and by planning using computer simulations and physical modeling. These are the tools used in making decisions. A robot is an executive tool type that can use all information directly (autonomous robots) or indirectly (in telemanipulators between the surgeon and the tool, we have a computer). Robotics, as the technical discipline, deals with the synthesis of certain functions of the man by means of using some mechanisms, sensors, actuators and computers. The purpose of surgical robots is to improve efficiency, repeatability (standardization) and to reduce the invasiveness of surgical procedures (extension of the group of patients for whom successful surgical intervention is possible). The initiated by the author project results are the family of **Robin Heart** robots and universal mechatronic tools series Robin Heart Uni System for use during minimally invasive surgery on the heart and other soft tissues. Coming out with the proposition of a new tool, a robot, we needed a new way of communicating with them. FRK conducted pioneering works in Poland in the field of using virtual space technology in medicine. We were the first to buy software (EON) enabling the creation of an interactive operating room to be able to plan and train the use of new tools - surgical robots. Using the virtual reality technology, an interactive, fully controllable operating room model equipped with various Robin Heart surgical telemanipulators was made at the FRK. Virtual reality technology is the perfect language for communication with surgeons and the field of testing innovative solutions.

FRK is a pioneer in Poland in the field of medical robots: heart prostheses and surgical robots. Designing medical robots is an extremely difficult and fascinating task. Especially if the control system element is a human and the object of operation is another human. Currently, we have focused our attention on the development of force feedback and the improvement of our telemanipulator's distance operation.

The history of the Polish surgical robot (2000) began with the simulation and modeling of the effects of cardiac surgery. The robot was created as a natural extension of the idea of planning and programming operations, because it is the only tool that can directly and practically use it. And why did we model the cardiovascular system? Of course, as a conceptual support for the design work of heart prostheses. When prof. Zbigniew Religa performed the first successful **heart** transplantation (1985), it was necessary to provide the waiting people with a chance to survive in good condition for surgery, i.e. an artificial heart. We have built and implemented a life-saving, heart support pump (1993). This is, of course, one version of the answer for the question "why?". Such "Feynman's sum over histories" constitutes the present state of affairs. Now we are taking the next steps towards the future with equal courage.

The key to modern medicine is the increase in productivity. It cannot be done without automation and robotics – from decision-making processes to therapy and rehabilitation. After telecommunications progress – sending INFORMATION at a distance, it is time for distance transmission of **ACTION**. Robots are necessary for this. Therefore - let's do the robots!

The integrative model of brain function in perspective of cortico-subcortical loops

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The evidence of the anatomical and physiological brain research supported by clinical data and theoretical models suggests there are at least five loops related to motor, emotional cognitive and visceral functioning control. The cortico-subcortical loops model explain integrated realization of visceral, motor, emotional, and cognitive functions. All these functions are involved in sensory processing, perception, as well as higher-level mental functions like decision making. This perspective is explain not only physiological processes of the central nervous system but also mental and neurological disorders such neuropsychiatric disorders, affective disorders, schizophrenia, addictions.

On the way to the total-body J-PET scanner

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The Jagiellonian Positron Emission Tomograph (J-PET) is the first prototype of the PET scanner built from plastic scintillators. The J-PET consists of 192 detection modules, arranged axially in three layers forming a cylindrical diagnostic chamber with the inner diameter of 85 cm and the axial field-of-view of 50 cm. An axial arrangement of long strips of plastic scintillators, their small light attenuation, superior timing properties makes the increase of the axial field-of-view relatively easy, opening promising perspectives for the cost effective construction of the total-body PET scanner, as well as for a construction of MR and CT compatible PET inserts [1 - 3]. The electronic system probes scintillation signals in the amplitude domain at four different thresholds. Thanks to the dense probing of signal's shape one can recovered an energy deposition in the scintillators without the need of direct measurement of signal's charge [4].

The next prototype, called Modular J-PET (MJ-PET), maintains 50 cm field-of-view, but provides novel readout electronics based on a multi-threshold readout of each of Silicon Photomultipliers (instead of vacuum tube ones) from a 1x4 matrix, on two separate thresholds. Transition to Silicon Photomultipliers minimizes the axial size of the detection system and enables an easy to manufacture, modular design. Progress in the Field Programmable Gate Arrays field gave the opportunity to digitize analog signals immediately at the place where they are produced [5, 6]. Tests in hospitals and proton therapy centers will be much easier to perform due to the modular design as well as the possibility to expand existing, crystal based PET scanners with MJ-PET [7].

The unique trait of the J-PET technology lies not only in utilization of plastic scintillators to detect annihilation photons, but the possibility of detection of annihilation into three photons, a measurement of the positronium life-time by calculating the time between prompt and annihilation photons and the determination of polarization of photons from positronium decay [8 - 10] as well. The lifetime of the ortho-positronium could be possibly employed as an additional diagnostic bio-marker in medicine [1, 8, 9, 11].

During the talk a description of each prototype will be provided and the way in which they operate will be explained. General parameters of the scanners, from the medical physics point of view, will be introduced and compared to existing PET systems and their advantages over standard, crystal based PETs will be discussed.

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Blue-emitting polystyrene scintillators for plastic scintillation dosimetry

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Plastic scintillators are used in many applications connected with medical devices, for example in time-of-flight positron emission tomography [1], long-axial field of view positron emission tomography scanners [2] and in plastic scintillation dosimetry [3].

Scintillators absorb ionizing radiation and convert its energy into visible light via fluorescence. Purpose of this research is to find optimal fluorescent dyes combination dissolved in polystyrene matrix. Polymer scintillators were synthesized from styrene monomer in bulk radical polymerization [4]. Polystyrene was selected as a base of scintillators due to its water equivalent needed in dosimetry.

In this research one the best fluorescent compound emitting ultraviolet light is combined with a few fluorescent dyes shifting scintillators emission to blue light [5]. Emission maxima of manufactured polystyrene scintillators are in blue region of visible light (400 – 480 nm) and are close to maximum quantum efficiency of light detectors used in plastic scintillation dosimetry. Light output of scintillators as a measure of gamma radiation conversion into blue light will be presented. High light output and matching emission spectra of scintillator with quantum efficiency of light detector is needed to obtain good signal-to-noise ratio in scintillation detectors [6]. Results of this work can be used in a reconfigurable three-dimensional detector matrix for measuring the spatial distribution of gamma radiation dose for applications in the preparation of individual patient treatment plans in oncology centers.

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3D printed lightweight and modular lithium-ion Uninterruptible Power Supply for medical devices

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Advanced devices for diagnostics and medical therapy require a constant and stable power source. With their development, their complexity and the risk of damage in the event of a sudden power outage increase. The disadvantage of

commonly used uninterruptible power supply (UPS) is the heavy weight [1, 2], centralization and the need to use specially prepared rooms and dedicated electrical installations. The aim of the presented research is to prepare a safe and reliable, economic, modular and scalable UPS. Low price and modularity are possible due to the use of 3D printing technology and lithium-ion cells, which will allow the construction of UPS installed in the immediate vicinity of the protected device with capacity and power adapted to the needs of the equipment operated. Among the available technologies of chemical energy storage, Li-ion cells are characterized by the high gravimetric and volumetric energy density [1, 2]. Currently, liquid electrolytes are used in Li-ion cells, which have good ionic conductivity, but are flammable, toxic and sensitive to lithium dendrite overgrowth, which may lead to an internal short circuit and damage to a given module. For safety reasons, a much better solution than liquid electrolyte would be solid electrolytes, which would not be flammable and hazardous to the environment. Due to the fact that solid electrolytes constitute a barrier to lithium dendrites, they can also extend the working time of individual cells [3]. Currently, there is no known material that would fit well as a solid electrolyte for li-ion cells. There are several materials under development such as LISICON, anti-perovskite-type, perovskite-type, and Li3N-type materials, but they are not ready for industrial applications [4, 5]. This presentation concerns the research conducted on solid electrolytes, synthesized in accordance with the principles of green chemistry with the use of cheap, environmentally safe raw materials. For this purpose, syntheses of materials based on silicon-boron glass, sucrose and polysaccharides of plant origin were performed, and then tests were carried out in symmetric lithium cells with solid electrolytes made of them. Measurements of the ionic conductivity of lithium ions in the prepared electrolytes were carried out using cyclic voltammetry using a MULTI AUTOLAB M204 device. Electrolytes based on potato starch, corn starch and food sucrose were tested in particular. Methods of syntheses and the results for measuring the ionic conductivity of the tested electrolytes will be presented. In the second part of the presentation, an example project of a UPS for J-PET mobile tomograph will be presented [6, 7], which was designed using Li-ion cells. The proposed UPS allows to power the mobile tomograph with a power of up to 6kW for 6 hours, and to load packages between tests, which allows to power the installation using a network not adapted to such heavy loads. The use of this solution with stationary diagnostic devices will allow not only to reduce electricity costs by loading the energy storage using a less expensive night tariff, and then using the collected energy during the day, but also to install the device in a room without access to the central UPS. The 3D printing technology allows for economic production of a single UPS, while adjusting the shape of individual packages to optimally use of available space. In addition, it will reduce the cost and time needed to replace or repair a damaged package.

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Isolation of extracellular vesicles: theoretical data vs experimental data

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Introduction: Intercellular communication plays an important role in the processes that take place in multicellular organisms. Within two different communications manners (direct cell-cell contact and distant para- or endocrine communication), the transport of secreted substances via extracellular vesicles (EVs) occupies its privileged position. EVs can be transferred even to distant target cells and can directly contact with them by internalization to control or interfere with a target cell [1]. EVs are heterogeneous membrane vesicles of 30-5000 nm in size, they transfer number of biomolecules including miRNA, non-coding RNA, proteins, lipids and metabolites [2].

The main goal of this study was to find optimal conditions to isolate homogenous population of EVs by means of differential centrifugation method. To achieve this goal, the theoretical model for EVs isolation conditions was developed and compared with results obtained experimentally.

Methods: Theoretical model used both the technical parameters of the rotor (i.e. rotor inclination angle, tube diameter), physicochemical parameters of the solvent (viscosity and density of conditioned medium) and the EVs density to calculate sedimentation efficiency. In order to simulate EV characteristics, Monte Carlo method was applied; sedimentation efficiency was calculated according to Livshits' model [3] incorporating our experimental conditions.

The EVs were isolated from conditioned media obtained from the endothelial immortalized cell line TIME. Medium was conditioned 48 h in high confluency of cell culture, collected and centrifuged at 2000xg for 30 min to sediment cells and apoptotic bodies. Ectosomes were isolated by centrifugation at 3000-18000xg, then the supernatant was ultracentrifuged for 90 min at 150000xg to isolate exosomes. EVs were analyzed using TRPS, flow cytometry and transmission electron microscopy (TEM).

Results: The theoretical data showed that centrifugation at 12,000xg allowed to obtain ectosomes, nevertheless 18000xg was the limit above which the sedimentation efficiency of ectosomes was independent of the physical properties of EVs (density) and solvent (viscosity). Centrifugation above 18000xg would be associated with strong reduction of exosome concentration during isolation. Using such centrifugation force, the purest exosome population was obtained, by cutting off the EVs above 100nm.

The experimental results showed that centrifugation at 12000 x g and 18000 x g allows to obtain the population of ectosomes closest to the theoretical model.

Cytometric analysis and analysis of TEM images showed cross-contamination of the EV populations and aggregates formation. Measurement of the Zeta-potential indicated the strong aggregating properties of exosomes.

Conclusion: Obtaining pure homogeneous subpopulations of ectosomes and exosomes is awkward due to small differences in size and density of different populations of EVs. Additionally, strong aggregating properties (in the case of EVs isolated from endothelial cells) interfere the isolation protocol.

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Quantification of β-cell-derived EVs using the high sensitivity flow cytometer – the swarm effect study

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Cells can communicate with neighbouring cells or with distant cells by sending out signals composed of single molecules or by complex packets carried with a specific of nucleic acids, proteins, and lipids, called extracellular vesicles (EVs). EVs are membrane-derived structures that include exosomes, macrovesicles, and apoptotic bodies. In literature it was shown that EVs are released under normal physiological conditions, as well as in the pathogenesis of vascular, haematological, neurological, and autoimmune diseases [1]. Quantifying and characterizing EVs using flow cytometry in a reproducible

and reliable manner is difficult due to their small size (exosomes diameter - 30 nm to 100 nm, ectosomes - 100 nm to 5000 nm) and often appearing swarm effect. The experiments were performed using EVs released into the culture medium by hypoglycaemic pancreatic β-cells and labelled with ExoGlow™-Protein EV Labelling Kit Green (System Biosciences). EVs analysis were performed using Amins® Cell Stream® Flow Cytometer (Luminex), which enables high-throughput flow cytometry with increased sensitivity for detecting small particles. Most instruments measure light scattered by the cells at right angles to the laser beam (side scatter, SS) and light scattered in a forward direction (forward scatter, FS). FS is used to detect the size. SS is usually used to decide regarding the granularity and complexity of the cell. The FSC to SSC histogram allows to identification and definition of the population of EVs. A series of sample dilutions was used to eliminate the swarm effect. It has been shown that a high concentration of samples equal to or above 100 million events per ml causes the swarm effect. In this case, the best analysis of the sample was performed by the cytometer at a 100x dilution. The concentration of EVs in the initial sample labelled with the CD9 PE vesicle marker was high, confirming the presence of EV in the sample. Summing up, these unwanted effects could only be observed and controlled by performing serial dilutions and analysing plots of light scatter (FCS/SSC) and fluorescence parameters.

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A simulation study to assess influence of Body Mass Index on scatter fraction in the Total Body J-PET

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Positron Emission Tomography (PET) is one of the most technologically advanced diagnostic methods which allows for non-invasive study of physiology, metabolism, and molecular pathways in the human body [1]. It plays a fundamental role in medical diagnostics, treatment monitoring, oncology, cardiology and neurology. However, the utility of the widely known PET tomographs is restricted mainly by their short longitudinal coverage either to only single organ imaging or bedmotion whole-body scans [2]. Moreover, their low sensitivity forces to use long imaging times and high radiation doses. The need for a system, which would address these drawbacks resulted in the creation of substantially extended scanners called Total Body PET tomographs [3]. The construction of the first Total Body PET (TB PET) systems such as 70-cm-long PennPET Explorer, 1-m-long Biograph Vision Quadra and 2-m-long uEXPLORER, has been completed recently [4-6].

First clinical studies have shown their large potential to expand and improve the molecular imaging technique by not only reducing the whole-body scan time or lowering of radiopharmaceutical dose but also by enabling simultaneous and dynamic multi-organ imaging. By increasing the geometric coverage they improved system sensitivity up to several dozen times, and one organ imaging sensitivity several times [7]. Despite many advantages, the introduction of TB PET tomographs in the common clinical practice poses an economic challenge due to its high construction cost.

Since 2013, there is an ongoing research to develop a novel PET system called JPET (Jagiellonian Positron Emission Tomograph) by the J-PET Collaboration at the Jagiellonian University in Cracow [8-9]. Unlike other scanners J-PET utilizes long, axially arranged organic scintillator detectors readout on both ends with silicon photomultipliers. By lowering the cost of scintillators and reducing the number of electronics, such an alternative approach enables a cost-effective construction of Total Body PET tomograph [10].

The extended axial field of view (AFOV) guaranteed in TB systems offers considerable improvement in count-rate performance. Nonetheless, this factor consists of not only counts contributing positively to the final image reconstruction

but also of degrading types like scattered and accidental coincidences [11]. Moreover, this enhancement is not uniform between different types of coincidences and it favors the disadvantageous types. An important metric, which can quantify such disproportion and shows the quality of the collected during the measurement data is the scatter fraction (SF). The SF is defined as the fraction of all detected scattered coincidences (events in which at least one of the annihilation photons underwent a scattering in the human body or phantom material and lead to misplacement of the reconstructed radioactive tracer position) to all detections [12].

In this simulation-based work we evaluate the scatter fraction values in four Total Body systems proposed by the J-PET Collaboration using the standard NEMA NU 2-2018 protocol and modified version of this protocol, which is more suitable for long AFOV scanners. Since in the clinical practice various amounts of radio-tracer activity can be chosen depending on the type and region of interest of medical imaging, we assess them as a function of the activity. Additionally, we investigate the influence of patient Body Mass Index (BMI) on the scatter fraction, by means of the cylindrical equivalent of the anthropomorphic phantoms. Finally, we estimate the effect of using an acceptance angle criterion on the collected data prior to SF calculation. The acceptance angle is a maximum azimuthal slope angle of lines connecting detection positions within each coincidence (so called line of responses LORs) for which they are considered during analysis and image reconstruction. This criterion allows to reject events with the longest photons trajectories within imaging material and hence the highest chance to scatter.

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Simulation study of the NEMA characteristics of the Modular J-PET

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Promising imaging performance of Positron Emission Tomography (PET) made it a suitable imaging modality for malignant lesion localization in oncology study, drug delivery, physiological studies, etc [1]. The concept of PET dates back to the 1950s and the first tomographs with clinical uses to the 1970s. Since then, many technological advancements enabled a constant search for improved systems [2].

There is an ongoing research of a new generation of PET tomographs done by J-PET Collaboration, which would be a competition to other clinically available systems. By utilizing organic, plastic scintillators as photon detectors with an axial arrangement and an innovative readout system, JPET technology not only allows for a significant decrease in the total cost of scanner but also for an accessible introduction of Total Body PET systems, which is an ultimate goal of the Collaboration [3,4]. Total Body PET scanners, which nowadays have become a hot research field in the development of tomographs, provide a larger axial field of view (AFOV) in order to cover all the patient's body with one single scan. Such tomographs increase the overall sensitivity and efficiency and lead to decrease in administered to the patient radioactive dose and shortens scan duration for dedicated imaging [5].

The currently investigated prototype of Jagiellonian PET is Modular J-PET. Its structure consists of 24 detection panels, that provide in total 50 cm of the AFOV. Each panel consists of 13 plastic scintillators situated next to another and read out on both ends by silicon photomultipliers [6]. The modularity of this prototype allows for simple construction and deconstruction, portability and the possibility of assembly with different numbers of panels depending on the patient size and clinical needs [7]. Moreover, such technology enables a new way of patient insertion - from the side instead of from the front, which cancels the need for large rooms in clinics.

National Electrical Manufacturers Association (NEMA) as a validated organization defines standards for various grades of electrical tools [8]. The presented study is a simulation-based investigation of some of the NEMA characteristic metrics of the Modular J-PET in order to evaluate its performance.

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Performance characteristics of the J-PEM prototype

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Positron Emission Tomography is currently one of the most used non-invasive imaging techniques that provides methods to determine and monitor stage of tumor and assessment of a response to the treatment [1]. The purpose of the presented investigations is to design, construct and establish the performance characteristics of the Jagiellonian Positron Emission Mammography (J-PEM), being designed for the detection and diagnosis of cancer. It's construction is based on a novel idea of PET tomography based on plastic scintillators [2,3] and wavelength shifters (WLS) [8,9] and a new concept of positronium imaging [4,5,6,7]. This study characterizes the performance of a newly developed J-PEM scanner prototype. The prototype system consists of a single module of plastic scintillators, built from two layers of plastic scintillator (6x24x500 mm) and one layer of the wavelength shifters (3x10x100 mm) [8,9] placed orthogonally between them. Each scintillator bar is attached at both ends to Silicon Photomultipliers for the signal readout. This 3D system is based on the novel idea of applying plastic scintillators to detect annihilation photons and improving spatial resolution by utilization of wavelength shifters (WLS). J-PEM can be an effective system for the detection and diagnosis of breast cancer in its early stage by improving sensitivity and specificity and it can be achieved by the combined use of plastic scintillators, which have superior timing properties, with the WLS. In addition this device will be developed in view of classification of malignancy based on the possibility of positronium mean lifetime imaging. Performance characteristics include the point spread function, and sensitivity that were estimated using Gate Simulation [10], furthermore simulations have been performed to optimize the geometry of the system. Results of simulations and measurements will be presented and discussed.

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A simulation study to estimate optimum energy window criterion for data acquisition in the Total Body J-PET

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Positron Emission Tomography (PET) allows to determine spatial and temporal distribution of injected radioactive substance and track biological and chemical processes inside the human body. The operation of PET scanner is based on molecular imaging, this feature has made PET the first candidate in lesion detectability, tumor grading, treatment monitoring, oncology, cardiology, neurology etc [1]. PET enables precise anatomical localization of malignant lesions and cancer metastases which can enhance survival rate of patient by helping physicians to choose proper treatment plan.

The principle of operation of obtaining image lies in the detection of photons created by a radioactive tracer. Maximization of such performance, so called count-rate, is the main goal of every PET system. However, this factor in itself does not reflect the quality of the reconstructed image [2].

The information about the position of radioactive substance and by means of that the imaging lesion is obtained from pairs of photons registered by the tomograph. The registration process is done using the coincidence detection technique. If two photons will reach PET scanner within a short time from each other and deposit considerable amount of their energy, such pair will be recorded [3]. The aforementioned count-rate is the total number of pair detections in a given time. Nonetheless, not all of the coincidences are positively contributing to the final image reconstruction. In many cases photon can interact and scatter in the human body or phantom material prior to the interaction with the detector, which leads to misplacement of the reconstructed radioactive tracer position. Multiple scatterings can also occur already within detector material. Moreover, the time window regime in coincidence-based detection doesn't exclude possibility of recording of two independent photons (so called accidental or random coincidences) [4].

There are many methods for dealing with the degrading type of already registered coincidences. However, the primary effort should be focused on the rejection techniques during the data acquisition. The commonly utilized practice is to introduce the energy window (EW) alongside with the time window. It takes advantage of the fact, that any photon interaction before reaching tomograph is reducing its primary energy and therefore, decreases the maximal possible deposition in the detectors [5]. Nevertheless, there exists a trade-off between scatter events rejection and PET system sensitivity. Narrowing of the EW to achieve better rejection of unwanted scatter coincidences will also reduce sensitivity. For that reason, the correct estimation of the energy window is imperative to maximize performance of any PET system.

There is an ongoing research to develop a novel PET system called J-PET (Jagiellonian Positron Emission Tomograph) by the J-PET Collaboration at the Jagiellonian University in Cracow [6,7]. As an alternative to common PET tomographs, axial arrangement of the organic scintillator detectors and innovative detection methods applied in J-PET technology, assist to introduce it as a cost-effective solution. Moreover, this engineering novelty allows for convenient conversion to the Total Body PET system. The Total Body PET is an answer to the drawbacks of current clinically available classic PET tomographs. Thanks to superior longitudinal coverage over the human body it enhances the sensitivity, reduces the whole-body scan time, lowers administered radiopharmaceutical dose and enables simultaneous and dynamic multi-organ imaging [8].

In this simulation-based study we want to evaluate influence of different energy windows on the quality of the data collected by Total Body system proposed by the J-PET Collaboration. We assess the data quality based on investigation of variations in contribution of different types of coincidences. Additionally, we consider standard PET metrics such as scatter fraction and noise equivalent count-rate. Furthermore, we estimate the degrading impact of utilizing EW on the sensitivity of the tomograph.

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Micro-Computed Tomography as a tool in the assessment of heavy metal distribution and accumulation

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Micro-computed tomography (micro-CT) is a technique, which enables visualization of the structures with sizes of micrometers, which is very important in medical and biological studies and can contribute e.g., to the better understanding of different anatomical structures [1, 2]. In this research, however, the usage of micro-CT was extended one step further – to the analysis of the distribution of heavy metals in fish opercula.

Two types of heavy metals were examined in this study: zinc (Zn) and cadmium (Cd), as well as a control group – not contaminated with any heavy metals. All the samples were derived from the Crucian Carps (C. Carassius) cultured in the environment containing the above-mentioned heavy metals – with a concentration of 4 mg/ml of water. The exposure to heavy metals in their environment allowed us to advance a hypothesis that an accumulation of these elements should be occurring and that their distribution should be visible after performing a micro-CT scan.

The measurement procedure involved putting the samples in the micro-CT chamber and also setting the right parameters (like beam energy – 80 keV, amperage – 100mA, filter – aluminum 0.5 mm, or rotation step – 0.3o), which had to be the same for all the examined samples.

The obtained results left us no doubt, that the accumulation of heavy metals can be seen not only on the distributions of shades of gray – where there is a shift to the higher values of shades of gray for metals with a higher atomic number – ranging from 175 for Zn contaminated samples to 190 for samples contaminated with mixture of Zn and Cd, whereas for the control group this value amounts to 162. These results, as well as visualization reconstructed from the images taken during the measurement, indicate that micro-CT is an advantageous tool when it comes to biomedical research, even as complex as heavy metal accumulation. The main advantage is the possibility to visualize the examined samples, which is impossible for any other method in this area of research.

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Influence of antioxidants on positronium lifetime – studies of melanocyte and melanoma cell cultures with Positron Annihilation Lifetime Spectroscopy

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Positronium, a bound state of positron and electron has been proposed as a novel biomarker for examining cancer cells [1]. This atom is copiously created in cells during Positron Emission Tomography (PET) imaging [2-3]. Our pre-clinical studies have shown significant differences in the lifetime of positronium between normal and neoplastic cells and tissues, however, the controlling mechanisms are unclear so far [4-5].

The concentration of free radicals, especially reactive oxygen species (ROS) have a significant influence on the properties of positronium, such as its lifetime and production intensity in the tissue. Presented research investigated the role of antioxidants, such as vitamin C and epigallocatechin gallate (EGCG), on the values of the newly proposed biomarker. Correlating the level of ROS in melanoma cells and melanocytes with the parameters of positronium would allow for better assessment of novel proposed biomarker in view of its future applications.

Presented studies were conducted on normal human cells: melanocyte HEMa-LP cell line and two cell lines of melanoma: WM115 (primary melanoma) and WM266-4 (metastatic melanoma) as an example of cancer cells with different degree of malignancy. Cells were cultured in various concentration of vitamin C (100, 1000 μM) and EGCG (10, 100 μM) – antioxidants acting as free radical scavengers to regulate ROS levels in cells. Additionally, solutions of vitamin C and EGCG in cell culture media were measured, in order to determine their influence on positronium parameters. Positronium lifetime was determined by means of Positron Annihilation Lifetime Spectroscopy. Presented values of o-Ps lifetime was obtained as an average from three consecutive measurements.

Obtained results showed differences in positronium lifetime, between normal and cancer cell in relation with their malignancy. Resulting o-Ps lifetime in HEMa-LP, WM115 and WM266-4 cells was equal to 1.91(02)ns, 1.95(03)ns, 1.99(01) ns, respectively in control; 1.93(02)ns, 1.96(01)ns, 1.98(01)ns in 1000 μM concentration of vitamin C and 1.91(02)ns, 1.93(01)ns, 1.89(02)ns in 100μM concentration of EGCG. No significant differences were observed in measured solutions or culture media, showing the differences in positronium lifetime in cell cultures were dependent on cell activity and microenvironment (ROS levels).

Outcome of our experiment confirmed the validity of employing positronium as an indicator, which can have a direct impact on better and more accurate diagnostics. Simultaneous PET and Positronium imaging can be performed with the Jagiellonian Positron Emission Tomography scanner [6-11], which is designed for imaging properties of positronium produced inside the entire human body simultaneously [2,12].

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Clinical reasoning learning analytics - how to visualise and measure the invisible?

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Clinical reasoning (CR) is a complex set of skills health professionals use to gather and interpret patient information that leads to adequate and efficient diagnosis and management of health problems. Flawed CR is often the cause of medical

errors that may result in harm for the patients and unjustified cost for the health care system. Yet, training of CR and its associated skills are a challenge due to the many tacit components of experts' thinking, which are difficult to explain to students and assess in their actions. Methods are sought how to support educators in teaching CR. The limited time availability of clinical teachers and reduced access to real patient cases is remedied by interactive virtual patient scenarios which are targeted to improve CR abilities.

The goal of this presentation is to summarise the current possibilities and challenges in the measurement of CR learning activities in computer-aided environments. The authors will share their experiences from development and curricular implementation of a CR learning tool integrated with an international virtual patient collection. The CR process is captured by concept maps developed by the students, while solving patient scenarios and compared with expert answers. The concepts in the maps are automatically suggested to the users from medical terminologies available in English, German, Polish, Portuguese and Spanish, and used when grading the answers. Students' learning activities in the system are visualised by a learning analytics dashboard.

The authors find opportunities for further study and development of CR learning analytics methods in the context of evaluation activities of the European project DID-ACT; a project that aims to develop a longitudinal CR curriculum. New CR skills indicators to be detected in student responses are informed by CR theories identified in literature. Further development will include deepening the levels of analysis of the concept maps which require solving natural language processing issues posed by different European languages.

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The way from eViP to iCoViP: the practice of implementing on-line virtual patient collections

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"An important tool in digital education of health professions are virtual patients. Their predominant aim is the development of clinical reasoning skills. It is widely agreed that clinical reasoning is best trained when students are confronted with many patient cases. A challenge is the cost of authoring and maintaining collections of numerous virtual patients. To solve this problem, international consortia are formed that share the development efforts of the cases and build the required technical infrastructure. This presentation summarises the challenges and available solutions for implementing on-line virtual patient collections against the backdrop of several international projects in which the authors participated.

A project that was the foundational stone of several other initiatives was eViP (2007-2010) in which a collection of 320 international virtual patients was developed. At that stage the addressed challenges included implementation of technologies that enabled transfer of virtual patient content between heterogeneous virtual patient systems (e.g. using MedBiquitous VPD standard). This approach changed in the years to come as exemplified by the WAVES project (2015-2017), which aimed (among other things) to widen access to virtual patient collections by enabling easy authentication/authorisation/integration mechanisms for students (with e.g. LTI) and exchange of logs from virtual patient learning activities for analytic purposes in a standardized format (xAPI).

The newly initiated project iCoViP (2021-2023) aims to create 125 new virtual patients and integrate them with an existing collection that will result in a set of 200 interactive cases. In the post COVID-19 era, the authors have to face new challenges related to virtual patient collections. One of them is how to handle the dynamism of changes of medical recommendations and the new clinical context in the patient cases in which telemedicine plays a more important role. It is also important to assure the provision of learners with an adequate mix of cases showing carefully selected symptoms, presented in the right order to optimize efficiency of learning clinical reasoning (e.g. virtual patient panels to detect and train against common cognitive errors). The focus shifts from treating virtual patient cases as isolated experiences towards presenting coherent series of cases that meet particular learning objectives as a whole. Finally, the aim is also to

swiftly coordinate authoring of the same content of virtual patients in five languages. The observed dramatic increase in the use of the authors virtual patients collections after the pandemic outbreak shows that their efforts meet an urgent need of the health professions education community.

Database of clinical case reports created to enrich the distance form of medical education not only in pandemic era

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One of the key aspects in medical education is the sharing of clinical experience by professionals, which serves as a bridge between theoretical and practical knowledge. During the history, various teaching methods have been integrated into the medical curricula to deliver this invaluable part of preparation for bedside teaching. Despite of the advances in current virtual and augmented reality and all their advantages, the traditional patient case reports remained a quite stable source of key clinical information including approaches the clinicians use in administration of their patients. The importance of case reports raised up especially during the last year of restrictions associated with the spread of coronavirus when medical universities have been forced to completely interrupt clinical teaching and to move everything into the online environment. Therefore, we decided to develop a unified case reports database which serves both our teachers and their students. The inconsistency in case reports based education materials offered to medical students at our faculty forced us not only to motivate our academic clinicians to participate on this development, but also to design a generalized case report framework to suit as many disciplines as possible while keeping authors a reasonable space for integration of their specifics, which may vary from case to case. Rather than to build a standalone learning management systems we integrated this database of case reports into our faculty's portal that acts as a central point to share various electronic education materials. In this way, the multimedia content can be easily managed and authors can provide users with access to their published materials according to different user roles. On the other hand, the students get individual clinical cases online and together with other types of study materials that can be classified according to disciplines, courses, departments, but also according to their teachers. Thanks to the cooperation of medical faculties involved in MEFANET network, individual case reports can be shared not only for our students, but also for all medical students at all medical faculties in Czech Republic and Slovakia. The first responses obtained from our students prove the database of clinical case reports offers very challenging opportunities to evolve their clinical skills and foster their scientific and critical thinking.

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Sano: Centre for Computational Medicine Research

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Sano is a brand-new non-profit research institute dedicated to advancement of the use of computing in healthcare. The overall goal of Sano is to develop computerized solutions which can provide healthcare professionals and patients with assistance in making optimal medical and health-related decisions. Sano combines expertise in large-scale computer simulation and machine learning/artificial intelligence.

The structure and the strategy towards achieving Sano's goals is presented. Directions of healthcare research and areas of applications that Sano undertakes is discussed.

Students' perceptions on different types of virtual patients

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Virtual patients (VPs) cases allow a medical student to take on a role of a health care professional in a safe environment. They are always available, cost-effective and allow the students to perform a various range of interactions. Because of those qualities VPs make a valuable addition to traditional bed-side teaching. A great diversity of VP systems is available which makes choosing the right tool a challenging task.

Since medical students are a principal target of VP cases, it is important to acknowledge and understand students' varying perceptions on different types of VPs. It would help researchers and case designers to tailor VPs more to the students' actual needs.

Our research follows-up a pilot study from 2018 in which we analysed in a focus group the general attitudes of students towards working with VPs. The goal of this presentation is to explore on a greater scale the students' views on linear, branched and template models of VPs. 127 students' opinions were gathered in 2020 after a class on VPs. The authors performed a qualitative content analysis of those statements and determined arguments for and against different types of VPs.

The qualitative content analysis resulted in four major themes: (1) virtual patient model preferences, (2) views on types of VPs' structures, (3) attitudes towards errors, (4) opportunities for reflection and others. The study delivered a balanced distribution of model preference with a tendency to prefer the branched model for the possibility of experiencing consequences of actions. A more structured approach exemplified by the linear model was valued for its clarity that led to efficient reach of the intended learning objectives and assimilation of the recommended handling schema. Interestingly, many of the students saw learning from errors as a valuable experience but there were also those with the opposite attitude seeing errors as a waste of time. Students also recognize the possibility the VPs give for reflective practice and to prove themselves.

We see further research opportunities in designing VP systems that would accommodate the different perspectives and needs of students. We hope to motivate the teachers and curriculum designers to take a closer look on how and when to use particular types of VPs to alleviate students' learning difficulties.

Design and implementation of an expert system for diagnostics of earache causes in both adolescents and adults

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Earache is one of the most unpleasant health conditions. Usually, it is not dangerous, but it can be an extremely troublesome ailment with the risk of serious complications in the future. In this work, an expert system for the diagnosis of various causes of earache in adolescents and adults was presented. The study is of a pilot study character. This work also describes in detail the complicated structure of the ear and the most common causes of ear pain. The most common difficulties in making an appropriate diagnosis were also covered with this paper. The work takes into account using various artificial intelligence tools. Additionally, the expert system code was described and an example application view was presented. Artificial intelligence tools and expert systems are very interesting tools, which could be potentially applied for diagnostic purposes and could be a good alternative to traditional methods. This work also presents a prototype application designed and developed by the first author of this work.

Computer methods of data processing in rheographic systems

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The paper presents innovative solutions in impedance plethysmography concerning both the improvement of the technical characteristics of the rheograph and the increase of the efficiency of developing rheograms using computer methods. The methods of ensuring the stability of parameters and extending the functionality of the rheographic system based on digital signal processing are described. This applies to the compensation of the base resistance with a digital potentiometer, digital synthesis of quadrature excitation signals and the performance of digital synchronous detection. Much attention is paid to methods of determining hemodynamic parameters by computer processing of rheograms. In this direction, three methods of elimination of respiratory artifacts have been proposed - based on the discrete cosine transform, the discrete wavelet transform and the approximation of the zero line with spline functions. Computer methods for determining physiological indicators, including those based on wavelet decomposition, were also proposed. The effectiveness of various reogram compression algorithms was tested; digital processing of rheographic signals; base impedance compensation; elimination of rheography artifacts; computer determination of the reogram characteristic points.

External force-caused fall analysis – preliminary research

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The problem of fall is a significant issue due to its severe impact, especially in a group of the elderly. They are highly vulnerable to femur neck or pelvis breakage etc. which, at this age, may often turn out to be fatal. Detection of fall makes way to reduce after effects of stability loss. The goal is to detect this kind of events as early as possible. Motion Capture systems are used to precisely track movement of human body in various situations. In following work different scenarios of backward fall were captured with the use of BTS 6000 DX – an optoelectronic system for motion analysis – along with AMTI's force platforms. Participants of this study were knocked over by another person pulling them by the rope, attached to the belt of a half body climbing harness. Some of pulling actions ended by fall, but in some cases the participants maintained stability. The pulls were performed both with gradually increasing and rapidly generated force. This method of data acquisition allows to simulate fall events that are similar to an incident of stability loss due to external force influence, for example during bus braking. Analysis of data proved that with external force acting on the participant, the fall is unavoidable even before the centre of mass (COM), described approximately in the middle of pelvis, exceeds the line of ankles. However, it is not possible to simply define a distance between COM and the line of the ankles beyond which fall incident will certainly occur. Presented research is a preliminary study for further fall issue analysis and an attempt at predicting the loss of stability moment before the fall begins with the use of Artificial Neural Networks.

Correlation of the results of textural analysis of wrist MRI images with age in boys aged 9-17

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Currently, bone age is assessed on the basis of X-rays. It allows us to assess the child's development. The determination of bone age is an important diagnostic factor. However, it is not a sufficient factor to diagnose a specific disease. Depending on how much it differs from the norms of bone age in physiologically developing children, it may suggest different diagnoses and different prognosis for the patient. Moreover, on its basis it is possible to predict the growth of the examined person after the end of the bone age, i.e. when the epiphyses are already fused. It also allows us to estimate the time of puberty onset.

The use of MRI images to assess the age aspect of the respondents would extend their diagnostic possibilities. Bone age testing could then become a routine screening test. Changing the method of determining bone age would also avoid the need for the patient to take a dose of ionizing radiation, which would make the test much less burdensome for the patient.

For this purpose, the regions of interest (ROI) containing the wrist area and the epiphyses of the radius are marked on the magnetic resonance imaging (MRI) of the non-dominant hand of 30 boys aged 9 to 17 years. These tests were performed with one MRI scanner. Carrying out a textural analysis using the qMazDa software showed the existing correlation (both with the Pearson's and Spearman's coefficients) between the image parameters and the age of the respondents.

The relationship between Internet use and health behaviours, utilisation of health services and life satisfaction of elderly people in Poland

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Introduction: The Internet may play an important role as the tool supporting social and vocational activities of elderly persons. Furthermore, it seems that Internet users gain easier access to health-related information that results in more beneficial health behaviours or more efficient handling of medical problems. On the other hand, older adults and elderly frequently suffer from a significant digital divide.

Aim of the study: The main aim of the study was the assessment of the relationship between Internet use and life satisfaction, health behaviours, and the utilisation of health care services.

Material and methods: The analysis was based on data collected during the 7th edition of The Survey of Health, Ageing and Retirement in Europe (SHARE). The survey collects data concerning various areas of life of elderly persons 50 years and over from 28 countries. The sample included 1142 respondents from Poland. The differences in life satisfaction were assessed with U Mann-Whitney test. The relationship between Internet use and variables reflecting health behaviours and the utilisation of health services, was assessed with multivariable logistic regression after adjusting for age and gender.

Results: There were 57.9% (n=661) females and over 68% of married persons in the study group. The mean age of the respondent was 71.23 years (SD=8.38). Only 20.8% (n=238) respondents have used the Internet in the last week. The percentage of respondents who assessed their computer skills as excellent was only 0.5% (n=6), and as good 2.5% (n=29). Nearly 70% (n=789) of participants admitted that they had never used a computer. The mean age of computer users was lower than of non-users (mean (standard deviation, SD): 65.19 (4.69) vs 72.82 (8.81), Student's t test, $p<0.001$). It appeared that computer users declared higher life satisfaction compared to non-users (U Mann-Whitney test, $p<0.001$). Internet users were less likely to be current smokers than non-users (OR, 95%Cl: 0.45, 0.24-0.83). However, Internet was not associated with the level of alcohol consumption (OR, 95%Cl: 1.35, 0.95-1.90). The analysis also showed that Internet users were more likely to visit a dentist or dental hygienist in the past year compared to non- users (OR, 95%CI: 2.67, 1.92-3.70). Furthermore, they were more likely to purchase additional insurance to cover services not reimbursed within public insurance system (OR, 95%Cl: 2.1, 1.24-3.56) and they were more frequently paying for medical visits or diagnostic services (OR, 95%Cl, 1.80, 1.26-2.58). Finally, Internet use showed no significant relationship with hospital stay in the past 12 months (OR, 95%Cl: 0.81, 0.54-1.21).

Conclusions: Internet users in the population 50+ show higher self-declared life satisfaction than non-users. It also seems that Internet use is associated with higher utilisation of health services and the ability to purchase private health insurance or pay for the health services.

Improving the quality of the classification between the healthy knee group and the chondromalacia or the chondromalacia and the osteoarthritis using selected vibroarthrographic signal features

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Vibroartrography (VAG) is used as a non-invasive method to analyse registered mechanical vibrations caused by friction of cartilaginous articular surfaces. The knee joint cartilage degeneration characterized by its gradual softening, fibrosing, fissures formation and erosion runs from three stages of chondromalacia to osteoarthritis.

Currently for analysis of VAG signals various types of spatiotemporal, time-frequency or statistical analysis are used. Frequent use are found in signal description by parameters: power spectral density for frequency of 50-250 Hz (P1), power spectral density for frequency of 250-450 Hz (P2), mean range (R4) and variation of mean square (VMS). However, it should be noted that there are problems with the classification of healthy - chondromalacia and chondromalacia-osteoarthritis classes.

The paper provides descriptors which increase the quality of the classification in mentioned above classes based on testing selected frequencies and processing spectrogram results. The alternative descriptor is based on computing spectrogram of selected signal, rejecting every frequency beyond specified range, summing up the obtained plane in the frequency dimension and using a moving mean filter. The average value of the obtained signal's slope is a VAG signal's feature. The comparison is conducted using the overlapping coefficient (OVL).

VAG signals in total number of 184 were used as a research sample: 66 signals of healthy knee (N), 26 signals of first stage chondromalacia (CHI), 30 signals of second stage chondromalacia (CHII), 36 signals of third stage chondromalacia (CHIII) and 26 signals of osteoarthritis (OA). The paper proves relevant diagnostic potential of classification accuracy of proposed descriptor.

Acceptance of remote healthcare services during the COVID-19 pandemic

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Introduction: During the pandemic COVID-19, remote advice became the preferred form of contact with a doctor. The objective of the study was to assess the use of remote medical care during the pandemic and to analyze the factors influencing the acceptance of telemedicine services during the pandemic COVID-19.
Methods: The analysis was based on data from an online survey conducted on a representative sample of 1002 Polish adult Internet users. The survey was carried out in the period of 1 week in June 2020. The survey questionnaire used in the survey consisted of the European Health Literacy Survey questionnaire in a version containing 16 questions, the polish version of the eHealth Literacy Scale, a set of questions on the use of e-health services during the epidemic risk and questions on socio-demographic factors. Satisfaction of e-health services were assessed on the basis of the answer to the question: did the respondent managed to address all issues and problems during a remote session, and acceptance based on opinions about the use of the e-health services in the future. Variables reflecting the satisfaction and acceptance of e-health services has been dichotomized before the predictive factors were analyzed. A logistic regression analysis was used to identify which factors like health literacy, e-health literacy and socio-demographic variable were influencing the satisfaction and acceptance of e-health services.
Results: E-health services during the COVID-19 pandemic were used by 60.5% (n = 607) of study participants. All respondents using e-health services, used remote telephone consultation. Only 3.5% of all respondents contacted a

healthcare professional via a videoconference system, 6.5% (n = 65) also used e-mail, and 7.7% (n = 77) from a medical facility website. As many as 42.5% (n = 426) of people received e-prescription, and 8.8% (n = 88) e-sick leave. Modeling using logistic regression showed that the level of satisfaction with e-health services depended on health competences (OR, 95% CI: 1.13; 1.07-1.18), e-health competences (1.07 1.03) -1.11), using remote services due to a chronic disease (1.4, 1.01-1.21) and to obtain an e-prescription (1.43, 1.02-1.97). There was no link between the satisfaction of e-health services and the social-demographic variables. The acceptance of such services showed a statistically significant link with the level of e-health literacy (1.06; 1.03-1.10), the place of residence (rural residents versus urban residents >500,000: 2.32; 1.37-3.96), with higher education compared to lower education than average education (1.78; 1.06-2.99) and the marital status (non-married persons vs. married persons: 1.89, 1.31-2.74). Also, the use of remote services to obtain e-prescriptions were related to a higher level of acceptance (1.47, 1.05-2.07). There was no statistically significant link between the acceptance of eHealth and the level of health literacy.

Conclusions: In the early part of the pandemic, a significant proportion of respondents already used e-health services. The satisfaction and acceptance of such services showed significant differences with regard to the factors that can play a determining role.

Design and development of a store-and-forward telemedicine system using sophisticated data analysis methods

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Telemedicine has become recently one of the most rapidly developing areas of medicine, particular during the current COVID pandemia. In this paper, which is of a concept character, the authors decided to present a project of a store-and-forward telemedicine system, which applies advanced, sophisticated signal processing and biomedical data analysis methods. Analysis of biomedical data, in particular biosignals is a very challenging task, mostly due to the non-stationary character of these signals and susceptibility to various interferences occurrence and therefore, choosing appropriate signal processing methods is very important. Telemedicine systems allow diagnosis and therapy to be carried out at a distance, with no necessity for patients' presence. In this paper state of the art of the most popular telemedicine systems have been presented. This work also covers a brief description of the most efficient signal processing methods applied for on-line analysis purposes. It is also important to mention that telemedicine will play a crucial role in or lives in the future and will become one of the most important branches of modern medicine. In this work also the most common types of store-and-forward telemedicine systems will be described and compared with the prototype/concept designed by the authors of this work.

Pneumatically assisted rehabilitation tricycle for physiotherapy of disabled patients – design stage

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The subject of the study is a new rehabilitation pneumatically assisted tricycle for the rehabilitation of adults with disabilities. The tricycle will be adapted to the rehabilitation of patients with Parkinson's disease, multiple sclerosis, stroke, spinal cord injury, movement disorders of the lower and upper limbs, the elderly, obese, after traffic accidents, and others. Patients after rehabilitation exercise on a tricycle will benefit from improving their health and overall physical condition. The rehabilitation tricycle will be effectively supporting the therapeutic exercises of patients with neurological and motor diseases, as well as exercises improving overall health. The environmentally friendly pneumatic tricycle will

be an excellent rehabilitation device in rehabilitation centers, social welfare centers, and at the patient's home. An innovative pneumatic assisted rehabilitation tricycle will be developed and made. The rehabilitation tricycle will have different drive modes, manual, foot, and pneumatic assist. In the foot mode, the rehabilitation tricycle will be equipped with a special control system consisting of exerting a constant pressure of the foot on the pedal. Since the pressure on the pedal is adjustable, it will be it can set the effort level to be as hard or soft as well as the duration of a therapy session. Therapeutic procedures with the use of a tricycle will be developed, which will consist of 3 stages: preliminary qualification, therapeutic treatment (pedaling), and analysis of the patient's condition. During the therapy, it will be possible to monitor the patient's physical condition, e.g., by checking blood pressure, heart rate, and breathing intensity. The tricycle will have a highly energy-efficient drive thanks to the use of a multistage air motor with the ability to recover braking energy. These solutions will enable the tricycle to move longer distances to rehabilitation centers. Due to the simple and low-cost structure, the rehabilitation tricycle can be purchased not only by health care units but also by non-specialized people, as it is suitable for home training without the need for a physiotherapist. The rehabilitation tricycle is also characterized by a high level of environmental protection. The production of heavy traction batteries, which produces about 200 kg of CO2 for every 1 kWh of battery capacity, was eliminated. The costly disposal of traction batteries has been eliminated. An ecological air motor was used, powered from composite compressed air cylinders under high pressure of approx. 200 bar. Charging the cylinder takes a few minutes compared to several hours of charging the traction batteries. The weight of the bicycle has been significantly reduced, which has increased ergonomics and ease of use. Electronic control, which is a frequent cause of electric bike failures, has been eliminated.

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The Bioinspired Traffic Sign Classifier

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In recent years, neural networks, and especially deep convolutional neural networks, have practically dominated the field of image classification. A specific subgroup of artificial neural networks are Spiking Neural Networks (SNNs). Unlike classical ones, including deep networks, they reflect the behaviour of biological neurons much more closely. The basic property of spiking models is taking into account the time dimension. A neuron's input signals influence its "cell membrane" potential. Only when the potential reaches a certain threshold value, an impulse is generated at the output, which stimulates subsequent neurons. An obvious application of this type of networks seems to be neuroscience and modelling the nervous systems of living organisms. However, there are also attempts to use SNNs in problems typical for "traditional" artificial neural networks. Their advantages include greater computational ability, resulting from taking into account the time dimension, and much higher energy efficiency. The latter results from the event-based operation - computations are not synchronised with an external clock, but only executed when needed, asynchronously. This seems to be particularly important given the current global efforts to reduce energy consumption. However, the potential benefits will only be possible when hardware platforms dedicated to neuromorphic computing become widely available. The first research prototypes, such as the Intel Loihi chip, are currently being developed. Several software simulators are also available to model SNNs using PCs. Spiking networks are one of the solutions that could replace the currently widely used traditional deep networks in the future. A rapid growth of the market related to neuromorphic calculations is expected in the next several years.

To explore the possibilities of using bioinspired solutions for embedded vision systems, we focus on the traffic sign classification problem. We propose a convolutional spiking neural network based on the LeNet5 architecture, with a Leaky-Integrate-and-Fire neuron model. For training, we use the GTSRB (German Traffic Sign Recognition Benchmark) database. We define multiple training experiments, varying in preprocessing and augmentation methods, to face the challenges of unbalanced and diverse (in terms of illumination, size, and quality) data.

For network design and development, we use NengoDL, which allows to develop spiking networks for the Intel Loihi neuromorphic platform. Since the spiking neuron models are non-differentiable, neurons are replaced with their

differentiable approximation (soft LIF) during backpropagation. For the in-depth analysis, we also train the static counterparts of the proposed spiking networks. Finally, we achieve up to 97% accuracy on the test set for our bioinspired classifier, depending on the number of time steps the input is presented to the spiking neural network.

The obtained results are confronted with other state-of-the-art static neural networks' classifiers and prove our solution to be comparable to other compact architectures.

Demonstrating the practical usefulness of such a solution remains an important problem. In theory, such a network, running on dedicated neuromorphic hardware should be characterised by low latency and low energy consumption. The simulation of SNN on general-purpose computers, GPUs, or even FPGAs is not very effective, as the mentioned platforms are synchronous. Nevertheless, performing the proposed preliminary research that focuses on both the exploration of possible applications of bioinspired algorithms, as well as theoretical - software - experiments is crucial for the dynamic development in the future, when the neuromorphic hardware shall be widely available.

Effectiveness of a passive-dynamic method of correction of static foot defects mainly hallux valgus

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Passive-dynamic hallux valgus correction method and coexisting static defects of the feet with the function of passive and dynamic valgus correction, often with coexisting transversely flat and flat-valgus feet is under consideration. The passive-dynamic correction strength the weak and stretches the contracted feet muscles in the above-mentioned forms of static defects, restoring the physiological balance of the pulling power of muscles. It has a dynamizing and relaxing function with tonus balancing between muscles, synergists and feet antagonists. In addition, it has a passive function consisting of stretching extra-articular and articular contractures. The method can be used in prevention (prevents the development of the above-mentioned feet defects) and treatment (inhibits the deepening of the above-mentioned feet defects and restores the physiological architecture of the feet conditioning its proper static function during standing and dynamic during walking). The study involved 29 patients with the first and second stage of hallux valgus. After 6 months of exercise, the mean valgus reduction was 87% for the first degree, and 69% for the second degree.

Failure analysis of ion nitrided orthopedic implant made from Ti-6Al-7Nb alloy for internal fixation of broken bone – important considerations in preventing fracture

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Most failures of orthopedic implants occur by fatigue. Failure by fatigue mechanism of internal dynamic implants is a common and serious problem. Fatigue failures of orthopedic implants is estimated for more than 90 percent of all service failures due to cyclic stresses. This presentation will cover the engineering and clinical aspects of failure analysis and fundamental root causes, the role of proper surface hardening by nitriding and design in failure prevention. This presentation will focus on failure of internal fixation orthopedic plate to help identify causes, prevent occurrence, improve reliability, fracture mechanics, failure mechanism, and failure prevention of surface hardened by nitriding of orthopedic implant made from titanium base alloy (Ti-6Al-7Nb) commonly used in orthopedic surgery. Fundamental and practical concepts of fracture will be presented in terms of stress analysis, evaluation surface hardened microstructure, and the mechanical behavior of materials. It is very important to understand relationship between surface hardened microstructure and resistance to fatigue fracture in order to solve existing fracture problems and prevent future ones. Applied mechanical load on the bone interacts with the biological process and has significant effects on the healing process. This presentation will explain how mechanical material behavior (especially resistance to fatigue fracture)

relates to surface hardened microstructure. Causes of failure of orthopedic internal fixation compressive plate and important factors on resistance to fatigue fracture will be explained. This presentation will help provide a better understanding of the mechanism of fatigue fracture in the surface of hardened implants by ion and preventing failure in the future. The improvement of resistance to fatigue fracture of orthopedic implants by proper surface hardening technology will contribute to the long term performance, reliability, and safety of internal dynamic compression implants. The technological development of internal dynamic compression fixation orthopedic implants has been extremely important in the successful results of many clinical cases. However, there is still a lot of work left to reach the expected results, which means the continuous search for new and better biomaterials and technology to satisfy the needs in orthopedic surgery. This failure analysis presentation will demonstrate that a great need exists to develop the proper thermo-chemical surface hardening technology to obtain microstructure without titanium nitride layers. Presence of titanium nitride layers in microstructure is not desirable in implants exposed to cycle stress. Titanium nitrides in microstructure decrease resistance to fatigue fracture. This presentation will be useful especially for failure analysis experts, development engineers, materials scientists, researchers, quality assurance specialists, quality control inspectors, biomaterials manufacturing engineers, and orthopedic surgeons.

Magnetic chamber for live cell measurements

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The aim of this study was to design a microscopic chamber dedicated for measurements of biological samples, especially cells, in a homogeneous magnetic field. We present a 3D printed microscopic stage that allows for observation of living cells in a uniform magnetic field. This field is generated by a magnetic unit that consists of a set of permanent neodymium magnets arranged in a Hallbach array. The size of the ring in which the magnets are mounted, as well as their number, can be easily changed and customized. Five various setups have been prepared with different sizes and inductions of magnets in such a manner that (1) the value of magnetic field induction does not exceed 150 mT in the observation field, which is thought to be neutral for the cells in an *in vitro* assay; (2) the system enabled measurements with an inverted optical microscope, and (3) the system allowed to make measurements under biological conditions, i.e. at 37 degrees Celsius, in high humidity and under elevated carbon dioxide concentration. All chambers were manufactured by 3D printing from PETG with the Ultimaker 3 printer. Magnetic field induction was measured in an area of 40 mm2 or 30 mm2 square in the center of the ring with the magnetic field induction meter TEL-Atomic Inc. smart magnetic sensor SMS 102. Based on the acquired induction of magnetic field the heterogeneity of magnetic field gradient was calculated for each ring. The designed chambers, alongside measurements of the magnetic field, its gradient, and examples of microscopic measurements will be shown in the poster.

3D printing as a convenient technique for adjusting optical microscopy towards the observation of living cells

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3D printing, especially FDM (fused deposition modelling), is becoming a widely used technique for medical and bioengineering applications. It allows for fast and inexpensive manufacturing of objects, even with a complicated

geometry, which may be used as unconventional parts of existing experimental equipment or become a base for a stand-alone high-quality lab kit. One can go from an idea to a fully operational model in one day.

Here we present a protocol for optimizing 3D printing for biomedical lab purposes, focusing mainly on microscopy and a prototypical microscopic compartment that was used for studying the behavior of living cells loaded with magnetic beads, under a uniform magnetic force. The setup was designed to meet three criteria: compatibility with a given model of an optical microscope, the strict range of generated magnetic fields, and the ability to provide and keep conditions suitable for biological samples, especially the temperature and CO2 concentration. Different architectures of the compartment, as well as four different materials were tested under various conditions, resulting in an optimal protocol and a functional compartment, which met all the criteria. We are convinced that our experience may be useful for other laboratory groups which already use (or plan to do so) 3D printed tools for optimizing their work and to perform original, nonstandard experiments by boosting their equipment.

Monte Carlo simulations of light transport in tissues and tissue-like media using monochromatic and multi-wavelength light sources

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Many biological processes depend on light. In humans, light absorption determines, e.g. synthesis of the vitamin D and intensity of pigmentation. Light absorption is also cause of diseases, including cancers. The origins of phototherapy date back to deep antiquity, while controlled phototherapy (PDT) was started in the early 1900s. Its development continued slowly until the 1960s, when the first clinical procedures for PDT were approved. Currently, PDT is an accepted clinical procedure for the treatment of many conditions, from cancer to bacterial infections. PDT uses a variety of light sources: sunlight (so called daylight PDT, dPDT), polychromatic and monochromatic sources (lasers, LEDs).The development of the PDT method also forced the development of therapy planning methods, including computer-based methods. PDT requires presence of a photosensitizer (PS), oxygen and light. The actual cell-destroying factor is singlet oxygen (in type II PDT), the production of which requires light absorption by a PS delivered to the site of the lesion. Determining the distribution of light within a tissue is the fundamental problem in planning the effectiveness of phototherapy. For this purpose, simulations of light transport in tissue and tissue-like media have been developed for many years, most often using Monte Carlo (MC) methods. MC methods use photons that are absorbed and scattered in tissue. In order to perform a full spectral simulation, we need to know the values of the tissue's optical parameters: its absorption and scattering coefficients, its anisotropy factor, and its refractive index as a function of wavelength. In this work, an attempt was made to simulate the light transport using MC approach for the full spectrum of light source. This approach is necessary for the simulation of dPDT, PDT with polychromatic sources and to simulate natural biological processes stimulated by light. Due to the fact that the MC simulation is carried out for a single photon (one wavelength), it is required to adapt the MC codes to these new requirements. In order to obtain the distribution of the absorbed dose of light within tissue layer (or other radiometric parameters), a dedicated Python application was developed. The application uses the following as input parameters: (1) optical parameters of the multilayer media (experimental data, if available or calculated using various interpolation formulas), (2) various light sources simulated by sampling the light intensity at selected wavelengths from the entire spectrum. Classic MC codes: MCML and CONV are used to carry out the MC simulations. The application performs simulations for successive wavelengths selected from the spectrum and calculates the radiometric quantities (fluence rate, reflectance, transmission, etc.), collecting the results in appropriate files and additionally presenting them in a graphical format. The paper discusses the structure of the program and shows the results of the spectral-dependent MC simulation of light transport within two different media: (1) absorbing (synthetic DOPA-melanin) and (2) scattering (Intralipid). We obtained a good agreement of the light field distribution (as a function of wavelength)

for both investigated phantom media. This allows for further testing of the suitability of the software for the analysis of PDT and other photobiological processes, including the multi-spectral diagnosis of neoplastic pigmentary lesions.

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Relative quantitative proteomic analysis of proteins present in ectosomes derived from urothelial bladder cancer and normal ureter epithelial cells

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Protein content of extracellular vesicles (EVs) can modulate different processes during carcinogenesis. Novel proteomic strategies have been applied several times to profile proteins present in exosomes released by urothelial bladder cancer (UBC) cells. However, similar studies have not been conducted so far on another population of EVs i.e. ectosomes.

In the present study we used a shotgun nanoLC–MS/MS proteomic approach to investigate the protein content of ectosomes released *in vitro* by T-24 UBC cells and HCV-29 normal ureter epithelial cells. Ectosomes were isolated from conditioned media (concentrated by low-vacuum filtration) by differential centrifugation at 18 000 x g. Peptides were analyzed using an UltiMate 3000 RSLCnano System coupled with a Q-Exactive mass spectrometer with nanospray source. Proteins identified in five or six replicates of ectosome samples with at least two peptides were subjected to relative quantification based on normalized spectrum abundance factors (*d*NSAFs), weighting distribution of unique and shared peptide-spectrum matches (PSMs). The equation used to calculate *d*NSAF was as follows:

$$d\text{NSAF} = \frac{\text{uSpc} + [(d)(\text{sSpC})]}{\text{uL} + \text{sL}}$$

$$d = \frac{\text{uSpC}}{\sum \text{uSpC}}$$

where spectral counts from peptides uniquely mapping to a protein are denoted as “uSpC”, and spectral counts from peptides shared between isoforms are labeled “sSpC”. Protein amino acid lengths mapping to unique and shared peptides are denoted as “uL” and “sL”, “*d*”denotes distribution factor. Only significantly altered proteins showing at least 2-fold change (FC) between conditions were considered for further analysis.

A total of 1158 proteins was identified in T-24-derived ectosomes, while HCV-29-derived ectosomes contained a lower number of 259 identified proteins. Normalized spectral counting-based quantitative analysis revealed several proteins that were up- or downregulated in T-24-derived ectosomes, suggesting their potential as novel UBC biomarkers. Regarding T-24-derived ectosomal proteins, filamin B (FC=7.19) and myoferlin (FC=4.05) showed the highest upregulation. Despite the fact that significantly more proteins were identified in T-24-derived ectosomes, there were more upregulated (FC<-2) proteins in HCV-29-derived ectosomes. The highest FC was observed for transforming growth factor beta-induced protein ig-h3 (TGFBI) (FC=-93.36). Integrin beta 3 subunit was the second most upregulated proteins identified in HCV-29-derived ectosomes (FC=-29.44).

The present study provided a focused identification of biologically relevant proteins in UBC-derived ectosomes, confirming their role in UBC development and progression, and their applicability for further biomarker-oriented studies in preclinical or clinical settings. Progressive research on EVs in UBC and other urological cancers holds a promise for a deeper understanding of disease biogenesis and pathogenesis, and might provide novel diagnostic targets.

Construction of the Dynamic Proteom in Silico

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The term proteom refers to all proteins in a living organism and is a consequence of decoding the human genome. This concept assumes a single protein as a basic unit. Static interaction between proteins can be studied based on data available in online databases, such as PDB (Protein Data Bank). However, defining dynamic protein interactions requires changing the way of understanding a concept of a basic unit structure – from a single molecule to an interactive regulation mechanism. Such a mechanism has to be capable of maintaining a stationary state despite the thermodynamically open nature of biological systems. A negative feedback loop based on the receptor-effector interactions can meet that criteria. To simulate the autoregulation behavior in silico, DES (Discrete Event Simulation) techniques can be applied. The simulation software has to imitate a behavior of the receptor and the effector, but various side effects like molecule outflows, communication between particular negative feedback loops, or event delays have to be taken into consideration, too. When testing the response of the system in different conditions, it should be possible to introduce variables, which can be specified before every simulation run. The proposed concept of the dynamic, predictable proteom can improve the understanding of complex interactions in biological systems that are difficult to observe in static models.

Review of the impact of Machine Learning applications on the evolution of selected sports disciplines

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Nowadays, technology is advancing at a very rapid pace. One of the technologies that is constantly developed and its usage is increasing in popularity is Machine Learning. It is being advanced every day and covers more and more broad areas of human life. One of those areas, in particular, is Sport. Machine Learning is used in sports more often for multitude of analyze methods and predictions related to performance and feasibility of improving results.

There are sources that present analysis of players movement on the football field, the hydration and dehydration of players, and even their fatigue. All this information allows coaches to plan the strategy for upcoming games and decide whether each player should play and when is the best time for a particular player to play. It is also possible to analyze data from performed matches in order to predict which team will most likely win the upcoming match or championship. Systems for such predictions are used not only in soccer but also in rugby and cricket. Coaches also use Machine Learning-based systems to evaluate which players are suitable candidates for joining their team and which are not. Additionally, Machine Learning is also used in tennis, and the list of other sports is constantly growing.

The objective of the research conducted by the author is to gather and summarize the most popular uses of Machine Learning in sports, and to present how this research methodology influences and challenges the process of decision making in Sports. Some of the exemplary uses of Machine Learning in Sports are also analyzed, as well as other technologies, which enable amazing progress in the development of Sports disciplines in combination with Machine Learning.

An analysis of molecular information transfer in Melanoma Metastasis Formation by combining Bioinformatics and Systems

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"The transfer of molecular information between cells is crucial in the formation of metastasis. One of the fundamental mechanisms used in this cell-to-cell crosstalk is extracellular vesicles (EVs). EVs transport nucleic acids, proteins and other bioactive molecules that modify the functions of the target cells. Next-generation sequencing methods allow tracking this process and decode vital biological signatures. Understanding the interactions between multi-dimensional biological data generated using different NGS methods and other platforms is a huge bioinformatic challenge. In such analyzes, the integration of multiple OMICS datasets together and the selection of variables is the key to obtaining interpretable results. Canonical Coronation Analysis (CCA) paired with Systems Biology is one of the most powerful duos for this research task. Over the last years, several promising results for implementing CCA in the integration of OMICS data have been proposed. To be able to analyze multi-OMICS datasets in the context of systems biology, an optimal approach to data integration, analysis and interpretation should be developed.

Here we introduce a canonical correlation analysis- based bioinformatics pipeline, that uses a multi-OMICS dataset to study molecular information transfer in melanoma metastasis formation. The input contains human skin melanoma data: (1) microvesicle-micro-RNA transcriptomics, (2) microvesicle proteomics, (3) cell-total-RNA transcriptomics. The proposed method applies a sparse CCA (sCCA) to three matrices, starting from the integration of experimental data. Validation using clinical data as well as supporting meta-data from databases allows the identification of highly significant molecular signatures. Based on that findings we generate mechanistic and functional hypotheses.

Dimensionality reduction on multi-omics data towards personalized medicine

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Modern high-throughput technologies allow us to collect massive amounts of multi-omics data. We can source data of different types (metabolome, transcriptome, proteome, genome, etc) for one biological experiment which could be analyzed collectively. Integrative analysis of those multi-dimensional biological data is key to understanding data itself, correlation, and causation.

In simultaneous analysis of multiple multi-dimensional data sets, we can use many methods which can lead to the understanding of data from different perspectives and can provide valuable guidance for inference. We have applied a few classical methods for dimensionality reduction to analyze combined data from microvesicle-micro-RNA transcriptomics, microvesicle proteomics, cell-total-RNA transcriptomics.

The presented results show comparing the methods used in the analysis of the above-mentioned data, with an emphasis on reducing the dimensionality of these data. We mostly focused on the "Partial Least Squares" family methods, as well as the Principal Component Analysis and Canonical Correlation (CCA and sparse CCA).

Segmentation of trypan blue stained hepatocitesin microscopic image

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Automatic detection and count of cells in microscopic images of cellular suspension could provide a useful tool for scientists, that have to perform this task by hand.

This paper presents an algorithm that can count and outline hepatocytes using a set of filters and texture analysis. On microscopic images of the suspended cell, a certain texture can be noticed on hepatocytes. This property of cells can be used in order to segment hepatocyte cells out of the image and leave other objects like erythrocytes and random debris untouched.

Described sets of filters and algorithms were tested in ImageJ distribution Fiji and ImageJ plugin MorphoLib.

Set of filters and algorithms that were used prior to morphological segmentation were in order: Enhancing local contrast using CLAHE algorithm, Morphological gradient with a structural element of the disk with radius 2, Anisotropic Diffusion, Sobel edge detector.

Those actions provide a good baseline for carrying out the segmentation of cells.

After this set of filters, morphological segmentation is carried out which consists of: Morphological gradient with structural element of disk with radius 2, Imposing minima, Watershed flooding.

Chosen set of filters and algorithms is able to segment out dead and alive cells from the image.

Further improving and developing of the algorithm is planned. Clustered cells need to be separated. When this goal is accomplished cells can be counted and an algorithm that is capable of classification of cells as dead or alive will be developed.

Analysis of voltammetric signals with chemometric techniques in fruit juices quality control

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Globalization of the food market has made consumers more vigilant about the quality of the products they buy. As a result, all over the world they attach great importance to the quality control of products that are available on the market. Fruit juices are a popular and frequently consumed drink. They owe their position in the market to a positive impact on human health. Fruit juices are a valuable source of vitamins, minerals and bioactive compounds. In the European Union, the average common citizen drinks 11.6 liters of fruit juice per year (Raport Market AIJN 2018). Often, sugar or Glucose - Fructose Syrup (GFS) is added to commercial juices. The addition of syrup is socially considered one of the causes of increasing obesity in society, especially among children [1-2].

In the study, combinations of analytical and chemometric techniques were used to evaluate the controlled GFS additives to apple juice (up to 50% by volume). The experiment included 17 apple juices of various origins. The data for the analysis was obtained by the differential pulse voltammetry technique with the use of an innovative quadruple-disc iridium electrode. Machine learning methods, i.e. linear regression algorithms (partial least squares - PLS, interval partial least squares - iPLS, principal components regression - PCR) and deep neural networks were used for chemometric analysis. The calibration models were constructed in the work for single juices and one universal for all juices. The calculations were realized in Python 3.8 with Keras 2.3 with TensorFlow 2.0 backend [3].

The measurements were performed under strictly controlled and optimized conditions. The use of the optimal interpretative approach, using the recurrent multi-layer neural networks with LSTM layer, allowed to achieve the assumed goal of the work. The value of the root mean squared error of prediction (RMSEP) was 1.9 - 2.1% of the GFS addition with the correlation (R2PRED) above 0.98. This approach made it possible to develop a universal procedure for testing the GFS content in apple juices.

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Influence of artefact removal on machine learning classification results in memory task EEG signal processing

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Pre-processing of EEG data before submitting them to machine learning algorithms is a common practice. Although most studies use frequency domain filters and some form of artefact removal methods, the effect of these data manipulations on classification results was not specifically investigated. EEG artefacts such as eye blinks or muscular electrical activity are characterized by amplitudes an order higher than brain signal and may mislead machine learning methods. This may be especially important in the case of artefact synchronization with the task itself. Eye blinks and jaw's muscles often accompany the execution of difficult tasks, which may bias classification results. On other hand, any form of artefact removal also reduces brain signal available for classification which may hinder classification.

Here we attempted to evaluate the effect of artefacts removal on the classification of memory task performed by multilayer perceptron on handcrafted features. For the features, we choose power spectra, as they are potentially most vulnerable to muscle and eye blink artefacts and coherence as one of the most robust feature. For comparisons, we used data cleaned by an automated procedure and raw signal.

Implementation of modern brain images analysis methods for the brain cancer diagnostics purposes

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Brain cancer is very hard to detect type of cancer, with frequently no visible signs until it gets more advanced and until it is too late for appropriate treatment application. Also the current medical situation, affected with the COVID made the access to appropriate diagnosis more difficult. Magnetic Resonance Imaging (MRI) is a very safe and efficient diagnostic method, although the equipment is very pricey and numerous clinics have no access to that. The MRI measurement is non-invasive and safe for patients and provides information regarding patients' brains with no need for brain surgery. When it comes to diagnostics it can be a good alternative to surgical intervention, which is still being used in clinics with no access to the MRI. In this paper some of the most popular methods for analysis of brain images recorded for the purpose of brain cancer diagnostics were briefly presented. This paper also covers the issues related with brain cancer diagnosis and some of the current most common methodologies. This work also contains some sample data analysis carried out by the authors of this work in order to show the efficiency of some of the most popular analysis methods applied for the purpose of MRI data analysis. The data used for this study was obtained from an open source data-base. The study described in this paper is of initial character, however, the obtained results were promising and proved the necessity and equity for applying them in the whole brain cancer diagnostic process.

Use of basic smoothing filters in analysis of electroencephalography data as a tool for assessment predisposition to alcohol addiction

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Alcoholism is one of the most popular addictions in the world, mostly due to the ease in obtaining the addicting substance - alcohol itself. The problem level is constantly growing. Also more and more young people become alcohol addicted and results of such situations affect the whole society. Also the current COVID situation with isolation made more people reach for alcohol. There are various favourable conditions for this type of addiction, such as among the others social or genetic. In this paper authors decided to analyse electroencephalography (EEG) data from an open source database using inter alia smoothing filters in order to check whether it is possible to assess vulnerability to addiction based on EEG data analysis only. It is also a well-known fact that alcohol (or any other drug) affects the quality of brain signals, to which the EEGs count. The choice for using smoothing filters was made based on some of the authors' experience with this type of data. The EEG data is of non-stationary character, prone to various artifacts and disturbances. Filtering of these data is a very challenging task as the EEG data can be characterised with low amplitude spectrum and frequency ranges. The applied filters made the data more legible and easy for diagnostics regarding alcohol addiction vulnerability purposes. The smoothing filters are a very good tool for filtering biomedical data, as they do not filter out too much important information. One of the most popular and efficient smoothing filters is Savitzky-Golay (S-G) filter, which has been applied in this study. In this work the data from alcohol addicted was compared with the data from the healthy (not addicted) control group.

Brain-computer interface for electric wheelchair based on alpha waves of EEG signal

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Helping patients suffering from serious neurological diseases that lead to hindering the independent movement is high of social importance and an interdisciplinary challenge for engineers. BCI interfaces based on the EEG signal, are not easy to use as they require time consuming multiple electrodes montage. We aimed to contribute in bringing BCI systems outside the laboratories so that it could be more accessible to patients, by designing a wheelchair fully controlled by an algorithm using alpha waves and only a small number of electrodes. The set of eight binary words are designed, that allow to move forward, backward, turn right and left, rotate 45 degrees as well as to increase and decrease the speed of the wheelchair. Our project includes: development of a mobile application which is used as graphical user interface, real-time signal processing of the EEG signal, development of electric wheelchair engines control system and mechanical construction. The average sensitivity, without training, was 79.58% and specificity 97.08%, on persons who had no previous contact with BCI. The proposed system can be helpful for people suffering from incurable diseases that make them closed in their bodies and for whom communication with the surrounding world is almost impossible.

Comparison of Data Distribution vs Data Quantity Influence on the Efficacy of Trained Deep Learning Model

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In recent years we are experiencing rapid development in Artificial Intelligence, Computer Vision and Robotics. Today it is not unusual to see robots working at a front desk as receptionists. In order to improve man-machine interaction it becomes necessary to be able to read facial expressions and emotions of human interlocutors. By combining Computer Vision with Artificial Intelligence it becomes possible to teach machines to recognize facial expressions and therefore lay the ground for further development of more advanced systems.

To detect faces the authors have used CUDA accelerated OpenCV DNN module. To recognize facial expression Deep Learning was used, as it is proven to perform well in Computer Vision tasks. The proposed implementation of Deep Learning model is performed in TensorFlow using the built in Keras API. The well-known AffectNet Dataset, which consists of hundreds of thousands images of labeled faces, was used for training the model. Having a dataset which was large enough, the Convolutional Neural Network was modeled, then the model was trained, tested and improved multiple times.

Initial results are promising, achieving over 70% accuracy in evaluation, with high potential for further improvement of model accuracy and for decreasing loss value. Due to uneven data distribution in the Dataset, the model achieved exceptionally well results in cases when it was recognizing classes with a greater share in the Dataset, and performed poorly with the classes of smaller share. In order to decrease loss value and thus potentially improve model accuracy or at least its certainty it is necessary to train model using more leveled data distribution, even at a cost of sacrificing overall data quantity.

A review of methods for analysis of emotions from the electroencephalography signals

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Emotions are considered to be an affective phenomena which change over time and can be triggered by either external or internal stimuli. Discussion about the nature of emotions, their functions, their relation to broad affective dimensions, the processes that activate them, and their role in everyday life is still emerging. Continued advances and research on human-computer interactions have led to the possibility of enhancing the human-computer interactions with an emotional context. However, in order to create a two-directional emotional link between a human and a computer, first a reliable approach to recognize human emotions is necessary. Human emotions can be recognized via different approaches, i.e. by analysing gestures or postural movements. Facial expressions, speech, or physiological signals are also techniques commonly used for emotion recognition. The problem is that the majority of these approaches might be ineffective because people may unintentionally or intentionally hide their true emotions. Only physiological signals, independent from human will, can lead to objective and reliable emotion recognition. Among all the physiological signals, the one that provides the richest emotional insight is an electroencephalographic (EEG) signal. This signal non-invasively measures the electrical activity of neurons in the human brain. The study of emotions based on EEG signals is still an ongoing topic with challenging issues concerning the methodology for translating signals to emotional states. The aim of this paper is to provide a review of methods used for emotion recognition from EEG signals, with the main focus on extracting features for optimal classification performance.

Brain-Computer Interface optimization with EEG-based detection of different types of errors

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Noninvasive brain-computer interfaces (BCIs), systems that allow for human-computer communication based on the detection and classification of signals from cortical brain activity, often using electroencephalography, are a tool for neurorehabilitation and daily support of people with limited mobility and communication (Rak et al., 2012). The high error rate of command recognition in BCIs makes optimizing their performance an important current challenge. One method of improving BCI reliability is to use information about the user's cognitive state to identify errors made by the interface (Chavarriaga et al., 2014). Error-related potentials (ErrPs) are characteristic EEG waveforms that can be found when an erroneous response is made in choice reaction tasks, also in human-computer interaction, when the user's command is misinterpreted. Interaction ErrPs can serve as a real-time source of information about an incorrect performance of the interface that can be employed to improve accuracy and real-time control of brain-computer interfaces.

Recent research has shown that it is possible to correct an error or to adapt the signal classifier when an occurrence of an error is automatically recognized, based on the EEG signal analysis (Chavarriaga et al., 2014; Mousavi et al., 2020; Yousefi et al., 2019). In the present study, we contribute to the research on the applicability of error-related brain activity as a feedback information source for BCI systems. The novelty of our research is that we use an experimental environment that exploits participants' natural motivation to perform well, but may create more difficulty in the precision of EEG measurement than a typical laboratory environment, as there are no clear-cut intervals between stimuli. The study was carried out on 15 subjects, who were asked to participate in a simple platform game task, in which an erroneous response to pressing the spacebar was randomly generated. Analysis of the collected EEG signal allowed to characterize the interaction error-related potential, present during the failed command execution, and the feedback error-related potential that corresponded to the collision followed by the end game screen after an error was made by the subject.

To evaluate the effectiveness of automatic error detection based on the signal elicited in a single trial, we used two classifiers based on machine learning methods. The first one allowed to distinguish between brain responses to errors of different origin and correct trials, while the second classifier specifically distinguished between brain responses to interface malfunction and events where the interface worked correctly. Before classification, the EEG data were preprocessed. Waveforms in time windows corresponding to the stimuli occurrences, i.e. interface errors, user errors or correct key presses, were cut. The values of 17 morphological features (Abootalebi et al., 2009) were calculated for each waveform, separately for each of 8 electrodes; each waveform was described by 136 features in total. A genetic algorithm was used for feature selection. As a result, we achieved an average accuracy of around 80% for both classifiers. The feature sets that enabled the best classification accuracy in both conditions were also obtained.

Our results show that error-related potentials can be successfully utilized in the automated optimization of brain-computer interfaces. It is possible to not only detect the bioelectrical correlates of error detection in EEG signals acquired during single-trial, spontaneous perception of errors during gameplay, but also to distinguish whether an error was made as a result of the incorrect performance of the interface or a mistake made by the user. This implies that BCIs can be improved by incorporating error-related brain activity recognition for real-time error correction and error-based learning.

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Brain-Computer Interfaces; EEG signal classification; Error-related Potentials; Event-related Potentials

Review of the application of the most current sophisticated image processing methods for the skin cancer diagnostics purposes

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This paper presents the most current and innovative solutions applying modern digital image processing methods for the purpose of skin cancer diagnostics. Skin cancer is one of the most common types of cancers. It is said that in the USA only, one in six people will develop skin cancer and this trend is constantly increasing. Implementation of new, non-invasive methods plays a crucial role in both identification and prevention of skin cancer occurrence. Early diagnosis and treatment are needed in order to decrease the number of deaths due to this disease. This paper also contains some information regarding the most common skin cancer types, mortality and epidemiological data for Poland, Europe, Canada and the USA. It also covers the most efficient and modern image recognition methods based on the artificial intelligence applied currently for diagnostics purposes. In this work, both professional, sophisticated as well as inexpensive solutions were presented. This paper is a review paper and covers the period of 2015 and 2021 when it comes to solutions and statistics. The authors decided to focus on the latest data, mostly due to the rapid technology development and increased number of new methods, which positively affects diagnosis and prognosis.

Design and concept of an innovative wheelchair for special tasks, controlled by biomedical signals

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The main aim of this project was to create a means of transport, in this case - a modern wheelchair for disabled people, which would be controlled by biomedical signals. The article describes the concept of a vehicle, which, unlike traditional devices of this type, was designed for driving in the so-called difficult conditions. The presented project illustrates a trolley that uses various types of biomedical signals, and in addition to fulfilling its basic function - transport, it is to enable overcoming the barrier, which is difficult terrain, on which moving on classic wheelchairs is often impossible. The aim of creating this project was to go beyond the existing devices supporting people with disabilities and enable them to enjoy life to a greater extent and increase their independence in overcoming various types of routes. In this paper also the psychosociological aspect of physical impairment was presented, which was one of the main motivations for this work. It also covers some of the existing solutions and interesting prototypes. Some of the most current methods for the analysis of biomedical data were also covered with this paper, which also contains a description of the most common diseases affecting human motor abilities.

Design of a hand orthosis manufactured by 3D printing

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The aim of the project is to design and manufacture a hand orthosis using the 3D printing method for an individual problem. Additive manufacture is a technological process which could be alternatively called “incremental shaping” and it is based on the layer-by-layer production of the designed components from wide variety of materials. Currently, the process is most often used for rapid prototyping, which enables dynamic modifications of the created elements as well as individual adjustment of the solution.

The purpose of producing a exo-prosthesis is to enable cycling in the case of post-accident hand paresis (paralysis). Paresis is a decrease in muscle strength which limits the range of motion. The problem that has arisen is the inability to tighten the muscles that prevent the transfer of loads.

The task of the project is to solve the problem of the stabilization of the joint and the arm section during dynamic bicycle descents, during which it is necessary to properly compensate the pressures and vibrations on the upper limb. The stabilizer should be properly designed to allow the mobility of the joints and, at the same time, to stiffen the relevant sections, thus allowing freedom of movement.

An individual 3D-scan of the arm will be used for the design – this enables to be sure, that the arm fits well with the orthosis design. Design accuracy will ensure a solid support and appropriate adjustment of mechanical elements to the disabled arm.

Commercial technological solutions to similar problems are currently unavailable on the market. The projects are created individually, which is a big problem for people with a similar disability. The inability to purchase a ready-made solution limits disabled people in their daily existence.

Spheroids as 3D systems for cancer research – comparison of different laboratory approaches

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Spheroids, cellular aggregates, appeared to be the most promising *in vitro* model for preclinical research. As 3D systems, they mimic structure, physiological properties, micro-environment, and gene expression patterns which are observed in solid tumors. A typical spheroid is a three-layered cell culture with proliferation rim in outermost, quiescent layer, and necrotic core in the innermost part of the spheroids [1-2].

The aim of this research was analysis of growth rate, shape and viability of spheroids developed from two human melanoma cell lines with different malignancy level (WM115 - primary tumor, WM266-4 - metastasis). Two different methods for spheroid culture were compared: hanging-drop and low adhesive 96-well plate.

In the first step, the dynamic of growth was evaluated by the analysis of the spheroid diameter. The shape of the spheroids was characterized by analysis of two different parameters by means of the ImageJ software (FIJI): solidity, circularity. The size of spheroids increased with the time of culturing and depended on the number of cells seeded and culturing method.

After 7 days in low adhesive 96-plate culture, the diameter of spheroids reached 657.8 μm and 887.6 μm for WM266-4 and WM115 respectively, while in hanging drop method, the diameter of spheroids reached 525 μm and 480 μm for WM266-4 and WM115, respectively. In the next step, the viability of spheroids was evaluated using the fluorescent microscopy and flow cytometry. With spheroid grow, the necrotic core increased and viable cells appeared only in quiescent layer and proliferating rim. The results from low adhesive plates method shows viability of cell ranged from 91.6% to 93.2% and from 65.4% to 72.7% for WM266 and WM115 cell line respectively, while in hanging-drop viability changed from 99.51% to 86.34% and from 99.96% to 70.65% for WM266-4 and WM115 cell lines respectively.

Depending on the methodology, shape, growth rate and solidity of spheroids were different and changed in different extend [3]. Our study on spheroids development and characteristics can help in further research on the effectiveness of boron neutron capture therapy (BNCT) and application of positronium as a new biomarker for the *in vivo* determination of cancer malignancy with total-body PET scanners [2,4].

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Liquid State Machines in parallel simulations of mammalian visual system on Raspberry Pi

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We examine the Liquid State Machines (LSM) in parallel simulations of a model of mammalian visual system. The LSM has emerged as a computational model that is more adequate than the Turing machine for describing computations in biological networks of neurons. Our model is built of Hodgkin-Huxley neural cells, which are organized into Retina (Input), and a modular Cortex built with four computational LSM columns.

The aim of this work is to examine how that architecture adapts to parallelization on multi-core machines. The authors propose an affordable system for neuromorphic computations that removes entry barriers and provides easy access to neural simulations. This is achieved by combining a free and open software with an affordable computer hardware that costs less than EUR 100 (PLN 389).

We perform simulations using the GEneral NEural SImulation System (GENESIS). The set of 4 Liquid State Machines, each consisting of 1024 Hodgkin-Huxley neurons, was simulated on a small, single-board, quad-core Raspberry Pi 4B computer. We propose a model that uses multiple cores to ensure scalability.

The results obtained by the computational model will be discussed. We explore the dynamics of each neural column in our system. Additionally, benchmarking results for using the traditional and parallel architectures will be presented to some extent. The research presented herein provides a good starting point for designing more advanced simulations of larger parts of the mammalian brain cortex on supercomputers, and it leads to a better understanding of the functionality of the human brain.

The SIR compartmental models in the study of the COVID-19 virus spread in Poland

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Infectious disease epidemiology is the study which aims to explain the complex relationships among the infectious agents (including viruses) and hosts [1]. Epidemiologists are tasked with establishing virus spread with or without disease. The main goal of viral epidemiologists is to predict the development of epidemics and determine interventions which could contain a virus outbreak. Mathematical modelling of infectious disease uses different approaches to predict spread of pandemic. One of its fields deals with the compartmental models. The SIR model [2] is a basic example of such a model and is used in epidemiology of infectious diseases. It can be used to predict the spread of disease based on the previously collected data. Thanks to that, it is possible to undertake suitable steps which can help with reducing or slowing down the development of the epidemic.

The aim of this work was to conduct the study of the spread of the COVID-19 in Poland to compare two separate SIR models and assess how they help with controlling the spread of the disease. First model was created by Batista [3] and the other one was self-made. The main difference between them is the definition of the N value, which in first case is delivered for each model separately [3], and in second one is understood as the number of the total population [4]. Based on the collected data (daily infected, recovered and dead), the contact and removal rate were estimated. This allowed for prediction of the spread of the pandemic, which was performed not only for the whole country, but also for three of its

voivodeships (Silesian, Lubusz and Lesser Poland) for the time period between 04.03.2020 and 15.11.2020. Different phases of COVID-19 spread were introduced based on various restrictions that were set in place and parameters for each one of them were estimated. The modelling was done using MATLAB 2019b. The results show different possible outcomes of the propagation of the COVID-19 in Poland. It turned out that even a small amount of additional data can significantly change the modelled spread of the pandemic. Moreover, it was found that the development of the disease in Poland can be divided by various criteria. What is more, it was concluded that the spread of the pandemic is dependent on the number of people living per given area. Furthermore, it was established that the results are influenced by the number of tests done per day. Because of that, the possible development of the model was presented in connection to its limitation. One of the things which is worth considering is to add one more compartment that would deal with the number of deaths separately from people who recovered (so called SIRD model). Moreover, as the vaccination against COVID-19 is progressing, it would be advised to study the probability of a person injected acting as the carrier of the disease. In the end it is important to remember that presented models can only try to describe the probable development of COVID-19 spread in Poland for particular voivodeships. Their results will not be able to give the definitive prediction of development of the pandemic.

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Unique Application of Mixed Reality to Reduce Preoperative Stress Levels in Surgical Oncology Patients

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The goal of this pilot study was to assess whether preoperative stress levels in surgical oncology patients may be mitigated through patient education. This was accomplished by transforming CT and MRI files into segmented models using 3D slicer, an NIH funded medical imaging analysis and visualization software, then displaying those models utilizing augmented reality via the Microsoft HoloLens 2. Given the well-documented relationship between preoperative stress and negative post-operative sequelae including increased length of stay and complications, a means of decreasing stress through increased understanding and relatability may benefit both patient and care-providing institutions. For the pilot phase of this prospective cohort study, six surgical oncology patients who were scheduled for operations covering hepatobiliary, endocrine, colorectal, pancreatic, and gastric procedures were recruited. These patients received standard of care instruction during pre-operative clinic visits prior to their pre-operative admission. Radiological scans were anonymized, segmented, and validated by a staff radiologist for anatomical validity prior to being shown to the patient using two HoloLens 2 devices, with the primary unit controlling the view on the secondary unit that patients wore. The day before surgery, patients completed a 7-point Likert Amsterdam Preoperative Anxiety and Information Scale along with the Brief Measure of Emotional Preoperative Stress scale prior to viewing the holographic model to determine baseline stress. Subsequently, each patient was shown the holographic model created from their CT or MRI scan and given the opportunity to ask questions and provide commentary during a 10-15-minute period, after which a repeat stress questionnaire was administered. Patients were followed post-operatively for complications. As a cohort comparing before viewing to after viewing the model, patients expressed a decreased level of stress (5.5 vs 2.7) and anxiety (5.7 vs 2.8), along with increased comprehension (1.5 vs 5.7) and engagement with their diagnosis and surgical plan (2.7 vs 5.2). To date no complications have been reported among discharged and inpatient subjects. This study highlights the immense impact that patient education may have in mitigating pre-operative stress levels. Given the established positive correlation between stress and post-operative complications that are associated with increased costs and morbidity, this strategy creates a unique opportunity to address the issue before it arises. While this pilot study is promising, continued data collection is ongoing.

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Using MRI data segmentation to deliver a 3D model that can be presented in mixed reality techniques – key difficulties and conclusion in regard to cerebral vessel imaging – case study

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Mixed reality techniques, such as holographic vision can be used to better visualize medical images, whether for pre-operative/clinical assessment or educational purposes. The possibility of interaction with a 3D model located in mixed reality instead of an usual 2D MRI scan slices shown on a screen, allows the user to better understand the shape, proportions and relations in space between presented objects, which can help a surgeon plan the operation or be an aid for students or patients to clearly visualize and understand the anatomy/pathology. In order to be able to create a model that can be shown in mixed reality, the 2D MRI data needs to be carefully processed and whether this process can be done yielding an valuable, high quality model, depends on a number of factors. The most important one of those is the quality of source data. In this case study, an anonymized DICOM dataset has been processed using an open-source software (3D Slicer v4.11). After analysis of 14 MRI series, the final source series consisted of 170 images, 640x640px in size, with acceptable contrast between tissues. After adjusting the Hounsfield window in Volumes module, a segment has been created in the Segment Editor, with Threshold tool being used in order to try and separate the cerebral vessels from the rest of the image. Due to the nature of the data, there has been no threshold value that would separate the arteries from a number of high-intensity points located mainly in the white matter and skull bone marrow. Using the fact that vessels are continuous and form connections with each other (no artifacts disrupting the continuity of any major vessels have been found in this MRI), the “Islands” function has been used on the model. Using “Keep largest island” algorithm would lead to elimination of the posterior cerebral circulation in this case, due to complete lack of posterior communicating arteries. Instead, after few adjustments, “Remove small islands” allowed the 3D model to consist of 4 segments of connected voxels (Islands). Two of these have been main vessels of anterior and posterior cerebral circulation respectively, and remaining two have been removed manually using “Scissors” function. Because structures of the body in general have a smooth surface, a good practice is to use Smoothing before finishing the model. This tool needs to be used with extreme precision when working on vessel models, both in regard to the algorithm (using opening or closing algorithm could lead to dangerous artifacts, gaussian and joint smoothing would destroy the image) and kernel size. Using median algorithm with kernel size 1mm allows for satisfactory smoothing of the surface without major information loss or artifact creation in this case. As the model is ready, it is exported as a.STL file that can be easily shown in mixed reality setups to help understand the condition it presents. This format would also allow 3D printing of the model. In conclusion – using a simple MRI dataset and open-source software, despite difficulties, a 3D.stl model can be prepared to be presented in mixed reality for better understanding of complex cases regarding cerebral vessels.

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Developing acquisition sequences for future use in the segmentation process

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Segmentation is the process of reconstructing (reverse engineering) medical imaging exams, like CT, MR, CBCT, Pet-CT, etc. Its result is a 3D solid anatomical structure representing the region (ROI) or its part. The purpose of such activities is to enhance the imaging diagnosis with additional information. The resulting model can be displayed using modern imaging techniques and 3D printing (Medical Addictive Manufacturing - MAM). As segmentation is based only on image data, their quality of such exams determines the scale of errors acquires in the reconstructed model.

A patient (14 years old) head an abdominal examination (CT with contrast) identify the pathology occurring in the area of the liver. The examination showed a cyst located at the base of the second quadrant. Based on the obtained data, the physicians' asked medical image specialists to process the segmentation. Due to the quality of the exam, it was impossible to visualize the bile ducts and blood vessels around the tumor. Another examination was performed, but this time MR was used (without applying contrast). Based on the performed examination, several new sequences have been developed that enable. The comparison of the results between the standard examination: CT + contrast and the use of specially developed MR sequences (without providing contrast) showed a significant difference in favor of MR.

Segmentation might be a reason to create non-standard protocols. That approach not only significantly improves the quality of the segmented model but also increases imaging quality and might be more beneficial for radiological diagnose.

Digital hearts - analysis of 3D segmented medical images with the use of Microsoft HoloLens

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The analysis of medical images in the form of segmentation plays a key role in the preoperative patient's assessment undertaken in clinics around the world. Planning treatments based on precise body models allows for better understanding of complex and unique human anatomy which reduces the risk of complications. Frequent outcomes in the form of computer visualization or 3D printing have their limitations such as high costs of printing materials, narrow sensory activation or restricted approach to individual compounds. In our opinion, present development of mixed-reality could help the process both before and during the procedure by creating an innovative refinement. Our case-report aims to validate mixed-reality using Microsoft HoloLens 2 based on 3D medical imaging segmentation. In order to demonstrate the versatility and potential of this multisensory integration method, two independent 3D cardiac models with comorbid cardiovascular defects have been prepared with the use of specialized graphic software. The obtained angio-CT examinations of the patient's thorax with various cardiovascular pathologies were subjected to the process of manual segmentation with particular emphasis on the flow of the marker through the heart and vessels. Based on CT raw data, semi-automatic heart segmentation of two medical cases has been performed. Each case was developed with the help of a different program - Mimics Medical and 3D Slicer. Quality of the image data needed to perform the segmentation to a large degree determines the outcomes. The distortions caused by numerous factors have been smoothed out with the estimation of the proper boundaries of the given structures. Additionally, selected thoracic structures have been specified to establish the location and mutual relations of individual organs. Creating the models, special emphasis was put on the details to maintain the highest possible diagnostic value. The use of mixed-reality enables multi-sensory activation and expanded interaction with the medical model in an advanced way that allows for even more detailed exploration of the multi-faceted structure of the medical models. Future investigations are pivotal to deliver superior user experience.

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Comprehensive medical data management - Holographic MedAssistant

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The project aims to develop a holographic medical assistant (Holographic MedAssistant) using an advanced holographic technology device - Microsoft's Azure Kinect DK camera and HoloLens 2 glasses. The project deals with digitalization and augmented reality use in rooms where doctors work, such as a doctor's office, an operating room, and a treatment room. The proposed solution will give new possibilities and enable additional support in the clinical diagnosis process, during medical procedures and the preview of the procedure from a different non-standard location without spatial restrictions related to the perspective of the Operator. The project will develop and implement methods for effective diagnostics and interpretation of biomedical signals and images (new effective classifiers) using Shannon's Information Theory and Artificial Intelligence (deep neural networks, spiking neural networks). It is planned to verify the proposed solutions using the methods of Biostatistics based on Mixed Models. The results obtained will allow doctor's access to innovative tools supporting the clinical diagnosis process and performing medical procedures. Both, the system and the application will make a significant contribution to improving the quality of work, training and the quality of performed treatments. Moreover, result of the project has wide application field, among others: training of doctors, assisting during diagnostics through support in selecting a patient's disease with the use of artificial intelligence module, assisting physicians from other hospitals/medical facilities in performing more complex procedures, virtual medical consultations with specialists in other fields without having to leave the treatment room. The novelty of the project is to combine visualization of surgical room, the patient's medical data with an automatic interpretation regarding the patient's health status.

A new visualization tool for advanced personalized medical education has been proposed.

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Social Paranoia Can Be Triggered by 360-Degree Videos in Virtual Reality: A Pilot of the patients with schizophrenia

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Virtual Reality (VR) has been widely used in psychiatry, including psychotic disorders. Since early 2000s, there has been plenty of research conducted on the mechanisms, symptom assessment and most recently – therapy of paranoia. The main advantage of VR is its high ecological validity and controllability of the virtual environment. Until now, one of the barriers preventing further dissemination of this technology was its high cost. Although the majority of research utilized computer generated virtual environments, there were some attempts to use 360-degree videos. Our main goal was to test whether, similarly to computer-generated VR, 360-degree videos are able to elicit a state of social paranoia in prone

individuals. Sixteen schizophrenia patients and twenty-three healthy individuals were recruited for the study. Both groups were assessed using Leibowitz Social Anxiety Scale (LSAS) and State-Trait Anxiety Inventory (STAI). Additionally, in the patient group, Positive and Negative Syndrome Scale (PANSS-6) and Peters Delusional Inventory were used. The participants viewed four 360-degree videos recorded in Cracow, with and without social stressors. The videos were presented on Gear VR goggles in two series with a simultaneous measurement of heart rate. Each series consisted of one neutral and one social video. Momentary anxiety and sense of presence were assessed with one-item scales, while paranoia with a social state paranoia scale (SSPS). The schizophrenia patients reported higher momentary anxiety, although the results of SSPS did not differ significantly between groups. A significant difference in heart rate resulting from interaction between group and video type, i.e. the first neutral and social video was observed, with patients experiencing an increase in heart rate and controls experiencing a decrease. There was a significant correlation of paranoid ideation experienced on daily basis (PDI) and elicited in VR (SPSS) in the patient group. Both patients and healthy controls reported relatively high sense of presence and positively rated the videos, although some of the subjects complained on lack of interaction. Paranoid responses can be triggered in patients with schizophrenia by 360-degree videos. Further studies are needed to investigate the potential of using 360-degree videos for treatment of paranoia in psychotic disorders.

Decrease in oculomotor performance in Alzheimer's disease

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INTRODUCTION: One of the neurodegenerative diseases that affect the patient by progressively decreasing cognitive functioning is Alzheimer disease (AD). It is the most common form of dementia, with the prevalence continuing to grow in part because of the aging world population. Cognitive impairment, as the most crucial aspect for the diagnosis, includes progressive memory loss, impaired attention, decrease in executive functioning, aphasia, praxis and complex visual processing deficit, which seems to be overlooked in AD studies. To date, there are some deficits that have been described, such as: impairments in motion perception and visuospatial processing. So far, the most frequently used eye tracking tests for AD patients are these that detect fixation, saccadic, and smooth pursuit tasks. There are already some characteristic findings: less accurate and increased saccadic movement, but higher number of saccades, along with shorter duration of fixation than in healthy controls.
MATERIAL AND METHODS: 104 people took part in the study. 30 people with mild and moderate Alzheimer's disease and 74 people in the control group matched for age and demographic characteristics. The Saccadometer Advanced measuring device was used in the study. The oculometric test called LAT (Latency Task) consisted in the fastest possible fixation of eyesight on a light point (produced by a laser) changing its position randomly along the horizontal axis, every 10deg. The parameters of horizontal eye movement in the range of 20deg (± 10deg from the central fixation position) were analyzed. Saccades performed in the direction of the stimulus were called - correct saccades, while saccades performed in a direction other than the stimulus - incorrect saccades. Each test consists of 10 calibration tests and 50 tests of the actual test (analyzed statistically). The STATISTICA 12 software was used. The distributions of the analyzed variables were checked using tests of normality and homogeneity of variance. Most of the variables differed from the normal distribution (Lilliefors $p < 0.05$, Shapiro-Wilk W $p < 0.05$), therefore it was decided to use the non-parametric Mann-Whitney U test of significance of differences.
RESULTS: The number of incorrect saccades in people with AD is over 30% higher, and the number of correct saccades is almost 12% lower than in the control group. The mean latency of correct saccades in people with AD is over 37% longer (statistically significant difference $p = 0.0000$), and the latency of left-sided correct saccades is 41% longer than in the control group ($p = 0.0000$). According to the ROC analysis, the best predictor is the mean latency of correct saccades, the area under the curve is 0.811, while the cut-off point suggested in this analysis is the result of 329 ms (above this latency value can be inferred about the disease), the correct intersection points are 282 ms and 77%.

CONCLUSION: The measurement of the dynamics of eye movement seems to be a good method for monitoring motor disorders in Alzheimer's disease. Oculomotor examination using the Saccadometer measuring system, which is automated and self-calibrating, was used in the clinic with good results, only the data analysis is complicated and it would be worth developing an automatic calculation of these parameters.

3D RECONSTRUCTION AND MIXED REALITY OF THE RADICULAR CYST AS A METHOD OF VISUALISATION IN DENTISTRY

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Background: Cysts are the most common pathological changes in the jaws and periarticular cysts are the most common type of cyst in the facial skeleton. Diagnosis and treatment outcome evaluation is traditionally based on the radiological examination like periapical X-ray pictures and cone-beam computed tomography (CBCT) imaging.
Aim: The study aimed to present the case of a patient with the use of 3D models and evaluate the advantages of this method compared to the traditional 2D imaging.
Materials and methods: 70-year-old patient of the University Dental Clinic in Krakow with an inflammatory cyst in the maxilla had been surgically treated. The treatment started with the antiseptic root canal treatment (conservative method) and the healing process was assessed using a stock of 2D radiological images. Because of the lack of evident signs of the healing of the periapical tissues after 16 months – surgical two-stage treatment was implemented. CBCTs were performed preoperatively, 5 months and 13 months after decompression procedure. Based on CBCT exams segmentation process was made. Its purpose was to reconstruct data shown on 2D images and convert them to a 3D model. Such model can be visualized using VR (virtual reality), AR (augmented reality), etc. or 3D printed. The studies showing the segmentation process (generating a 3D model based on 2D imaging) may increase diagnostic data and help validate the diagnosis. Segmentation (3D reconstruction) revealed the detail of the pathology, as well as comfortable and easy-accessible insight into the structures that ware captured in radiological examination. The possibility of preparing a cross-section of pathology was also appreciated. Conclusions: 3D digital models provide good quality medical documentation of treatment. Structures/ pathologies that are easy to overlook are more distinct here. This visualization may be specially valuable in treatment planning and dental education.

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ANALYSIS OF BIOMECHANICAL SIGNALS IN THE SUBCLINICAL ASSESSMENT OF PSYCHOMOTOR FUNCTIONS IN SENSORY-MOTORS PROCESSING CONTROLLED BY CORTICO-SUBCORTICAL LOOPS

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Introduction: In opioid addicted patients the impaired psychomotor function is observed. Patients have significant difficulty in initiating and controlling movements, impaired coordination, irregular movements and reduce the precision and speed. The study analyzed the signal representing the movement of the upper limb in mapping geometric shapes. Precision mapping requires the full involvement of centers of the nervous system responsible for eye-hand coordination. Obtained signals can be used as objective methods supporting the diagnostic process.

The aim of the study is an objective assessment graphomotor and psychomotor skills and eye-hand coordination in opiate addicted patients treated with substitution therapy. The paper presents the results of statistical and amplitude-frequency analysis of signals obtained during psychomotor tests.

Method and Material: The experimental group consists of 139 opioid addicted patients treated with substitution therapy. Among them 77 are HIV+ (age: 36.2 +- 10.1 years old) and 62 are HIV- (age: 32.8 ± 6.7 y.o.). Healthy control group contains 44 patients (age: 31.3 ± 9.3 y.o.). The original test implemented on a tablet was used. The most accurate mapping of the geometric shapes printed on the sheet with the dominant upper limb was the task of the patients. Patients were tested twice, immediately before and approximately 1 – 1.5 hour after administration of single dose of drug (methadone).

For spectrum of dominant upper limb analysis Fast Fourier Transform (FFT) is used. As a measure of the non-linear distortion wave, Total Harmonic Distortion (THD) ratio was used. THD is defined as the ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency.

Results: The analysis of signals shows reduction of upper limb tremor amplitude after administration of single dose of methadone in the drawing task. Analysis of the spectra of tremors indicate a slight deterioration in the stability of the execute motion in HIV (-) patients and statistically significant improvement in the stability of motion in HIV (+) patients (reduction of amplitude variations for all components, $p < 0.05$).

Conclusions: A single dose of methadone in opioid-addicted individuals improve graphomotor and psychomotor functioning. A reduce of hand tremors and better stability of the upper limb movement are observed, particularly in HIV (+) patients.

Optimization process in operating room

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Every company try to be most effective and achieve quality. Optimization processes are very important in hospitals - operating room. The consequences of poor work planning can have consequences for whole process, ergonomics of work in operating room. To achieve those goals, the organization of the workplace is very important. It shall be maximally adapted to the operation process which provides an added value through saved time. Thanks to the study of work processes time, it is possible to determine the workload of individual activities and its continuity. It could be realized by using the basic methods of working time analysis, e.g., time study, activity study, comparisons and estimations, and methods of time measurement. The concept of the work is to analyse work time of selected activities and the proposal to reorganize the workplace in operation room. Every activity steps is recorded on video. Then, all elementary movements were described and the reorganization of the workplace was proposed. Knowing the course of the process steps of each subassemblies and by analysing all obtained results, the organization of the workplace could be modified to minimize the process time as much as possible. Optimizing the work time can bring benefits, eg. reduction of the operation time, good management of materials and tool and cleanliness in the operating room.

3D printed replica of the corrosion cast demonstrating the internal vasculature of the human kidney

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The most difficult for accurate 3D modelling seems to be intra-organ vascular network. The kidney is a good example of an

organ which vascular pattern is simply in terms of the fractal geometry, however enough complicated for rapid prototyping to produce 3D models including all anatomical details.

The aim of this study is was to demonstrate possibilities of the 3D printing technology for fabrication replicas of the corrosion casts specimens demonstrating intra-renal vasculature.

To prepare 3D models of the renal vasculature selected corrosion casts of the human kidney were scanned using a Nanotom 180N device produced by GE Sensing & Inspection Technologies Phoenix X-ray Gmbh. The spatial resolution of the reconstructed object was 60 μm. The reconstruction of scanned samples was done with the aid of proprietary GE software datosX ver. 2.1.0 using the Feldkamp algorithm for cone beam X-ray CT [3]. The post-reconstruction data treatment was performed by means of the VGStudio Max 2.1

Further, the MeshLab software was used for final preparing the printable 3D mesh model.

For materializing virtual mesh models of the renal vasculature we used desktop 3D printer Nobel 1.0 A. This 3D printing technology is based on stereolithography (SLA). The 3D printed models were created with photopolymer resin which solidified after exposed to the ultraviolet laser light, however remains flexible and mimics elasticity of the blood vessels. Alternatively, we also used powder 3D printer for manufacturing the same models. We used the Lisa 3D printer by Sinterit, which works in SLS (Selective Laser Sintering) technology.

3D printed models manufactured by means of the SLA 3D printer Nobel 1.0 replicated only main divisions of the renal vascular tree. Much better fidelity of anatomical details between 3D printed models and original corrosion cast specimens was attained using powder-based SLS 3D printing technology. Thus, obtained 3D models revealed correctly anatomical details of the vascular tree but we found minor artefacts being the oval endings of the terminal vascular branches, instead of the sharply pointed segments.

3D printed models of the renal vasculature system show high level of accuracy of subsequent divisions both in arterial and venous tree. Thereby, such models may serve for demonstrating normal vascular anatomy of the kidney, and the potential morphological anomalies of the intrarenal vasculature. Hence, the 3D printed models of the renal vasculature can be used for the medical students educational and for the surgeons practicing at the field of urology.

Application of the Virtual and Augmented Realities based tools in medical distance education - evaluation study among medical students and academic teachers in Poland

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Virtual Reality (VR) and Augmented Reality (AR) based technologies gain more popularity and user trust in various applications fields. Their application especially in medical sciences is of huge importance. Immersive technologies give more possibilities in the transmission of curriculum content in remote learning, i.e. e-learning, in particular in COVID-19 pandemic ensuring the greatest participation in classes. Moreover, sharing the screens of the tutor contribute to better absorption of knowledge by students. This research aimed to examine the general pedagogical potential and value of immersive technologies in distance teaching, especially in medical distance training. We surveyed a group of 200 students and 40 academic teachers in the Jagiellonian University Medical College, Krakow, Poland, regarding the VR and AR use in the process of distance teaching. We have analyzed the relation between the AR application in the medical training taking into account user age and the professional position. It turned out that 70 % of students and 60 % of the academy lecturers think that VR/AR supported education has more advantages than a classical one. Surprisingly the main issue was connected with availability, only 5 % student has access to AR/VR technologies, while 17 % of academic teacher use it in work and 36 % of them have only the occasional access. The VR/AR technologies seem to be an efficient solution to support medical education, especially in distance teaching. They can improve students' skills avoiding without putting patients at unnecessary risk. VR/AR-based lessons or course contents and scenarios give a unique opportunity to exchange experiences inside and outside the medical community.

Disturbances in velocity and amplitude of saccades after contrast administration in patients undergoing coronary angiography

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INTRODUCTION: The aim of the study is to evaluate eye movements before and after contrast administration in patients undergoing coronary angiography and coronary angioplasty. Coronary angiography is an invasive test to visualize the narrowing of the coronary arteries. Coronary angiography is often used for the diagnosis of heart diseases, but also before planned surgeries, such as placing coronary artery bypass grafting or before performing coronary angioplasty. The procedure consists in inserting a catheter into the coronary arteries through the peripheral arteries and administering contrast and taking X-rays showing the condition of the contrasted vessels. A contrast agent, like any substance introduced during treatments, may cause side effects, although not everyone will experience them. Usually, transient, mild side effects of the contrast effect are described, however, life-threatening and severe reactions also occur. In the current scientific reports, there are no results of studies on the assessment of eye movements associated with cardiovascular diseases, therefore this work could outline whether there is a relationship between the administration of contrast agents in cardiological procedures and the movement of the eyeballs.
MATERIAL AND METHODS: The research was carried out on a group of 35 people, including: 14 women and 21 men, the mean age was 65.2 years (aged 53 to 79 years). Each of the people was also measured from the blood sample GFR - which is an indicator measuring the amount of blood that is filtered by the kidneys. This indicator had to be assessed before giving the contrast. All participants had an eye movement test performed with the Saccadometer Advanced (Ober Consulting Poland). Saccadometer Advanced are considered by FDA as being Class II Medical Devices. The first measurements with the Saccadometer were carried out in the morning, and the next ones after the procedure. Each patient during the procedure was administered a non-ionic contrast agent: Optiray and Omnipaque in amounts appropriately adjusted to the weight.
RESULTS: Comparing the parameters of eye movements in the control group (without the contrast agent administered), it was found that the velocity and amplitude increased, and the latency and duration increased after coronary angiography and angioplasty for incorrect saccades (movement in the opposite direction from the stimulus), while for correct saccades there were no differences. Most statistically significant parameters consist of left-sided saccades, which may indicate a disturbance of laterality after the procedure.
CONCLUSION: The study found a possible effect of contrast agent administration on oculomotor functions, as shown by the disturbances in the velocity and amplitude of saccades in patients with stable coronary artery disease.