VYSOKÁ ŠKOLA BÁŇSKÁ-TECHNICKÁ UNIVERZITA OSTRAVA

Fakulta elektrotechniky a informatiky, Katedra kybernetiky a biomedicínského inženýrství

Trendy v biomedicínském inženýrství

Sborník šestnáctého ročníku česko-slovenské konference

Setkání vysokoškolských pracovišť v rámci konference Trendy v biomedicínském inženýrství 2025 a řešitelů projektu LERCO

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Autor: Kolektiv autorů

Editor: Marek Penhaker, Martin Augustynek

Katedra, institut: FEI, Katedra kybernetiky a biomedicínského inženýrství.

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Trendy v biomedicínském inženýrství

Konference je zaměřena na diskuzi aktuálních trendů ve vývoji vědy, výzkumu a výuky v oblasti biomedicínského inženýrství v České a Slovenské republice. Navazuje na dlouhodobou tradici pravidelných setkávání, která se konají ve dvouletém cyklu a představují jedinečnou příležitost pro sdílení zkušeností a poznatků mezi pedagogickými i vědeckými pracovníky oboru.

Hlavním cílem letošního ročníku je propojit řešitelské týmy s potenciálními uživateli výsledků projektu LERCO a vytvořit platformu pro odbornou diskuzi mezi výzkumnými institucemi a aplikační sférou. Konference tak podporuje nejen výměnu vědeckých informací, ale i vznik nových spoluprací, které mohou přispět k rychlejšímu přenosu poznatků do praxe a k rozvoji biomedicínského inženýrství v širším kontextu.

<u>Pořadatel:</u>

VŠB TECHNICKÁ UNIVERZITA OSTRAVA | FAKULTA ELEKTROTECHNIKY A INFORMATIKY | KATEDRA KYBERNETIKY A BIOMEDICÍNSKÉHO INŽENÝRSTVÍ

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LERCO

Spolupořadatelé:

- Česká společnost biomedicínského inženýrství a lékařské informatiky České lékařské společnosti J.E.Purkyně
- Spoločnosť biomedicínskeho inžinierstva a medicínskej informatiky Slovenskej lekárskej spoločnosti
- Česká společnost pro zdravotnickou techniku

Sponzoři:

Místo konání

Místem konání 16. ročníku konference Trendy v biomedicínském inženýrství bude tradiční beskydský hotel Tanečnica na Pustevnách. Tento horský hotel, slavnostně otevřený v roce 1926, leží v nadmořské výšce 1018 m, stranou turistického ruchu. Nabízí stylové ubytování v jednolůžkových a dvoulůžkových pokojích a také v čtyřlůžkových chatkách s vlastní koupelnou, TV a WiFi. Hotel je ideálním výchozím bodem pro turistiku, cyklistiku i běžecké lyžování. V okolí se nachází Stezka Valaška, Běžecký areál Pustevny a každoroční festival Ledové sochy. Mezi jeho významné hosty patřil i prezident T. G. Masaryk.

A nyní zde proběhne také 16. ročník konference trendy v biomedicínském inženýrství za hojné účasti všech zástupců z České i Slovenské republiky.

Klidné prostředí resortu Pustevny v tradičním beskydském hotelu Tanečnica nabízí ubytování pro více jak 100 osob v rámci hotelu a k dispozici je také ubytování ve vytápěných chatkách. V době pobytu je v ceně zahrnut vstup do vnitřního plaveckého bazénu a hotelové sauny.

Obsah

VENTRICULAR ACTIVATION TIME MAPS OF HEALTHY YOUNG ADULTS

Katarína Kozlíková

Institute of Medical Physics and Biophysics, Faculty of Medicine, Comenius University Bratislava, Bratislava, Slovakia

Abstract

Ventricular activation time (VAT), or R-peak time, is the interval on an ECG lead from the start of the QRS complex to the peak of the R wave [1]. It reflects the duration of electrical activation from the endocardium to the epicardium and can indicate conditions such as heart failure or ventricular tachycardia when prolonged [2]. Normal ranges vary by lead; for example, the upper limit for VAT in the right ventricle is about 35 ms (from leads V_1 and V_2), and for the left ventricle, it is about 45 ms (from leads V_5 and V_6). When using bod surface potential maps (multi-lead electrocardiography), it is possible to evaluate VAT on the whole chest surface. Therefore, the aim of our study was to analyse VAT maps in healthy young adults. Isochrone body surface VAT maps were registered and analysed in 90 healthy volunteers (42 males), 18 to 19 years of age. Electrocardiograms were recorded using the mapping system ProCardio [3]; next calculations were performed using MS EXCEL. Mean VAT maps showed that activation typically begins in the upper right chest and ends in the upper back, with a predominantly counter-clockwise progression. This implies a predictable pattern of electrical activity spread in the ventricles. There were no statistically significant differences between males and females in the mean map patterns, in the QRS duration (M: 92 ± 12 ms; F: 90 ± 13 ms), in the shortest VAT time – activation begin (both: 21 ± 8 ms), in the longest VAT time – activation end (M: 79 ± 9 ms; F: 76 ± 11 ms). The activation beginnings and ends were always outside of the positions of standard chest electrodes. Given our results, when using VAT maps for diagnostic purposes, it is not necessarily necessary to maintain an exact ratio of men to women compared to the patients in the selection and composition of control groups of young adults.

Key words

body surface potential mapping; ventricular activation time

Acknowledgement

This work was partially supported by the grants KEGA 040UK-4/2022 and VEGA 1/0727/2014, both provided by the Ministry of Education, Science, Research and Sport of the Slovak Republic.

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TRENDS IN ARTIFICIAL INTELLIGENCE–RELATED PATENTS IN MEDICINE AND HEALTHCARE

Vratislav, Harabiš[1,2], Filip, Korbel[1]

[1]PatentEnter s.r.o.

[2]Departmen of Biomedical Engineering, Brno Univ. of Technology

Abstrakt

Machine learning methods have become increasingly common. Their role in medicine and healthcare has been evolving for several years, mainly due to the large volume of data generated in medicine. Machine learning methods have proven useful in processing large amounts of data, such as that provided by medical imaging systems. Processing such data is very time-consuming for a doctor or specialist and places high demands on concentration during data analysis.

In connection with the development of these methods, the number of patent applications and subsequently granted patents involving artificial intelligence methods has also been increasing, as shown by the authors in [1], who focused on patent activity in the US and at the EPO. The increase in patent applications in the field of artificial intelligence in medicine occurred between 2013 and 2014, and since then this trend has accelerated significantly.

This is demonstrated by our analysis, conducted in the commercial patent database Patsnap, which currently includes over 200 million patent documents from 172 jurisdictions. We focused on the total number of patent documents related to artificial intelligence in medicine and healthcare. We used the following search strategy: "TACD_ALL:((artificial AND intelligence) OR ((machine OR deep) AND learn*)) AND TACD_ALL:(medical OR health*)". The result is more than 554,000 patent families. The graph in Figure 1 shows a sharp increase in published applications. In 2020, 23,731 patent documents were published, in 2022 this number rose to 51,108, and in 2024 it was already 125,238. Data for 2025 so far indicate 147,270 published documents.

Figure 1 Published patents in area of artificial intelligence in medicine per year.

The most active countries include China, followed by the US and India. The most active applicant is Samsung Electronics, with more than 16,800 patent documents in this field. Other significant applicants include large multinational corporations that control various technology companies, such as Softbank Group and Tencent Technology, as well as major technology companies such as Huawei, Qualcomm, LG Electronics, IBM, Microsoft, Intel, Apple, and Google. Among the twenty largest applicants in this field, there are three academic institutions: Zhejiang University, Tsinghua University, and the Regents of the University of California (which oversees universities in California).

This trend also brings further challenges not only for patent attorneys and specialists, but also for patent office examiners. Artificial intelligence methods are essentially mathematical methods, which are excluded from patentability. In the case of an invention that involves these methods, it is important to correctly define the technical nature of the invention, which is a highly complex issue. Patent authorities themselves are aware of this, and the EPO, for example, is seeking to update and supplement its guidelines to respond to the development of computer-implemented inventions. The Guidelines for Examination in the EPO (EPC Guidelines) give instructions on the practice and procedure to be followed in the various aspects of the examination of European applications and patents in accordance with the European Patent Convention and its Implementing Regulations, see [2].

It is therefore highly desirable that patent attorneys or specialist who prepare application texts are familiar with the these guidelines and follow them. Guidelines are also a valuable source of information for inventors, who can prepare a more precise and detailed description of their invention for the patent attorneys or specialists.

Key words
Artificial intelligence, machine learning, deep learning, medicine, healthcare, patent, EPO

Acknowledgement
This research would not have been possible without PatentEnter s.r.o. I would also like to thank Michal Jordán for his advice.

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PŘEDSTAVENÍ PROJEKTU LERCO - LIFE ENVIRONMENT RESEARCH CENTER OSTRAVA: VÝZKUMNÝ PROGRAM 9 - BIOMEDICÍNSKÉ INŽENÝRSTVÍ

Marek Penhaker

VŠB–TUO, FEI, Katedra kybernetiky a biomedicínského inženýrství, 17. listopadu 2172/15, 708 00 Ostrava-Poruba

Abstrakt

Projekt LERCO (Life Environment Research Center Ostrava) je nově budovaný vědecko-výzkumný hub, který jako jeden z nástrojů umožňuje transformaci Moravskoslezského kraje (dále MSK) z „uhelného" na „zdravější a chytřejší" region. Špičkově vybavené zázemí a 9 excelentních výzkumných týmů projektu umožní realizaci aktivit v širokém a unikátním mezioborovém zaměření v biomedicínských, přírodovědných a behaviorálních oborech, od základního výzkumu přes experimentální vývoj po aplikovaný výzkum, napříč VaV institucemi (OU, FNO, VŠB-TUO) a dalšími spolupracujícími VaV i komerčními subjekty z praxe v ČR/zahraničí (1).

Cílem projektu je komplexní podpora rozvoje inovačního VaV potenciálu MSK kraje v netechnických oborech s dopadem na: zdraví obyvatelstva, rozvoj spolupráce VaV s komerční sférou (podpora vzniku spin-off firem), podporu zaměstnanosti v kraji, zvýšení atraktivnosti regionu ve VaV, vzdělávání a municipality poskytnutím inovačních nástrojů (1).

Výzkumný program VP9 Biomedicínské inženýrství je jeden z devídi výzkumných program, které jsou součástí projektu LERCO. VP9 – Biomedicínské inženýrství představuje ucelenou platformu aplikovaného výzkumu a vývoje v biomedicínském inženýrství se zacílením na diagnostiku, terapii a dlouhodobé monitorování pacientů. Program je strukturován do čtyř podúloh a dvanácti hlavních aktivit, které pokrývají vývoj pokročilých HW/SW nástrojů, telemedicínských řešení, kardiovaskulárních metod a zpracování medicínských dat. Cílem je převést výsledky základního a aplikovaného výzkumu do ověřených prototypů, algoritmů a metodik s potenciálem klinického nasazení a ochrany duševního vlastnictví.

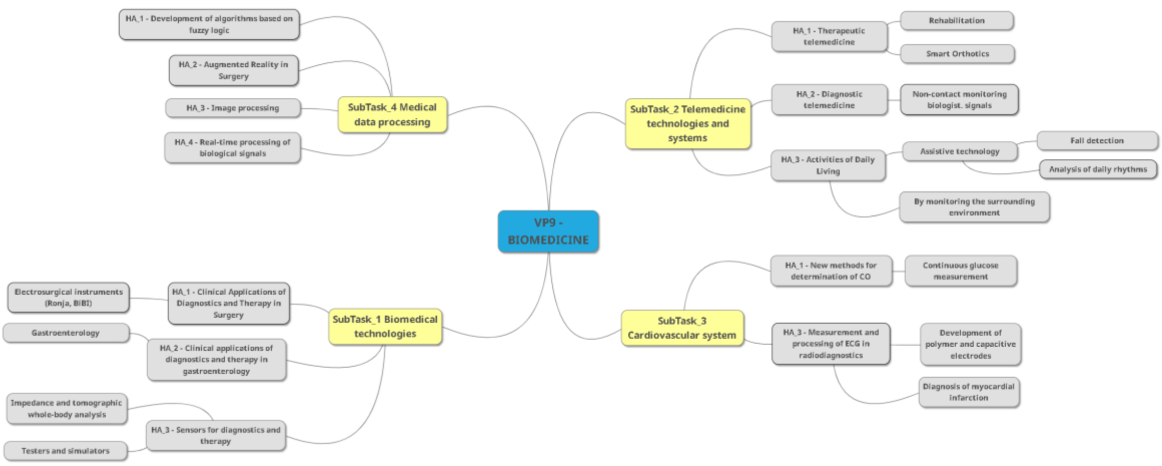

Figure 2 Struktura Výzkumného programu Biomedicínské inženýrství v rámci projektu LERCO.

V podúloze Biomedicínské technologie vyvíjíme nástroje pro automatickou segmentaci jater z CT dat včetně validace, tvorby optimalizovaných 3D modelů pro AR/VR a podpory předoperačního plánování; souběžně probíhá výzkum radiofrekvenčních nástrojů RONJA a bioptického nástroje „BIBI“ s ošetřením vpichu RF energií a rozvoj metodiky elektrogastrografie. Telemedicínské technologie a systémy zahrnují bezkontaktní radarové snímání vitálních funkcí (MIMO/FMCW) pro přirozené domácí prostředí, unikátní vložky do obuvi pro měření smykových sil během chůze a monitorování aktivit denního života ve „living labs“ s využitím senzoriky prostředí a prvků domácí automatizace.

V oblasti Kardiovaskulárního systému se zaměřujeme na novou metodu stanovení srdečního výdeje na principu glykodiluce s využitím kontinuálního senzoru glukózy a katetrizačního systému včetně laboratorní a preklinické validace; dále na měření a zpracování EKG v radiodiagnostice (polymerní/kapacitní elektrody) a algoritmy vektorové kardiografie pro automatickou diagnostiku ischemické choroby srdeční. V podúloze Zpracování medicínských dat vyvíjíme metody založené na fuzzy logice a strojovém učení pro detekci a kvantifikaci biologických struktur, AR registraci CT a peroperačních dat, autonomní biometrickou identifikaci onkologických pacientů a rozhraní pro real-time zpracování biosignálů (BCI) pro neurorehabilitaci.

Projekt probíhá v úzké spolupráci s klinickými partnery a je koncipován s důrazem na přenositelnost do praxe, validace na zvířecím modelu i u pacientů, ochranu výsledků (patenty) a publikace. Očekávanými výstupy jsou funkční prototypy senzorů a nástrojů, SW moduly (segmentace, klasifikace, AR/VR, telemetrie), metodiky měření a hodnocení a řízené datové sady. Díky modulární architektuře a návaznosti aktivit projekt směřuje k budoucí integraci do digitálního dvojčete vybraných procesů, umožňujícího prediktivní simulace a on-line podporu klinického rozhodování.

Key words

biomedicínské inženýrství, telemedicína, kardiovaskulární systém, glykodiluce, kontinuální senzor glukózy, augmentovaná realita, segmentace jater, nositelné senzory, radarové snímání vitálních funkcí, aktivity denního života,

Acknowledgement

Tento článek vznikl za finanční podpory Evropské unie v rámci projektu LERCO s reg. číslem CZ.10.03.01/00/22_003/0000003, prostřednictvím Operačního programu Spravedlivá transformace.

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FRAMEWORK PRO MODELOVÁNÍ FUNKČNÍ ELEKTROAKTIVNÍ VRSTVY

Vojtěch, Lindauer[1],

[1]Fakulta Zdravotnických studií, Technická Univerzita v Liberci, Liberec,

Abstrakt

Během prezentace chceme představit výsledky naší práce, která bude předmětem brzké publikace. Zabývali jsme se modelováním elektroaktivní piezoelektrické funkční vrstvy na implantátu, která by elektricky stimulovala okolní buňky při zatížení. Jedná se o složitý systém, který vyžaduje celý modelovací framework stávající se z propojení elektrochemického modelu elektrické dvojvrstvy u silně nabitého rozhraní a to v složitém elektrolytu tkáňové tekutiny (obvykle simulovaný tzv. SBF) a pevné feroelektrické vrstvy, která je zdrojem náboje na rozhraní elektrické dvojvrstvy. Případ složitého roztoku a velkého náboje/potenciálu na rozhraní dosud představovovaly limity analytického modelování elektrické dvojvrstvy. Vycházeje ze sterického modelu vyvinutého Kilicem et. al. v roce 2007 jsme vytvořili modelovací framework elektrochemických jevů na rozhraní feroelektrika a elektrolytu, který tyto teoretické obtíže překonává.

Key words

elektrická dvojvrstva, elektrochemický model, rozhraní feroelektrika/elektrolytu

Acknowledgement

N/A

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DEVELOPMENT OF AN INDIVIDUAL REHABILITATION ORTHOSIS FOR TETRAPLEGICS

Branko Štefanovič[1]

[1]Department of Biomedical Engineering and Measurement, Faculty of Mechanical Engineering, Technical University of Košice, Letná 1/9, 04200, Košice, Slovakia

Abstract

Intensive rehabilitation of motor functions is important in patients for whom reduced or lost grip strength is indicated [1]. These are mainly tetraplegic patients, stroke patients and patients with spinal cord injury [2,3]. It is proven that this rehabilitation helps not only to improve the grip function of the hand, but also to restore the neurological brain, which is favourable for the patient's return to active daily life [1]. Rehabilitation consists in actively or passively grasping and moving standardized objects. In case of insufficient strength in the upper limb, the rehabilitation assistant assists the patient in performing specific tasks. To eliminate the need for an assistant and improve the rehabilitation itself, special rehabilitation mechatronic orthoses were created, which help in the rehabilitation of motor functions of the hand [1-3]. Developed in scientific institutions around the world, these devices have been tested on patients with no or insufficient upper limb grip strength and have had a positive effect on their overall health. Few mechatronic orthoses are currently used in practice due to their complicated construction, operation, and high production costs [1,2,4-6]. For this reason, it is necessary to design and manufacture a low-cost mechatronic rehabilitation orthosis with simple control and individual design. To create such a tool, it is advisable to use modern technologies from 3D scanners to additive manufacturing [6,7,8]. Scanning the body surface using 3D scanners is, from a practical point of view, an adequate method for designing orthotic aids [8-12]. From the positive obtained by 3D scanning a model of the orthotic aid may be designed in a suitable CAD (Computer Aided Design) software [12,13]. Using this method, a precise individual 3D design of an orthotic device is created, which can then be produced by additive manufacturing [12]. Additive manufacturing is the production of objects by combining selected materials according to a 3D model divided vertically into horizontal layers [13-15]. The biggest advantage of 3D printing is the possibility of producing structures and shapes that are too complex to produce with commonly used technologies [14]. Its advantage is a reduction in production time, a large selection of suitable materials, a reduction in the amount of waste, the possibility of rapid production, etc. Thanks to this, additive manufacturing and 3D scanning are widely used in the medical field [8,10]. The aim of this project is to design and manufacture a low-cost mechatronic rehabilitation assistive orthosis for subjects with impaired grip strength using CAD/CAM systems.

Key words

Rehabilitation, impaired grip strength, mechatronic orthosis, individual orthotics

Acknowledgement

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RECONDITIONING DEVICES FOR LOCOMOTION OF THE BEDRIDDEN PATIENTS

Aleš Richter[1], Josef Černohoský[2], Jana Sehnalová[1,3]

[1]Faculty of Health Studies, Technical University of Liberec, Czech Republic, ales.richter@tul.cz

[2] Faculty of Mechatronics, Informatics and Interdisciplinary Studies, Technical University of Liberec, Czech Republic, josef.cernohorský@tul.cz

[3]Regional Hospital Liberec, CARIM, Czech Republic, jana.sehnalová@tul.cz

Abstract

The long-term cooperation between Technical University of Liberec and Regional Hospital Liberec, CARIM, Intensive Care Unit (ICU) is presented. This solution provides passive reconditioning for ICU bedridden patients with limited mobility. We focus on simple assistive systems for the care of immobilized patients who are conscious. It allows for the rehabilitation in existing hospital beds, minimizing disruption to treatment routines. In particular, we focus on systems with top-down access so that patients are not restricted in terms of monitoring invasive access and ensuring life support. The aim of the project is to map the effectiveness of the necessary locomotion of these patients, which is currently only provided by specialized healthcare professionals. At conclusion the clinical verification process for a specific device will be presented.

Key words

Physiotherapy, Passive reconditioning, Bedridden patients, Assistive systems, Machine learning,

Acknowledgement

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NEW PILOT PROJECT: "EARLY DETECTION AND PREVENTION OF HEALTH COMPLICATIONS IN PREMATURE BABIES"

Petr Kudrna[1,2]

[1]Department of Gynecology, Obstetrics and Neonatology, First Faculty of Medicine, Charles University and General Teaching Hospital, Prague, Czech Republic

[2] Department of Biomedical Technology, Faculty of Biomedical Engineering, Czech Technical University in Prague, Czech Republic

Abstrakt

Approximately 7% of all children in the Czech Republic are born prematurely, and this group requires intensive and specialized care. With the increasing number of cases, more complex interventions are needed immediately after birth. Therefore, on March 1, 2024, with the support of the European Social Fund Plus and the Employment Plus Operational Program, a pilot project entitled "Early Detection and Prevention of Health Complications in Premature Babies" was launched, implemented by the National Screening Center of the Institute of Health Information and Statistics of the Czech Republic. The project focuses on the early detection and reduction of health risks in premature babies (PB), namely malnutrition, bronchopulmonary dysplasia, and developmental psychopathology at the age of 5.

The project focuses on three areas of early detection and reduction of health risks in prematures babies:

Home-based controlled monitoring and optimization of oxygen therapy – Currently, there is no standard screening tool in place for the comprehensive monitoring of long-term home oxygen therapy for children. This intervention significantly reduces the length of hospitalization, supports the child's mental and physical development, and provides psychological support to parents. Parents have direct contact with a doctor for regular consultations and monitoring.

Managed nutrition in PB – Nutrition is a key factor influencing PB morbidity, so it is necessary to monitor each PB case over the long term and set up an individual nutrition plan for them. The result should be progressive weight gain, growth in length, and improvement in the child's overall health. The emphasis is on long-term monitoring and individualized nutrition that reflects the child's current condition and accelerates the transition to enteral feeding. This leads to a reduction in morbidity and mortality, reduces the risk of bronchopulmonary dysplasia and other complications, shortens the stay in the ICU, and promotes earlier contact between mother and child.

Early detection of developmental deviations in PB at the age of 5 – Currently, monitoring of PB up to the age of 2 with an assessment of psychomotor development is mandatory in the Czech Republic. Clinical practice shows that it is necessary to perform examinations at the preschool age of 5, when the child is integrated into the group. This intervention includes early detection of borderline findings, which prevents the development of pathology, improves the child's social skills and communication, and facilitates their integration into the peer group.

The implementation of these key areas is expected to bring about a significant improvement in the health and quality of life of PBs and their families, and to provide healthcare professionals working with this specific group of children with the necessary information and support.

Key words
prevention,premature babies, home oxygen therapy, controlled nutrition, developmental abnormalities

Acknowledgement
Project Early detection and prevention of health complications in premature babies, registration number CZ.03.02.02/00/22_005/0002020 is funded by the European Social Fund – Operational Program Employment Plus and the National Screening Center of the Czech Republic

ZMĚNY V AKREDITACI STUDIJNÍHO PROGRAMU LÉKAŘSKÁ ELEKTRONIKA A BIOINFORMATIKA NA FEL ČVUT V PRAZE

Jan Havlík, Roman Čmejla, Jan Kybic

Fakulta elektrotechnická, České vysoké učení technické v Praze

Technická 2, 166 27 Praha 6, email: xhavlikj@fel.cvut.cz

Abstrakt

Od roku 2018 jsou na Fakultě elektrotechnické ČVUT v Praze akreditovány pro prezenční výuku bakalářský i magisterský studijní program Lékařská elektronika a bioinformatika , obě stávající akreditace mají platnost do roku 2028. Na FEL ČVUT tak aktuálně probíhá proces reakreditace obou studijních programů. Vznik stávající bakalářské akreditace reflektoval poptávku po biomedicínsky orientovaném studijním programu na FEL ČVUT a potřebu výchovy vlastních bakalářů pro navazující magisterský program, postupem času se však ukázaly některé jeho limity, především celkově velmi obecná skladba předmětů.

V nové bakalářské akreditaci byl proto snížen rozsah výuky matematiky a fyziky a to tak, aby ve studijním plánu vznikl prostor pro oborové předměty. Na uvolněné místo pak byly zařazeny nové předměty, případně přesunuty některé předměty z magisterské etapy, a to tak, aby vznikl studijní program poskytující komplexní bakalářské vzdělání v oblasti biomedicínského inženýrství.

V nové magisterské akreditaci pak došlo k redukci počtu specializací z čtyřech na dvě – hardwarově orientovanou Lékařskou elektroniku a softwarově orientovanou Lékařskou informatiku, s poměrně širokou možností výběru povinně volitelných a volitelných předmětů. Vznikl tak unikátní studijní program, který reflektuje zájem průmyslových partnerů, výzkumných pracovišť, požadavky klinické praxe i zpětnou vazbu studentů a absolventů.

Akreditační proces obou studijních programů je aktuálně před dokončením, první studenti by do nových akreditací měli nastupovat v ZS 2026/2027 (bakalářský studijní program), resp. o rok později (magisterský studijní program).

Key words

biomedicínské inženýrství, akreditace, studijní program, Fakulta elektrotechnická, České vysoké učení technické v Praze

Úvod

Od roku 2018 jsou na Fakultě elektrotechnické ČVUT v Praze akreditovány pro prezenční výuku bakalářský i magisterský studijní program Lékařská elektronika a bioinformatika [1]. Cílem obou programů je vychovávat absolventy, kteří jsou schopni řešit inženýrské problémy zejména v oblasti návrhu a vývoje moderních elektronických zařízení a softwarových aplikací v oblasti medicíny a biologie. Absolventi nacházejí uplatnění ve zdravotnických zařízeních, ve výzkumných nebo vývojových týmech, i v nejrůznějších manažerských pozicích. Mají taktéž dobrý základ pro samostatnou vědeckou práci a pro pokračování v doktorských studijních programech. Akreditace obou studijních programů byly Národním akreditačním úřadem uděleny na 10 let a jejich platnost tak uplyne v roce 2028 [2]. Na FEL ČVUT tak aktuálně probíhá proces reakreditace uvedených studijních programů.

Tento příspěvek proto přináší přehled prováděných změn v akreditaci výuky biomedicínského inženýrství na FEL ČVUT a diskusi důvodů, které k těmto změnám vedly.

Stávající akreditace

Vznik stávající bakalářské akreditace reflektoval poptávku po biomedicínsky orientovaném studijním programu na FEL ČVUT a potřebu výchovy vlastních bakalářů pro navazující magisterský program, který má na FEL ČVUT dlouholetou tradici a jehož studenty byli před vznikem bakalářské akreditace především absolventi bakalářských programů Elektronika a komunikace a Kybernetika a robotika, a částečně pak i studenti přicházející z jiných fakult nebo vysokých škol. Skladba předmětů byla koncipována tak, aby pokrývala jak elektrotechniku (37 %), tak informatiku (37 %) a zdravotnické obory (26 %) [3]. Stávající magisterská akreditace pak kopírovala dřívější podobu magisterského studijního programu a byla rozdělená na čtyři specializace – Bioinformatika, Lékařská technika, Zpracování obrazů a Zpracování signálů.

V průběhu času se postupně ukázaly některé limity stávající bakalářské akreditace, které již nebylo možné řešit drobnými zásahy do jednotlivých předmětů a které jsou proto řešeny v rámci právě probíhající reakreditace obou studijních programů. Jedná se především o celkovou skladbu předmětů v bakalářské etapě, která byla studenty i zaměstnavateli vnímána jako příliš obecná, navíc s ohledem na původně požadovaný rozsah výuky matematiky a fyziky se blížila spíše tradičním elektrotechnickým programům než studijním programům orientovaným na biomedicínské inženýrství.

Nová akreditace

V nové bakalářské akreditaci byl proto snížen rozsah výuky matematiky a fyziky a to tak, aby ve studijním plánu vznikl prostor pro oborové předměty. Ze studijního plánu tak vypadly předměty Diferenciální rovnice a numerické metody a Komplexní analýza, jejichž látka se na potřebné úrovni objevuje i v odborných elektrotechnických a signálových předmětech, a předměty Signály a soustavy a Biomedicínské senzory, které byly nahrazeny jinými obdobnými předměty. Na uvolněné místo pak byly zařazeny nové předměty Lékařská elektronika a Základy hlubokého učení a z magisterské etapy přesunuty předměty Biologické signály, Zobrazovací systémy a Statistická analýza dat. Předmět Biologické senzory byl naopak přesunut do magisterské etapy studia. V novém studijním plánu je vyhrazen i prostor na volitelné předměty, které poskytují studentům možnost částečné specializace již v průběhu bakalářské etapy studia. Vznikl tak studijní plán, který dává studentům možnost komplexního bakalářského vzdělání v oblasti biomedicínského inženýrství a umožňuje jim tak i případný smysluplný odchod do praxe již po absolvování bakalářské etapy studia, kdy doposud měly spíše jen hluboké teoretické znalosti obtížně prakticky uplatnitelné.

Hod. / Sem.	1–30								kredity
1	Matematická analýza 1, 6, zk	Lineární algebra, 7, zk	Fyzika 1, 5, kz	Algorimy a program., 6, zk	Úvod do biomed.inž., 6, kz				30
2	Matematická analýza 2, 6, zk	Fyzika 2, 7, zk	Zákl.elektr.obvodů, 5, zk	Zákl.zprac.signálů, 6, zk	Zákl. anatomie, 6, zk				30
3	Biologické signály, 5, zk	Procedurální progr., 4, kz	Apl el.mag v bio, 4, zk	Měření pro bioinž., 4, kz	Chemie pro bioinž., 3, kz	Zákl.fyz a patofyz., 4, zk	Povinně volitelné př., 4	Volitelný, 2	30
4	Statist.a pravděpod, 5, zk	Biofyzika, 5, zk	Zobr. systémy v lékařství, 4, zk	Digitální zpracování obrazu, 6, zk	Elektronické obvody 1, 6, zk	Povinně volitelné př., 4			30
5	Bakalářský project, 5, kz	Optimalizace, 7, zk	Lékařská elektronika, 6, zk	Rozpoznávání a stroj.učení, 6, zk	Povinně volitelné př., 4	Volitelný, 2			30
6	Bakalářská práce, 14, z	Statistická analýza dat, 6, zk	Základy hlubokého učení, 4, zk	Povinně volitelné př., 4, zk	Volitelný, 2				30
									180

Obrázek 1: Studijní plán bakalářského studia Lékařská elektronika a bioinformatika

V nové magisterské akreditaci pak z důvodu zvýšení efektivity výuky došlo k redukci počtu specializací z čtyřech na dvě – hardwarově orientovanou Lékařskou elektroniku a softwarově orientovanou Lékařskou informatiku. Obě specializace mají celkem pět společných povinných předmětů, které dávají studentům základní oborové znalosti. Jedná se o předměty Lékařská technika, Legislativa a management zdravotnických prostředků, Pokročilé metody DSP, Zpracování medicínských obrazů a Bioinformatika (v obrázku 2 označeno jako povinně volitelné předměty programu typu A). Tyto předměty jsou pak doplněny povinnými předměty jednotlivých specializací, pro Lékařskou elektroniku předměty Biomedicínské senzory, Fyzika pro diagnostiku a terapii, Konstrukce lékařských systémů, Mikroprocesory a základy elektromagnetické kompatibility, pro Lékařskou informatiku předměty Foundation of Machine Learning, Kombinatorická optimalizace, Metody počítačového vidění, Pokročilá algoritmizace a Pokročilé hluboké učení (v obrázku 2 označeno jako povinně volitelné předměty specializace). Další předměty studijního plánu jsou již povinně volitelné předměty a předměty celofakultní nabídky, které umožňují studentům specializaci do konkrétních oblastí jejich zájmu. Vzniká tak unikátní studijní program, který reflektuje zájem průmyslových partnerů, výzkumných pracovišť, požadavky klinické praxe i zpětnou vazbu studentů a absolventů.

1.semestr	PV programu typ A	PV programu typ A	PV specializace	PV specializace	PV specializace	30kr
2. semestr	PV programu typ A	PV programu typ A	PV specializace	PV specializace	PV	30kr
3. semestr	Diplomový projekt	PV	PV	PV	volitelný	30kr
4. semestr	Diplomová práce					30kr

Obrázek 2: Studijní plán magisterského studia Lékařská elektronika a bioinformatika

Závěr

Cílem prováděných změn v akreditacích bakalářského i magisterského studijního programu Lékařská elektronika a bioinformatika na FEL ČVUT v Praze je vznik moderního studijního programu, který již v bakalářské etapě umožní studentům získat oborové znalosti a který sleduje aktuální vývoj v oblasti biomedicínského inženýrství včetně výzev souvisejících s aplikacemi nanotechnologií a využitím umělé inteligence a pokročilých metod zpracování dat v medicíně.

Akreditační proces obou studijních programů je již v poměrně pokročilé fázi a měl by být dokončen v druhé polovině roku 2025 nebo z kraje roku 2026 s tím, že první studenti bakalářského studia by do nově akreditovaného programu nastupovali v ZS 2026/2027, první studenti magisterského studia pak o rok později.

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SMARTWATCH-BASED MONITORING AS A MEANS OF SUPPORTING HUMAN HEALTH

Stanislav Ďuriš[1], Jan Rybář[2], Peter Onderčo[3], Andrej Smetánka[4], Jana Gerneschová[5]

[1]Institute of Automation, Informatization, and Measurement, Faculty of Mechanical Engineering, Slovak University of Technology in Bratislava, Nám. slobody 17, 812 31 Bratislava, Slovakia; stanislav.duris@stuba.sk

[2]Institute of Automation, Informatization, and Measurement, Faculty of Mechanical Engineering, Slovak University of Technology in Bratislava, Nám. slobody 17, 812 31 Bratislava, Slovakia; jan.rybar@stuba.sk

[3]Institute of Automation, Informatization, and Measurement, Faculty of Mechanical Engineering, Slovak University of Technology in Bratislava, Nám. slobody 17, 812 31 Bratislava, Slovakia; peter.onderco@stuba.sk

[4]Institute of Automation, Informatization, and Measurement, Faculty of Mechanical Engineering, Slovak University of Technology in Bratislava, Nám. slobody 17, 812 31 Bratislava, Slovakia; andrej.smetanka@stuba.sk

[5]Primary Metrology Laboratories Prague, Czech Metrology Institute, Okružní 31, Brno 638 00, Czech Republic /workplace Praha, Czech Republic/ & Institute of Automation, Informatization, and Measurement, Faculty of Mechanical Engineering, Slovak University of Technology, Nám. slobody 17, Bratislava 812 31, Slovakia; jana.gerneschova@stuba.sk

Abstract

This paper addresses the use of smartwatches as an innovative tool for continuous monitoring of users' health status. Equipped with integrated sensors such as optical heart rate monitors, accelerometers, and gyroscopes, smartwatches enable the collection of data on key physiological parameters—including heart rate, physical activity, sleep quality, and stress levels. Such data hold significant potential for the prevention of chronic diseases, early detection of health abnormalities, and the promotion of a healthy lifestyle through personalized recommendations. [1]

In the context of medical metrology, ensuring the accuracy, repeatability, and comparability of measurements performed by smartwatches is essential. Metrological traceability of measured quantities to international standards facilitates the validation and certification of these devices, which is critical for their reliable use in healthcare practice. This paper also analyzes challenges related to sensor calibration, validation methodologies, and data integration into clinical systems, emphasizing the need for standardization and a metrological framework to support the development of precise and safe wearable medical devices. [1; 2]

The aim of this contribution is to demonstrate the potential of smartwatches as an effective tool for modern healthcare while highlighting the necessity of metrological support [3] to ensure the quality and reliability of the acquired data.

Key words
healthcare, medical metrology, monitoring, smartwatch

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The authors hereby express their sincere gratitude to the Slovak University of Technology in Bratislava (Faculty of Mechanical Engineering), the Czech Metrology Institute, the KEGA grant agency (project number 024STU-4/2023: Building a Laboratory of Medical Metrology), and the APVV grant agency (project numbers APVV-21-0216: Advanced Mathematical and Statistical Methods for Measurement and Metrology, and APVV-21-0195: Research the Possibility of Digital Transformation of Continuous Transport Systems) for their invaluable support.

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RULES FOR METROLOGICAL TRACEABILITY OF MEASURING DEVICES IN MEDICAL METROLOGY

Jan Rybář[1], Jana Gerneschová[2], Simona Nevyhoštěná[3]

[1]Institute of Automation, Informatization, and Measurement, Faculty of Mechanical Engineering, Slovak University of Technology in Bratislava, Nám. slobody 17, 812 31 Bratislava, Slovakia; jan.rybar@stuba.sk

[2]Primary Metrology Laboratories Prague, Czech Metrology Institute, Okružní 31, Brno 638 00, Czech Republic /workplace Praha, Czech Republic/ & Institute of Automation, Informatization, and Measurement, Faculty of Mechanical Engineering, Slovak University of Technology, Nám. slobody 17, Bratislava 812 31, Slovakia; jana.gerneschova@stuba.sk

[3]Institute of Biophysics and Informatics, First Faculty of Medicine, Charles University, Kateřinská 32, 121 08, Praha 2, Czech Republic; simona.nevyhostena@gmail.com

Abstract

In the field of medical technology, metrological assurance of instruments with measuring functions is crucial to ensuring their correct and precise operation, which is essential for the diagnosis, treatment, and monitoring of patients' health. This research presents a solution for the metrological assurance of instruments with measuring functions classified in category "C" [1], which require the provision of both the instrument with measuring capability and its metrological reliability, with reference to the transfer standard [2] as a benchmark for classical traceability and clinically evaluated instruments [3] when used in clinical conditions.

The proposed approach utilizes a combination of clinical trials and transfer standards as tools for validating the performance and accuracy of measuring devices. A clinical trial, conducted under typical healthcare conditions, allows for the verification of the functionality of instruments in real-world settings and helps identify potential deviations that may affect measurement results. The transfer standard, in turn, provides a metrological reference to ensure the continuity of measurements and the correctness of instrument calibration over the long term. This process not only involves determining measurement accuracy but also monitoring the stability and repeatability of the measured parameters during routine inspection cycles. [4]

The proper metrological assurance of instruments using this integrated approach not only ensures compliance with normative requirements but also contributes to greater safety and the quality of healthcare services provided. [5] This approach can serve as a model for the metrological assurance of other devices with measuring functions, thus contributing to harmonization and ensuring quality within the healthcare sector at the international level.

Key words

calibration, clinical trial, healthcare, medical devices, metrology, transfer standard

Acknowledgement
The authors would like to express their sincere gratitude to the Slovak University of Technology in Bratislava (Faculty of Mechanical Engineering), the Czech Metrology Institute, the Charles University (First Faculty of Medicine), the KEGA grant agency (Project No. 024STU-4/2023: Building a Laboratory of Medical Metrology), and the APVV grant agency (Project Nos. APVV-21-0216: Advanced Mathematical and Statistical Methods for Measurement and Metrology, and APVV-21-0195: Research the Possibility of Digital Transformation of Continuous Transport Systems) for their valuable support.

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NEW LABORATORY FOR MEDICAL METROLOGY

Jan Rybář[1], Stanislav Ďuriš[2], Jozef Leja[3]

[1]Institute of Automation, Informatization, and Measurement, Faculty of Mechanical Engineering, Slovak University of Technology in Bratislava, Nám. slobody 17, 812 31 Bratislava, Slovakia; jan.rybar@stuba.sk

[2]Institute of Automation, Informatization, and Measurement, Faculty of Mechanical Engineering, Slovak University of Technology in Bratislava, Nám. slobody 17, 812 31 Bratislava, Slovakia; stanislav.duris@stuba.sk

[3]Institute of Mathematics and Physics, Faculty of Mechanical Engineering, Slovak University of Technology in Bratislava, Nám. slobody 17, 812 31 Bratislava, Slovakia; jozef.leja@stuba.sk

Abstract

As part of the educational activities and ongoing projects at the Faculty of Mechanical Engineering, Slovak University of Technology in Bratislava, we have set the goal of establishing a modern research and educational center focusing on the development and application of precise measurement methods in the field of medicine. The KEGA project 024STU-4/2023, titled "Building a Laboratory of Medical Metrology", responds to the growing need for high-quality and reliable measurement in healthcare, diagnostics, and research, where measurement accuracy is crucial for ensuring patient safety and treatment efficacy. This project has reached a successful conclusion.

The laboratory is equipped with state-of-the-art technologies for the metrological control of medical devices, analysis of biological samples, and the development of new measurement techniques. A significant contribution to education is the provision of specialized training, workshops, and practical exercises for students in the fields of measurement and testing, as well as medicine, biomedical sciences, and engineering, thus strengthening the connection between theory and practice. [1; 2]

The project has not only contributed to the advancement of scientific research in the field of medical metrology but also to the innovation of measurement methodologies in medical technology. [3] The long-term goal is to support the development of new, more accurate, and efficient diagnostic and therapeutic methods, which have the potential to improve healthcare globally.

This conference paper presents an investment in the development of science, education, and healthcare, with a direct impact on enhancing the quality and safety of healthcare services and facilities.

Key words

education, healthcare, laboratory, medical metrology, project

Acknowledgement

The authors express their sincere gratitude to the Slovak University of Technology in Bratislava (Faculty of Mechanical Engineering), the KEGA grant agency (project number 024STU-4/2023: Building a Laboratory of Medical Metrology), and the APVV grant agency (project numbers APVV-21-0216: Advanced Mathematical and Statistical Methods for Measurement and Metrology, and APVV-21-0195: Research the Possibility of Digital Transformation of Continuous Transport Systems) for their invaluable support.

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IONIZING RADIATION AND ITS IMPACT ON CELLS AND TISSUES

Jozef Leja[1], Jan Rybář[2], Peter Onderčo[3], Jana Gerneschová[4], Simona Nevyhoštěná[5]

[1]Institute of Mathematics and Physics, Faculty of Mechanical Engineering, Slovak University of Technology in Bratislava, Nám. slobody 17, 812 31 Bratislava, Slovakia; jozef.leja@stuba.sk

[2]Institute of Automation, Informatization, and Measurement, Faculty of Mechanical Engineering, Slovak University of Technology in Bratislava, Nám. slobody 17, 812 31 Bratislava, Slovakia; jan.rybar@stuba.sk

[3]Institute of Automation, Informatization, and Measurement, Faculty of Mechanical Engineering, Slovak University of Technology in Bratislava, Nám. slobody 17, 812 31 Bratislava, Slovakia; peter.onderco@stuba.sk

[4]Primary Metrology Laboratories Prague, Czech Metrology Institute, Okružní 31, Brno 638 00, Czech Republic /workplace Praha, Czech Republic/ & Institute of Automation, Informatization, and Measurement, Faculty of Mechanical Engineering, Slovak University of Technology, Nám. slobody 17, Bratislava 812 31, Slovakia; jana.gerneschova@stuba.sk

[5]Institute of Biophysics and Informatics, First Faculty of Medicine, Charles University, Kateřinská 32, 121 08, Praha 2, Czech Republic; simona.nevyhostena@gmail.com

Abstract

The biological effects of ionizing radiation arise from its interaction with matter at the molecular and cellular levels, particularly concerning its impact on cells and tissues [1]. The topic also includes radiological physics, which provides the physical basis for understanding the propagation and absorption of radiation in biological tissues [2]. To assess the risks associated with radiation exposure, biologically weighted doses are used, such as equivalent and effective doses, which take into account the type of radiation and the sensitivity of individual tissues. In this context, the current ICRP recommendations [3] are presented, including weighting factors, natural background radiation, doses from medical procedures, and exposure limits for different population groups.

The conference paper describes the health effects of ionizing radiation, ranging from acute deterministic to long-term stochastic effects, and presents lethal dose values for various organisms [4]. Its aim is to emphasize the importance of proper assessment and control of radiation exposure for health protection. Ensuring safety when working with ionizing radiation is essential to minimize harmful biological effects at the cellular and tissue levels. Adhering to appropriate protective measures, monitoring doses, and respecting exposure limits contribute to reducing both immediate and long-term health risks.

More detailed information will be provided directly in the conference paper, where the biological effects on cellular and tissue structures will be analyzed in depth. Attention will also be given to current safety standards, dose assessment methods, and strategies to reduce exposure and protect human health. [1; 4]

Key words

environment, health, ionizing radiation, metrology

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TRAFFIC NOISE – LAWS, MEASUREMENT, HUMAN HEALTH

Peter Onderčo[1], Jan Rybář[2], Jozef Leja[3]

[1]Institute of Automation, Informatization, and Measurement, Faculty of Mechanical Engineering, Slovak University of Technology in Bratislava, Nám. slobody 17, 812 31 Bratislava, Slovakia; peter.onderco@stuba.sk

[2]Institute of Automation, Informatization, and Measurement, Faculty of Mechanical Engineering, Slovak University of Technology in Bratislava, Nám. slobody 17, 812 31 Bratislava, Slovakia; jan.rybar@stuba.sk

[3]Institute of Mathematics and Physics, Faculty of Mechanical Engineering, Slovak University of Technology in Bratislava, Nám. slobody 17, 812 31 Bratislava, Slovakia; jozef.leja@stuba.sk

Abstract

Traffic noise is a subset of the broader category of environmental noise. When assessing noise, the source determines the applicable standards and permissible limits. The most common environmental noise sources (also referred to as applications) include traffic noise (road, rail, and aircraft), industrial noise, recreational noise, neighbor noise, and construction site noise. Most legal requirements—such as rating levels, measurement methodologies, and health protection—are defined within standardized regulations. [1; 2]

According to data reported in 2017 under the Environmental Noise Directive, it is estimated that at least 18 million people are highly annoyed and 5 million suffer significant sleep disturbance due to long-term exposure to traffic noise. The European Union's Zero Pollution Action Plan aims to reduce the number of people affected by transport noise by 30%. [3]

Traffic noise is the largest single source of environmental noise. There are several strategies to reduce it, primarily focused on protecting human health and improving comfort. These strategies generally fall into three main categories: limiting noise generation at its source; preventing the spread of noise toward exposed individuals; and implementing protective measures in sensitive environments such as hospitals. [4; 5]

The impact of traffic noise plays a significant role in evaluating its effects on public health and in the design of effective mitigation measures. Proper measurement and its influence on the surrounding environment will be presented in more detail as part of the conference paper.

Key words

environmental noise, human health, laws, measurement, traffic noise

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THE IMPORTANCE OF METROLOGICAL TRACEABILITY IN HEALTHCARE – THE ROLE OF NATIONAL STANDARDS OF THE SLOVAK REPUBLIC IN ENSURING RELIABLE MEASUREMENTS

Andrej Smetánka[1], Jan Rybář[2], Jozef Leja[3]

[1]Institute of Automation, Informatization, and Measurement, Faculty of Mechanical Engineering, Slovak University of Technology in Bratislava, Nám. slobody 17, 812 31 Bratislava, Slovakia; andrej.smetanka@stuba.sk

[2]Institute of Automation, Informatization, and Measurement, Faculty of Mechanical Engineering, Slovak University of Technology in Bratislava, Nám. slobody 17, 812 31 Bratislava, Slovakia; jan.rybar@stuba.sk

[3]Institute of Mathematics and Physics, Faculty of Mechanical Engineering, Slovak University of Technology in Bratislava, Nám. slobody 17, 812 31 Bratislava, Slovakia; jozef.leja@stuba.sk

Abstract

Reliable and accurate operation of medical devices is essential for safe and effective healthcare. According to current legislation in the Slovak Republic, only a specific group of measuring instruments—referred to as "specified measuring instruments"—is subject to regular and independent metrological control. These instruments must be verified at intervals defined by a government regulation. This group includes devices such as blood pressure monitors, dosimeters, medical thermometers, and others. Ensuring the traceability of these instruments is crucial for achieving reliable measurement results. [1]

The metrological traceability [2] chain represents a sequence starting from the SI base units, through national standards, down to the individual measuring instrument. In Slovakia, national standards are managed by the Slovak Institute of Metrology [3], which is responsible for their development and maintenance. Although legislation mandates independent metrological control only for specified measuring instruments, in practice, there is an increasing emphasis on ensuring metrological control—i.e., calibration—even for other medical devices with a measuring function. This is because accurate and reliable measurement results are essential for making correct diagnoses and setting optimal treatments. A typical example is pressure metrology in healthcare [4].

This conference paper highlights the importance of national standards in the context of direct metrological traceability of selected quantities in the field of healthcare.

Key words

healthcare, medical metrology, metrological traceability, national standard

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VYUŽITÍ SENZORŮ S TVAROVOU PAMĚTÍ K DETEKCI PERISTALTIKY STŘEV

Simona Nevyhoštěná[1], Jan Zeman[2], Jan Rybář[3]

[1]Ústav biofyziky a informatiky, 1. lékařská fakulta, Univerzita Karlova, Kateřinská 32, 121 08, Praha 2, Česká republika; simona.nevyhostena@gmail.com

[2]Ústav biofyziky a informatiky, 1. lékařská fakulta, Univerzita Karlova, Kateřinská 32, 121 08, Praha 2, Česká republika; jan.zeman@lf1.cuni.cz

[3]Ústav automatizácie a merania, Strojnícká fakulta Slovenskej technickej univerzity v Bratislavě, Nám. Slobody 17, 812 31 Bratislava, Slovensko; jan.rybar@stuba.sk

Abstrakt

Slitiny s tvarovou pamětí (SMA) představují specifickou skupinu materiálů, které vykazují dvě unikátní vlastnosti – efekt tvarové paměti a superelasticitu. Díky nim jsou SMA senzory schopny reagovat na malé mechanické deformace a převádět je na měřitelný výstup. Tato kombinace vlastností je činí atraktivními pro využití v biomedicínském inženýrství, zejména v situacích, kde je požadována vysoká citlivost a flexibilita při snímání pohybů. V posledních desetiletích se SMA senzory objevují v různých aplikacích, od ortopedických implantátů až po aktuátory v miniinvazivních přístrojích. Cílem tohoto výzkumu je posoudit možnost využití SMA senzorů k neinvazivní detekci peristaltiky střev. Peristaltika představuje klíčový fyziologický jev, jehož poruchy mohou signalizovat závažná onemocnění gastrointestinálního traktu. Plánované měření by probíhalo pomocí SMA senzorů umístěných pod levým žeberním obloukem a v dolní části břicha, kde předpokládáme minimální vliv okolních fyziologických procesů, například činnosti bránice nebo pulzace aorty. Tento výběr lokalit by mohl zvýšit šanci na zachycení specifických mechanických signálů spojených s pohybem střevní stěny. Tento výzkum má potenciál rozšířit možnosti diagnostiky a monitorování gastrointestinálních poruch a zároveň přispět k většímu komfortu a bezpečnosti pacientů. Do budoucna by tato metoda mohla představovat významný krok směrem k personalizované medicíně, která kombinuje vysokou přesnost měření s minimální invazivitou.

Key words

Senzory s tvarovou pamětí, SMA, peristaltika střev,

Acknowledgement

Poděkování patří všem spoluautorům a také Technické univerzitě v Liberci, která je nedílnou součástí výroby vhodného senzoru s tvarovou pamětí.

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VISIBILITY OF PREMATURE BEATS IN PHOTOPLETHYSMOGRAPHY SIGNALS

Enikö Vargová[1], Milan Sepši[2], Andrea Němcová[1]

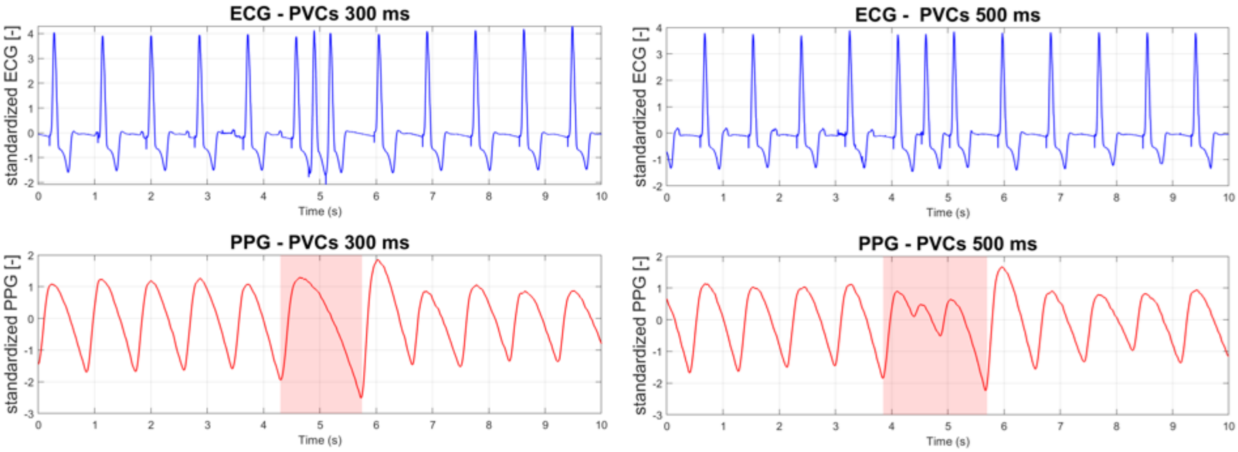
[1] Department of Biomedical Engineering, Faculty of Electrical Engineering and Communication, Brno University of Technology, Brno, Czech Republic

[2] Department of Internal Medicine and Cardiology, University Hospital Brno and Faculty of Medicine of Masaryk University, Brno, Czech Republic

Abstract

Photoplethysmography (PPG) has recently emerged as a promising non-invasive tool for cardiac arrhythmia (CA) detection, particularly when integrated into wearable or smart devices, offering continuous and accessible cardiac monitoring [1]. However, premature beats (PBs) do not always produce clearly observable peaks in PPG signals [2], which can complicate their detection and, consequently the identification of CAs.

To investigate this, we conducted a study with 20 subjects in which PBs were induced by pacing from implantable cardioverter-defibrillator or pacemaker at coupling intervals ranging from 300 to 500 ms in 50ms increments. During each measurement protocol, both PPG signals and reference ECG recordings were collected. The pacing protocol was structured as follows: to induce premature atrial contractions (PACs), double and triple pacing stimuli were delivered to right atrium across all coupling intervals from 300 to 500 ms. In addition, quadruple and quintuple stimuli were applied at coupling intervals of 450 ms and 500 ms, respectively, to induce supraventricular tachycardia. The same sequence was then performed for premature ventricular contractions (PVCs), with 2×–3× pacing stimuli delivered to right ventricle across 300–500 ms coupling intervals, followed by 4× and 5× stimuli at 450 ms and 500 ms to induce ventricular tachycardia. In total, this protocol yielded 280 measurements. Each measurement was assigned a binary visibility label based on the following criterion: if all PPG peaks corresponding to all PBs were clearly identifiable, visibility was defined as 1, otherwise, it was defined as 0. Some measurements were excluded from analysis because pacing at very short coupling intervals failed to propagate in the myocardium or PPG recordings were corrupted by motion artifacts.



Analysis of the resulting PPG data showed that the proportion of visible PBs increased with longer coupling intervals, underscoring the importance of identifying the threshold at which reliable detection is achieved. Let p denote the proportion of measurements with all PB peaks visible out of the total number of measurements at a given coupling interval. At 300 ms, none of the 22 measurements showed all PBs visible (p = 0, 95% CI [0.0–0.15]); at 350 ms, the proportion increased to $p \approx 0.59$ (95% CI [0.39–0.76], 29 measurements); at 400 ms, it rose further to $p \approx 0.86$ (95% CI [0.71–0.95], 37 measurements); and at 450 ms and 500 ms, all PBs were visible in all measurements (77 and 78, respectively). These findings indicate that PB detection in PPG can be considered reliably achievable from coupling intervals of 400 ms and above, providing quantitative guidance for interpreting and applying PPG-based CAs monitoring in clinical and research settings.

Key words

Photoplethysmography, Premature beats, Coupling intervals

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PREDICTION OF THERAPY IN CHILDREN WITH DEEP CERVICAL INFLAMMATION

Jan, Šíma[1,2], Klára, Perce[1], Milan, Urík[1]

[1] Department of Pediatric Otorhinolaryngology, University Hospital Brno and Faculty of Medicine of Masaryk University, Brno, Czech Republic

[2]Department of Biomedical Engineering, Brno University of Technology, Brno, Czech Republic

Abstract

Deep cervical inflammation in children is a serious infectious disease that affects deep areas of the cervical region and poses a significant risk of complications, including the spread of inflammation to surrounding structures such as the mediastinum. Children are a particularly vulnerable group because they have limited communication skills, which complicates diagnosis. The main diagnostic methods include contrast-enhanced computed tomography (CT), or magnetic resonance imaging (MRI) or ultrasound (US), supplemented by biochemical monitoring of inflammatory markers, such as checking the amount of C-reactive protein (CRP) or the number of leukocytes in the blood. Treatment usually involves a combination of broad-spectrum antibiotics (ATB) and surgical intervention, including abscess drainage. Early diagnosis and proper treatment are key to successfully managing this disease and preventing serious complications such as sepsis. This work focuses on predicting the specific type of treatment. The main objective is therefore to verify the reliability of predicting the type of treatment from available data and to determine which symptoms most influence the choice of treatment type.

The study includes patients admitted to the Children's University Hospital in Brno with severe throat inflammation between 2010 and 2022, a total of 78 patients. The patients were aged 0–17 years. Fifty-one patients underwent surgery, and conservative treatment with antibiotics was used to cure 27 cases. A total of 22 symptoms and the type of treatment (surgical or conservative) were identified for each case. Two irrelevant symptoms were omitted, namely the total length of hospitalisation (a symptom occurring after treatment) and the imaging method (89.7% CT, 2.6% MR and 7.7%), which was performed on all patients. Numerical symptoms included age, abscess volume, leukocyte count, neutrophil count, percentage of neutrophils in leukocytes, CRP, and duration of symptoms prior to hospitalization. Binary symptoms included gender, abscess >2 cm^3, compression of large vessels, dysphagia, odynophagia, pain, limited mobility, bulging, trismus, respiratory distress, and dysphonia. And two categorical variables: side of the abscess (bilateral, left, and right) and location of the abscess (parapharyngeal, retropharyngeal, multiple, and other).

As part of the analysis of symptoms, we compared their relationship to the choice of treatment and also the mutual associations between individual variables. Spearman's correlation analysis (association between numerical variables), Cramer's V coefficient (association between categorical variables), and Eta-squared analysis (statistically compares the significance of the means of numerical variables in individual categories of the variable) were used to determine the relationships between the parameters (in Figure 1). Exploratory analysis showed that the key factor for indicating a surgical solution is primarily the size of the abscess, especially if it exceeds 2 cm³. This symptom appears to be the most significant predictor across all models used. Furthermore, the values of inflammatory markers (CRP, neutrophils, and leukocytes), which also correlate significantly with each other, appear to be essential. In addition, symptoms such as odynophagia and dysphagia and odynophagia and dysphonia are closely related, which supports outpatient findings. [1] Associations between predictors showed that some characteristics are closely related (e.g., the binary variable abscess >2 cm³ has an impact on the continuous variable CRP value, i.e., the larger the abscess volume, the higher the CRP).

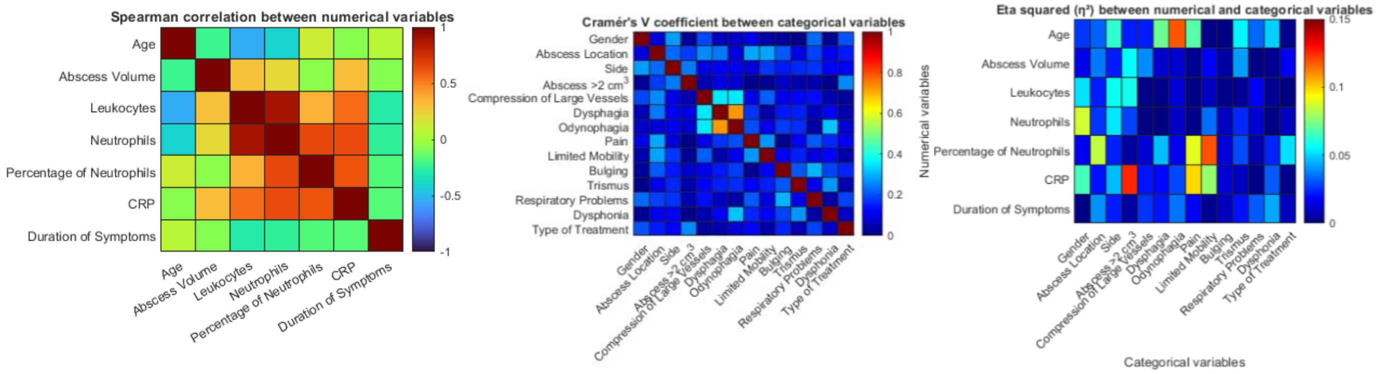

Figure 1. Correlation analysis using Spearman, Cramér, and Eta squared for both numerical and categorical variables.

When analyzing the symptoms, one hypothesis was tested: whether there is a correlation between the location of deep cervical inflammation and the type of treatment at a significance level of 0.05. Fisher's exact test was used to calculate the independence test based on the contingency table. The calculation of the chi-square test based on the contingency table gave a p-value of 0.63. Therefore, the null hypothesis of independence cannot be rejected.

As part of the preprocessing, normalization was performed for continuous variables using the Zscore method and for categorical variables using the OneHotEncoder method. The following models with the following settings were selected for predicting the type of treatment: 1. Logistic regression (LR) with ElasticNet, 2. Linear discriminant analysis (LDA) with shrinkage, 3. Random Forest (RF) machine learning model with regularization. Stratified 5-fold cross-validation (with shuffling and random state 42) was used for validation. For the unsupervised LDA method, cross-validation was used to test model stability. LDA is stochastic in nature, so results may vary even with the same input data. The metrics used were AUC, Accuracy, Sensitivity (surgical detection), Specificity (conservative detection), F1 score, and Precision.

Table 1. Results of prediction of deep cervical inflammation..

Model	AUC	Accuracy	Sensitivity	Specificity	F1 score	Precision
LR	**0,695**	0,603	0,607	**0,600**	0,665	**0,765**
LDA	0,629	0,590	0,702	0,373	**0,686**	0,675
RF	0,597	**0,640**	**0,802**	0,340	0,741	0,697

In summary, data analysis supports clinical experience that abscess size and clinical blood markers are decisive factors for surgical procedure. To verify the dependence of abscess location and type of treatment, p-values of 0.63 were obtained. This means that at a significance level of 0.05, there is no statistically significant evidence of a dependence between the location of deep cervical inflammation and the type of treatment.

Based on the results of the treatment type prediction (in Table 1), the main hypothesis can be evaluated, namely whether the type of therapy for deep cervical inflammation can be reliably predicted using these symptoms. Yes, the type of therapy can be predicted to a certain extent, but the discriminatory power of this data is rather moderate. The best AUC was obtained for the LR model (0.695). It has a high sensitivity and specificity value. This is close to the limit of acceptable predictive performance. In terms of clinical credibility, this prediction is insufficient, and the accuracy of the prediction could be improved by expanding the dataset or adding and finding more symptoms. The LDA and RF methods would be applicable if the clinical priority was not to overlook surgical cases. However, the aim here is to accurately separate and predict conservative and surgical cases at the beginning of treatment during diagnosis, so a more general LR model is more appropriate.

Key words
Deep cervical inflammation, Machine learning, Linear discriminant analysis

Acknowledgement
This research would not have been possible without the cooperation of Brno University Hospital.

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HODNOCENÍ VLIVU ELEKTROMAGNETICKÉHO POLE EMITOVANÉHO ELEKTROMOBILY NA KARDIOSTIMULAČNÍ TECHNIKU

Tomáš, Souček[1,2], Adam, Urbančík[1], Lukáš, Krčmář[2]

[1]Fakulta zdravotnických studií, Technická univerzita v Liberci, Liberec, Česká republika

[2]Fakulta mechatroniky, informatiky a mezioborových studií, Technická univerzita v Liberci, Liberec, Česká republika

Abstrakt

Kardiostimulační přístroje mohou být za určitých okolností ovlivněny vnějším elektromagnetickým polem. Z tohoto důvodu je nutné znát potenciálně rizikové zdroje rušivých polí i vliv, který mohou mít na zdraví pacienta. Cílem příspěvku je zhodnotit rizika používání elektromobilů u pacientů s kardiostimulátory. Ve vybraných modelech elektromobilů bylo provedeno měření intenzit elektrického a magnetického pole. Zároveň byl pomocí zkonstruovaného fantomu lidského těla a explantovaných kardiostimulátorů ověřeno, zda emitovaná pole mohou ovlivnit funkci stimulačních zařízení, případně posoudit klinický význam. Oba experimenty proběhly při maximálním zatížení v modelových situacích – na sedadle řidiče a spolujezdce, na zadním sedadle a v těsné blízkosti nabíjecího kabelu během nabíjení. Zachycené elektrické a magnetické pole nebyly hodnoceny jako významné z hlediska rizika pro kardiostimulační systém. Na základě sledovaných elektrogramů a stimulačních parametrů nebylo identifikováno žádné ovlivnění funkce kardiostimulátorů.

Key words

Elektromobilita, kardiostimulátor, elektromagnetická interference

Acknowledgement

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CURRENT PERSPECTIVES ON LIGHT MODULATION OF MESENCHYMAL STEM CELLS

Veronika, Sedláková[1], Radovan, Hudák[1], Teodor Tóth[1], Richard Staško[1], Peter Szedlák[1], Dominik Hakulin[2]

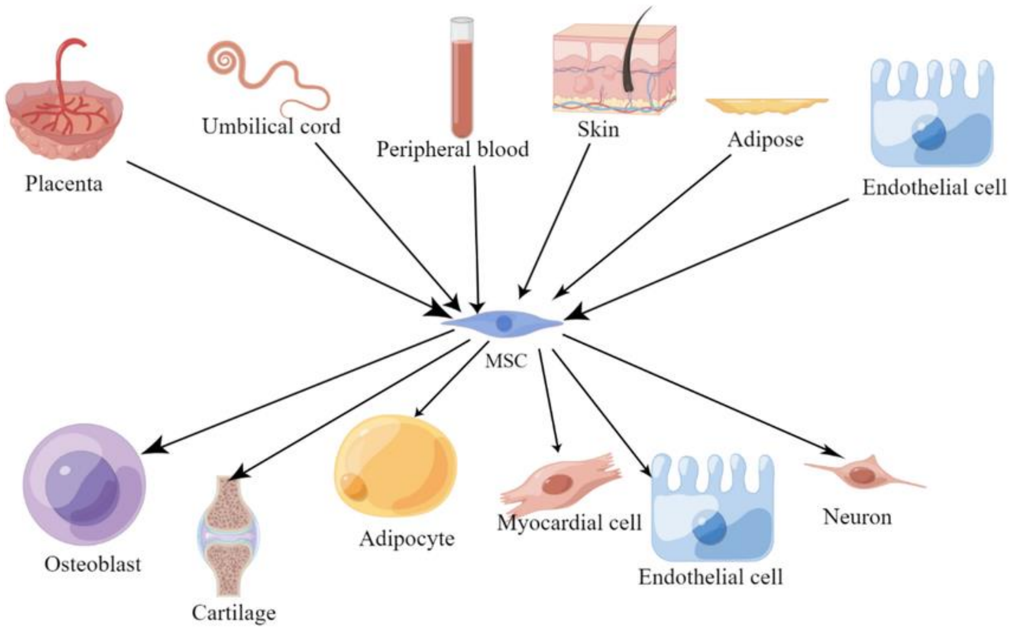
[1] Department of Biomedical Engineering and Measurement, Faculty of Mechanical Engineering, TUKE, Košice, Slovakia

[2]Datacomp s.r.o, Moldavská cesta 32, 040 11 Košice, Slovakia

Abstrakt

Mesenchymal stem cells (MSCs) are among the key tools in regenerative medicine due to their ability for self-renewal, differentiation into multiple cell lineages, and secretion of bioactive molecules that promote tissue repair [1,2,3,4]. Recent research has focused on optimizing not only the microenvironment of MSCs but also external factors that influence their viability and function. One promising non-invasive approach is photobiomodulation with red light, which has been shown to stimulate mitochondrial activity, enhance energy metabolism, and modulate cytokine secretion through interactions with chromophores such as cytochrome c oxidase [5,6].

MSCs can be isolated from a wide variety of sources, including bone marrow, adipose tissue, umbilical cord blood, placenta, and skin. All these sources demonstrate strong differentiation potential into osteoblasts, chondrocytes, adipocytes, cardiomyocytes, or neurons [7,8]. Various biofactors, vitamins, and cytokines have been studied for their effects on MSC proliferation and differentiation, but maintaining self-renewal and multipotency remains a central challenge [9]. Photobiomodulation therefore emerges as a promising supportive strategy to enhance the therapeutic potential of MSCs before their clinical application [10].



Obr. 1 Mesenchymal Stem Cell Sources and Differentiation Potential

Evidence indicates that red light in the range of 600–1000 nm increases MSC proliferation, paracrine activity, and secretion of key factors such as interleukin-6 (IL-6) and vascular endothelial growth factor (VEGF). These effects have been particularly confirmed in adipose-derived MSCs, where an increase in metabolic activity was observed 24 hours after irradiation, accompanied by enhanced nitric oxide production without significant changes in oxidative stress [11]. By contrast, blue light (410–470 nm) has been associated with reduced MSC proliferation, increased production of reactive oxygen species (ROS), and overall negative effects on cell viability [12,13]. These contrasting findings highlight the importance of carefully selecting appropriate wavelengths for therapeutic applications.

Despite many promising results, inconsistencies in experimental parameters such as wavelength, irradiance, or exposure time remain a significant limitation for reproducibility across studies [5,6]. Standardization of protocols and a deeper understanding of the underlying biological mechanisms are therefore essential. Such advancements will allow photobiomodulation to be more effectively applied in MSC preconditioning and ultimately support its translation into clinical practice [11,12,13].

Key words
mesenchymal stem cells, regenerative medicine, red light, photobiomodulation

Acknowledgement
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BEYOND THE FINISH LINE: ACUTE GLUCOSE RESPONSE IS LINKED WITH AEROBIC FITNESS

Lucie Šaclová[1], Andrea Němcová[1], Kateřina Hyková[1], Tobiáš Goldschmidt[1,2], Lukáš Smital[1], Daniela Chlíbková[2], Martin Králík[1], Radovan Smíšek[1], Oliver Jaroš[1,2], Jaromír Hubálek[3]

[1]Department of Biomedical Engineering, Faculty of Electrical Engineering and Communication, Brno University of Technology

[2]Centre of Sports Activities, Brno University of Technology

[3]Central European Institute of Technology, Brno University of Technology

Abstract

Acute high-intensity physical exercise can affect blood glucose levels even in healthy individuals, depending on exercise intensity and duration, training status, and metabolic adaptations. Changes in glucose during exercise may reflect differences in energy metabolism capacity and hormonal response [1]. The aim of this study was to determine whether an increase in glucose during a maximal graded exercise test is associated with aerobic fitness (VO_2max) and glucose variability in the previous and following days.

Thirty-three healthy recreational and competitive athletes, aged 18–50 years, wore a continuous glucose monitoring device (Dexcom G7, recording glucose level every 5 minutes) for 10 days. During the monitoring period, they completed a graded exercise test to exhaustion (5 min warm-up, workload increased every 2 min, 5 min cooldown, total duration 20–30 min), and VO_2max was established. Data for VO_2max calculation were measured continuously with a gas analyzer MetaLyzer 3B (Cortex, Germany). The criterion of reaching VO_2max was respiratory exchange ratio (RER) above 1.1. The glucose difference between two time points: 10 min after the test and 10 min before the test was calculated, accounting for the delay between interstitial and plasma glucose levels. Furthermore, the coefficient of variation was calculated for the day before the test, the day of the test, and the first and second days after the test.

Participants were divided into two groups: 1) glucose increase <1 mmol/l (n = 19) and 2) glucose increase ≥1 mmol/l (n = 14)) according to the difference in glucose between the above-mentioned two time points. Differences between groups in VO_2max and glucose variability (coefficient of variation) on the day before the test, on the test day, and on the first and second days after the test were assessed. Data normality was evaluated using the Shapiro–Wilk test, which indicated that the data were not normally distributed ($p < 0.05$); therefore, differences between groups were analyzed using the non-parametric Mann–Whitney U test, ($p < 0.05$) meaning statistical significance.

The group with a glucose increase ≥1 mmol/l had a higher median VO_2max (52 $ml \cdot kg^{-1} \cdot min^{-1}$, IQR 50-56 $ml \cdot kg^{-1} \cdot min^{-1}$) compared to the group without an increase (44 $ml \cdot kg^{-1} \cdot min^{-1}$, IQR 35-50 $ml \cdot kg^{-1} \cdot min^{-1}$), with the difference being statistically significant ($p = 0.0177$). Glucose variability on the first day after the test was also higher in the increased-glucose group (18.06%, IQR 11-16% vs. 14.32%, IQR 15-22%), which was statistically significant ($p = 0.0139$). No statistically

significant differences in glucose variability were observed on the day before the test, on the test day, and on the second day after the test.

These findings suggest that an acute increase in glucose after maximal exercise is associated with higher aerobic capacity and increased glucose variability on the following day. These findings are consistent with the conclusions reported in Flockhart's et al. study [2]. This phenomenon may reflect a different metabolic and hormonal response in more trained individuals. Insignificant differences in glucose variability the day before and on the day of the test support the hypothesis that the observed changes are induced by exercise itself.

Key words

glucose, graded exercise test, VO2max, glucose variability, continuous glucose monitoring, CGM

Acknowledgement

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NÁVRH A KONŠTRUKCIA ZARIADENIA NA FARBENIE 3D TLAČENÉHO MATERIÁLU PA12

Petra Babicová[1], Norbert Ferenčík[1], Radovan Hudák[1]

[1] Katedra biomedicínskeho inžinierstva a merania, Technická univerzita v Košiciach

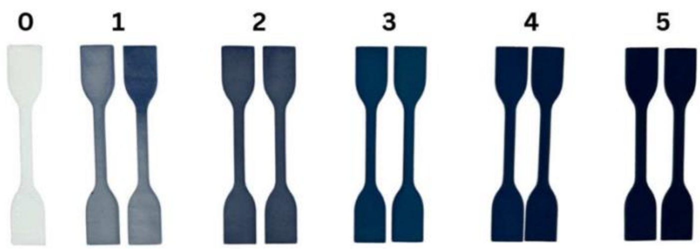
Abstrakt

Polyamid 12 (PA12) patrí medzi najčastejšie používané polyméry v oblasti aditívnej výroby pre medicínske aj priemyselné aplikácie vďaka svojej biokompatibilite, chemickej odolnosti a mechanickej stabilite. Estetické a funkčné požiadavky na tieto komponenty viedli k potrebe vyvinúť kontrolovateľný systém farbenia, ktorý by zabezpečil homogénnu farebnú úpravu bez narušenia vlastností materiálu.

V článku predstavujeme návrh, konštrukciu a testovanie kompaktného zariadenia na farbenie 3D tlačených vzoriek z PA12, využívajúceho priemyselný mordant N-RIT-88150-BUN1. Systém označený ako Controlled Mordant Dyeing System (CMDS) bol navrhnutý s dôrazom na presnú reguláciu teploty, koncentrácie mordantu a času ponoru. Inšpiráciou pre jeho vývoj bol predchádzajúci prototyp „MorPA“, založený na konštrukcii práčky, ktorý však nevyhovoval požiadavkám na prenosnosť a flexibilitu.

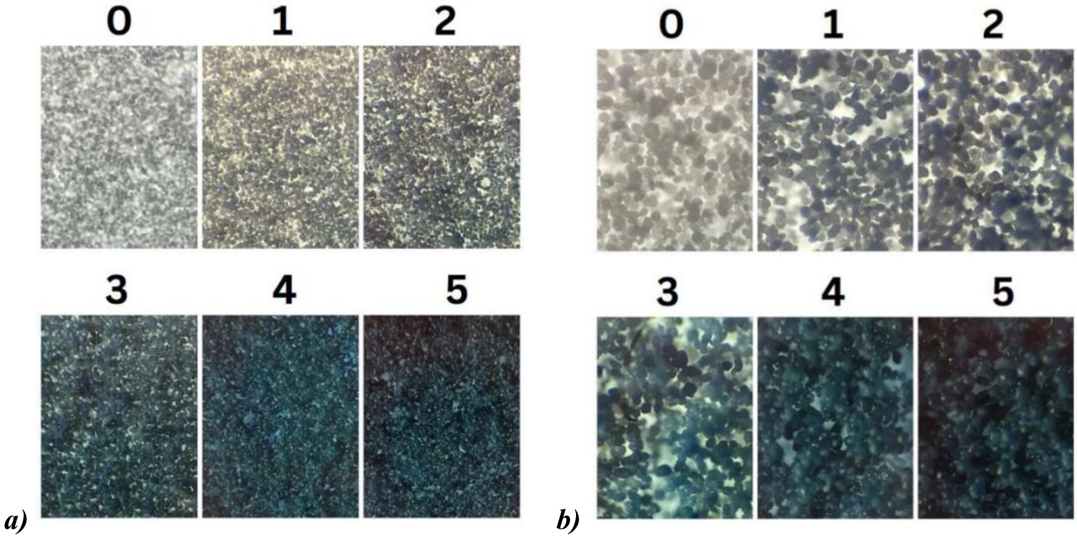
Obr. 1 Dokončený systém na morenie materiálu PA12

V rámci experimentálnej časti boli použité vzorky PA12 (HP 3D High Reusability PA12) vytlačené technológiou SLS (EOS P390). Materiál spĺňa normy USP Class I–VI a ISO 10993 pre biokompatibilitu. Vzorky s rozmermi 75×12×2 mm boli po tlači povrchovo upravené balotinovaním. Farbenie prebiehalo postupne v piatich cykloch s rastúcou koncentráciou mordantu (0,08 g – 1,20 g v 3 l vody, 90–100 °C), pričom každý cyklus trval 15 minút.



Obr. 2 Farbené vzorky PA12

Vyhodnotenie bolo realizované vizuálne aj mikroskopicky (40× a 100×). S rastúcou koncentráciou sa dosiahla vyššia intenzita farby a lepšia homogenita pokrytia povrchu. Pri najnižšej koncentrácii boli zreteľné biele póry a nerovnomerné sfarbenie, zatiaľ čo pri najvyššej koncentrácii bol povrch rovnomerne sýty a bez viditeľných defektov. Celý proces farbenia trval približne 80 minút.



Obr. 3 Farbené vzorky PA12 pri a) 40-násobnom zväčšení a b) 100-násobnom zväčšení

Výsledky potvrdzujú, že zariadenie je schopné zabezpečiť opakovateľný, kontrolovaný a efektívny proces farbenia bez ovplyvnenia mechanických vlastností PA12. Výskum týmto prispieva k rozšíreniu poznatkov o chemickej modifikácii povrchu 3D tlačených polymérov v súlade s požiadavkami biomedicínskeho inžinierstva.

Záverečná časť navrhuje perspektívu využitia prírodných farbív ako ekologickej alternatívy, s dôrazom na zachovanie farebnej stálosti, adhézie a biokompatibility. Do budúcnosti sa plánuje aj testovanie dlhodobej farebnej stability a adaptácia zariadenia na väčšie objemy alebo automatizovanú prevádzku.

Key words
3D tlač, Polyamid 12, moridlo, povrchová úprava PA12

Acknowledgement
Táto práca bola realizovaná s podporou projektu VEGA 1/0387/22 Vývoj a testovanie systémov na riadenú stimuláciu rastu buniek v bioreaktorovom prostredí s využitím počítačového videnia a projektu MEC_SZ 149477, ktorý bol implementovaný s podporou Ministerstva kultúry a inovácií Maďarska prostredníctvom Národného fondu pre výskum, vývoj a inovácie v rámci schémy MEC_24.

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BIOMEDICAL ENGINEERING IN PUBLIC TRANSPORTATION: A MULTI-FACETED APPROACH TO TRAM DRIVER SAFETY

Peter Onderčo[1], Jan Rybář[2], Jozef Leja[3], Jana Gerneschová[4], Simona Nevyhoštěná[5]

[1]Institute of Automation, Informatization, and Measurement, Faculty of Mechanical Engineering, Slovak University of Technology in Bratislava, Nám. slobody 17, 812 31 Bratislava, Slovakia; peter.onderco@stuba.sk

[2]Institute of Automation, Informatization, and Measurement, Faculty of Mechanical Engineering, Slovak University of Technology in Bratislava, Nám. slobody 17, 812 31 Bratislava, Slovakia; jan.rybar@stuba.sk

[3]Institute of Mathematics and Physics, Faculty of Mechanical Engineering, Slovak University of Technology in Bratislava, Nám. slobody 17, 812 31 Bratislava, Slovakia; jozef.leja@stuba.sk

[4]Primary Metrology Laboratories Prague, Czech Metrology Institute, Okružní 31, Brno 638 00, Czech Republic /workplace Praha, Czech Republic/ & Institute of Automation, Informatization, and Measurement, Faculty of Mechanical Engineering, Slovak University of Technology, Nám. slobody 17, Bratislava 812 31, Slovakia; jana.gerneschova@stuba.sk

[5]Institute of Biophysics and Informatics, First Faculty of Medicine, Charles University, Kateřinská 32, 121 08, Praha 2, Czech Republic; simona.nevyhostena@gmail.com

Abstract

Biomedical engineering and its advanced tools are playing an increasingly significant role in ensuring the health, professional, and psychological fitness of tram drivers. In the realm of health fitness, diagnostic equipment, such as modern imaging techniques (MRI, CT) and vital sign monitoring sensors, are employed for the early detection of health issues that could compromise driving safety. Specifically, more extensive screenings using MRI and CT scans enable the detection of neurological conditions, such as brain tumors or vascular abnormalities, that could lead to sudden loss of consciousness or impaired cognitive function. Sensors monitoring vital signs, including ECG, EEG, and pulse oximetry, can detect cardiac arrhythmias, changes in brain activity indicative of fatigue, or decreased blood oxygen levels, allowing for timely intervention and the prevention of potential accidents [1].

In assessing professional fitness, simulators and virtual reality are used for training and testing drivers in various driving scenarios, thereby improving their reaction time and decision-making skills. Simulators, equipped with realistic controls and visual environments, allow drivers to practice their responses to unexpected situations, such as sudden track obstructions, signal failures, or pedestrian collisions. Virtual reality adds another dimension, allowing drivers to experience real-world environments and simulate complex situations, such as driving in adverse weather conditions or at night. These training methods help drivers refine their skills and develop strategies for safe driving [2].

In the area of psychological fitness, neurofeedback and eye-tracking are utilized to identify and address stress, fatigue, and other psychological factors that can affect drivers' attention and reactions [2]. Neurofeedback, a technique that uses feedback on brain activity, enables drivers to learn to regulate their brainwaves and reduce levels of stress and fatigue. Eye-tracking

analyzes drivers' gaze patterns, revealing potential attention problems, such as excessive focus on specific points or overlooking important information. This data is then used for personalized training and interventions that help drivers improve their concentration and ability to react quickly to changes in the traffic environment.

These biomedical engineering tools thus contribute to enhancing the safety of both passengers and drivers through more precise diagnostic methods, more effective training, and improvements in the psychological state of tram drivers. Ultimately, the integration of these advanced technologies represents a significant step forward in transportation safety, enabling a proactive approach to accident prevention and ensuring a safe and reliable public transportation system [2; 3; 4]. The topic will be presented in further detail in a poster presentation.

Key words
biomedical engineering, diagnostics, safety, tram drivers

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VPLYV ZLOŽENIA A SIEŤOVANIA NA MECHANICKÉ SPRÁVANIE 3D TLAČENÝCH HYDROGELOVÝCH KONŠTRUKTOV

Mária Danko[1], Jana Hlubeňová[1], Norbert Ferenčík[1], Radovan Hudák[1], Marianna Trebuňová[1], Peter Kneppo[1], Richard Staško[1], Peter Szedlák[1], Jozef Živčák[1]

[1]Technická univerzita v Košiciach, SjF, KBIaM

Abstrakt
Cieľom tejto štúdie bolo vyvinúť a charakterizovať biotlačiteľné hydrogélové systémy na báze prírodných polymérov s rôznym objemovým pomerom alginátu a želatíny. Bolo pripravených deväť experimentálnych skupín (J1–J9), ktoré sa líšili obsahom alginátu (10–90 %). Vzorky boli vyrobené pomocou 3D biotlače a stabilizované dvojstupňovým zosieťovaním kombinujúcim ionotropnú geláciu a termálnu geláciu želatíny. Mechanické vlastnosti štandardizovaných skúšobných telies („dogbone“, ISO 527-2, typ 5A) boli analyzované jednoosovou ťahovou skúškou na zariadení Gel4ce Puller. Hodnotili sa pevnosť v ťahu, predĺženie pri pretrhnutí, Youngov modul a tvarová vernosť (TSA). Výsledky ukázali, že zloženie bioatramentu významne ovplyvňuje mechanické aj geometrické parametre. Stredné podiely alginátu (30–50 %) poskytli najlepšiu kombináciu pevnosti, elasticity a tvarovej stability (TSA A/B), zatiaľ čo vysoký obsah alginátu (> 70 %) síce zvyšoval pevnosť, ale spôsoboval výrazné zmršťovanie a deformácie po zosieťovaní. Zaznamenaný bol aj fenomén artefaktu terminálneho napučania, ktorý bol výraznejší pri nízkom obsahu alginátu. Štúdia potvrdzuje, že precízna optimalizácia zloženia, zosieťovania a podmienok biotlače je nevyhnutná pri návrhu funkčných hydrogélových lešení pre aplikácie v tkanivovom inžinierstve či regeneratívnej medicíne.

Kľúčové slová
hydrogel, 3D biotlač, sieťovanie, polymer, mechanické testovanie

1. Úvod

Alginátovo-želatínové hydrogély patria v súčasnosti medzi najčastejšie skúmané biomateriály [1] v oblasti tkanivového inžinierstva [2], regeneratívnej medicíny a farmaceutických aplikácií [3]. Ich popularita vyplýva z výnimočnej schopnosti viazať veľké množstvo vody [2], čím vytvárajú mäkké, vysoko hydratované a flexibilné 3D štruktúry, ktoré napodobňujú extracelulárnu matricu (ECM) [4]. Tým poskytujú priaznivé mikroprostredie podporujúce adhéziu, proliferáciu a diferenciáciu buniek [6], čo ich predurčuje na využitie pri vývoji bioaktívnych lešení a nosičových systémov.

Kombinácia alginátu a želatíny prináša výrazný synergický efekt z hľadiska chemického zloženia [6], mikroštruktúry [7] aj biomedicínskej funkčnosti [8]. Ide o unikátnu zmes prírodných polymérov s vysokou biokompatibilitou [9, 10], vhodnou mechanickou stabilitou [3, 10] a biologickou aktivitou [11–13]. Napriek rozsiahlemu výskumu však mechanické vlastnosti 3D biotlačených hydrogélov s rôznymi pomermi zložiek a rôznym stupňom sieťovania zostávajú nedostatočne preskúmané. Táto poznatková medzera je významná najmä pri výrobe viacvrstvových konštruktov, kde mechanické parametre zásadne ovplyvňujú tvarovú vernosť, štrukturálnu stabilitu a vhodnosť pre bunkovú kultiváciu.

Alginát sodný, získavaný z hnedých morských rias [4], je aniónový polysacharid tvorený opakujúcimi sa jednotkami kyseliny mannurónovej a gulurónovej. Je známy svojou schopnosťou vytvárať stabilné hydrogély prostredníctvom ionotropnej gelácie v prítomnosti dvojmocných katiónov, najmä Ca^{2+} [14, 15]. Napriek jeho nízkej bunkovej afinitete [16] a slabej adhézii k tkanivu [17, 18], disponuje vhodnými reologickými vlastnosťami a vysokou stabilitou vo vlhkom prostredí, čo z neho robí atraktívnu zložku pre tvorbu bioatramentov.

Želatína, denaturovaná forma kolagénu, dokáže napodobniť štruktúru extracelulárnej matrice a podporuje adhéziu aj proliferáciu buniek [6, 7], čo je zásadné pre aplikácie v tkanivovom inžinierstve. Rozlišujeme želatínu typu A (kyslá hydrolýza, pI ≈ 7,0–9,0) a typu B (alkalická hydrolýza, pI ≈ 4,8–5,2), pričom rozdiely v chemických vlastnostiach a elektrostatickom správaní ovplyvňujú ich interakcie s inými biopolymérmi, ako je napríklad alginát [18]. Želatína typu A sa často využíva v biotlači pre svoju vyšší schopnosť gelácie, lepšie viskózne vlastnosti pri telesnej teplote [19] a priaznivú kompatibilitu s bunkami. Oba typy obsahujú RGD sekvencie, ktoré podporujú bunkovú adhéziu a široko sa využívajú pri tvorbe bioatramentov a hydrogélových lešení [20, 21].

Kombinácia želatíny typu A s vysokou Bloomovou hodnotou a alginátu sodného umožňuje navrhovať hydrogélové systémy s laditeľnými mechanickými a reologickými vlastnosťami [2, 26, 27]. Takéto systémy sú obzvlášť perspektívne pre vývoj lešení mäkkých tkanív [28], pokročilých obväzov či 3D biotlače komplexných štruktúr [28, 29].

Cieľom tejto štúdie je pripraviť a mechanicky charakterizovať sériu hydrogélových formulácií J1–J9 s rozdielnymi objemovými pomermi alginátu a želatíny. Hydrogély boli podrobené jednoosovej ťahovej skúške s cieľom identifikovať optimálne zloženie z hľadiska pevnosti v ťahu, elasticity a spracovateľnosti pre potenciálne aplikácie v tkanivovom inžinierstve.

Výskumná hypotéza predpokladá, že zmena pomeru želatíny a alginátu významne ovplyvní mechanické vlastnosti hydrogélov: vyšší podiel želatíny zlepší flexibilitu a spracovateľnosť, zatiaľ čo vyšší podiel alginátu prispeje k zvýšenej pevnosti v ťahu.

2. Materiál a metodika

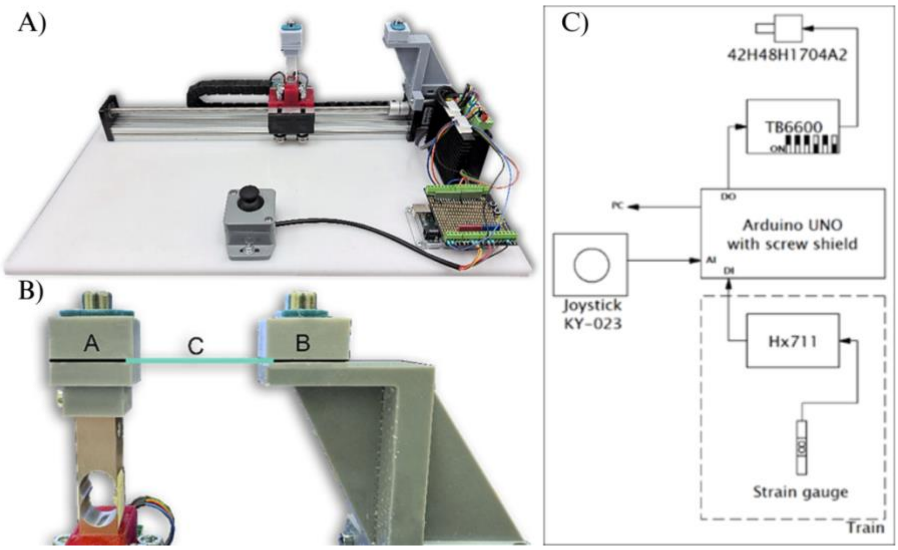
Pre prípravu biotlačiteľných hydrogelových bioatramentov boli použité dva biologicky kompatibilné polyméry: sodná soľ alginátu (≥ 99 % čistota, Sigma-Aldrich, Nemecko) a želatína typu A s vysokou Bloomovou hodnotou (300 Bloom, Sigma-Aldrich, Nemecko). Obe zložky boli rozpustené v sterilnom fyziologickom roztoku (0,9 % NaCl). Iontropné zosieťovanie bolo realizované pomocou chloridu vápenatého ($CaCl_2$) (≥ 99 %, Sigma-Aldrich, Nemecko).

Bolo pripravených deväť experimentálnych skupín hydrogélov (J1–J9) s rozdielnym objemovým podielom alginátu (10 %, 20 %, 30 %, 40 %, 50 %, 60 %, 70 %, 80 % a 90 %). Celková koncentrácia polymérov bola udržiavaná konštantná pri 16,6 % w/v. Bioatramenty boli pripravené aseptickým miešaním jednotlivých zložiek pri teplote 45 °C až do úplného rozpustenia, pričom sa zabezpečila ich homogenita pomocou magnetickej miešačky.

Hydrogélové konštrukty boli vyrobené pomocou 3D biotlačiarne Regemat3D REG4LIVE (Regemat, Španielsko) pomocou sterilných 3 ml karťuší a kužeľovitých plastových trysiek (22G, Ø = 0,41 mm). Na tlač sa použil štandardizovaný STL model skúšobného telesa typu dogbone (ISO 527-2, typ 5A). Tlač prebiehala pri laboratórnej teplote 22 °C, s rýchlosťou extrúzie 2 mm/s a teplotou tlačovej hlavy 45 °C a chladenou podložkou (15°C), ktorá bola experimentálne stanovená pomocou nášho algoritmu pre zavádzanie nových bioatramentov [26]. Pričom sa nanieslo päť vrstiev materiálu na každú vzorku. Parametre biotlače (rýchlosť extrúzie, tlak, výška vrstvy) boli optimalizované s cieľom dosiahnuť konzistentnú kvalitu konštruktov naprieč všetkými skupinami.

Po dokončení tlače boli vzorky podrobené dvojstupňovému sieťovaniu. V prvom kroku boli vzorky rýchlo stabilizované fyzikálnym ochladením na podložke (15°C), čo umožnilo zachovanie presnej geometrie počas následného chemického procesu. V druhom kroku bola aplikovaná ionotropná gelácia ponorením vzoriek do kúpeľa chloridu vápenatého počas piatich minút, čím došlo k zosieťovaniu alginátovej zložky a zvýšeniu štrukturálnej stability výsledného hydrogélu. Toto zosieťovanie prebehlo ionotropne ponorením do roztoku $CaCl_2$ (100 mM) počas päť minút, čím sa stabilizovali alginátové reťazce. Po sieťovaní boli vzorky čiastočne dehydratované na vzduchu pri teplote 22 °C a relatívnej vlhkosti nad 65 %, aby sa eliminovala prebytočná voda a stabilizovala konečná mechanická odozva materiálu. Tým sa dosiahla kombinácia mechanickej stability a udržania biologickej aktivity hydrogélov.

Mechanické charakteristiky boli vyhodnocované pomocou jednoosovej ťahovej skúšky na experimentálnej zostave Gel4ce puller (Technická univerzita v Košiciach, Slovensko), ktorá bola vyvinutá špeciálne na testovanie mäkkých biomateriálov. Testovacie zariadenie pozostáva z krokového motora s rozlíšením 0,1 mm, snímača sily s rozsahom 1000 g a riadiacej jednotky Arduino UNO. Pred začiatkom experimentov bola zostava kalibrovaná pomocou referenčných záváží a overená podľa postupov uvedených v norme ASTM D638 (Standard Test Method for Tensile Properties of Plastics), upravenej pre hydrogélové materiály. Zvolená geometria vzoriek zodpovedala odporúčaniam normy ISO 527-2 a výsledky boli porovnané s validačnými dátami publikovanými v predchádzajúcich štúdiách, čím sa potvrdila presnosť a opakovateľnosť meraní.



Obrázok 1: A) Gel4ce trhačka; B) Ukážka uchytenia vzorky; C) Ukážka zapojenia

Vzorky boli upnuté medzi špeciálne navrhnuté svorky eliminujúce lokálne poškodenie a zaťažované konštantnou rýchlosťou 1 mm/s až do ich úplného pretrhnutia. Počas skúšky boli kontinuálne zaznamenávané priebehy zaťaženia a deformácie, pričom surové dáta boli spracované v prostredí MATLAB. Na základe týchto dát boli stanovené kľúčové parametre charakterizujúce mechanické správanie hydrogélov, vrátane Youngovho modulu pružnosti (E) ako ukazovateľa tuhosti materiálu, maximálnej pevnosti v ťahu (σ_{max}) definovanej ako najvyššie dosiahnuté napätie pred porušením, predĺženia pri pretrhnutí (%) ako miery schopnosti materiálu plasticky sa deformovať.

Tvarová vernosť vzoriek bola hodnotená prostredníctvom parametra Total Shape Accuracy (TSA), definovaného ako pomer medzi reálnymi rozmermi vzorky po zosieťovaní a ideálnymi rozmermi CAD modelu. Hodnotenie prebiehalo vizuálne aj kvantitatívne, pričom sa používala päťstupňová škála:

- TSA A (95–100 %) – žiadne viditeľné deformácie,
- TSA B (85–95 %) – minimálne deformácie,

- TSA C (70–85 %) – mierne zmeny tvaru,
- TSA D (50–70 %) – výrazné deformácie,
- TSA E (<50 %) – ťažká deformácia vzorky.

Zároveň bol pri niektorých skupinách pozorovaný jav označený ako artefakt terminálneho napučania, ktorý spôsoboval lokálne zväčšenie priemeru skúšobných telies v oblasti úchopov. Tento fenomén bol dokumentovaný a zahrnutý do hodnotenia TSA.

Všetky experimentálne merania boli vykonané minimálne na n = 8 vzorkách pre každú skupinu. Normalita rozdelenia bola overená Shapiro–Wilkovým testom a homogenita variancií Leveneho testom. Keďže dáta spĺňali predpoklady parametrických testov, na porovnanie skupín bola použitá jednofaktorová analýza rozptylu (ANOVA) s následným posthoc testom Tukey HSD. Hladina štatistickej významnosti bola nastavená na $\alpha = 0,05$. Okrem p hodnôt boli vypočítané aj efekty veľkosti (η2) pre posúdenie podielu variability vysvetlenej faktorom zloženia.

3. Výsledky

Mechanické vlastnosti biotlačených alginátovo-želatínových konštruktov boli hodnotené pomocou jednoosovej ťahovej skúšky na štandardizovaných vzorkách tvaru „dogbone“ podľa normy ISO 5272, typ 5A. Hodnotené parametre zahŕňali maximálnu pevnosť v ťahu (σ_{max}), predĺženie pri pretrhnutí (ε) a Youngov modul pružnosti (E). Súhrnné výsledky vrátane priemerov a štandardných odchýlok sú uvedené v tabuľke 1.

Výsledky ukázali, že podiel alginátu v bioatramente významne ovplyvňuje mechanické správanie hydrogélov. Pri **nízkych koncentráciách alginátu** (skupiny J1–J2; 10–20 %) boli namerané najnižšie hodnoty σ_{max} (0,08–0,11 MPa) aj EEE (0,20–0,27 MPa), pričom vzorky vykazovali **najvyššiu tvarovú vernosť** (TSA > 95 %) a minimálne deformácie po zosieťovaní.

Tabuľka 1: Priemerné mechanické vlastnosti biotlačených hydrogélov J1–J9. Hodnoty sú uvedené ako priemer ± SD

Skupina	Podiel alginátu [%]	Pevnosť v ťahu σmax [MPa]	Predĺženie ε [%]	Youngov modul E [MPa]
J1	10	0.087 ± 0.013	42.23 ± 3.24	0.208 ± 0.036
J2	20	0.106 ± 0.008	40.10 ± 2.75	0.267 ± 0.035
J3	30	0.139 ± 0.011	38.18 ± 2.69	0.365 ± 0.035
J4	40	0.171 ± 0.018	38.18 ± 1.87	0.451 ± 0.060
J5	50	**0.179 ± 0.016**	35.05 ± 3.05	**0.510 ± 0.069**
J6	60	0.174 ± 0.014	32.75 ± 2.16	**0.533 ± 0.067**
J7	70	0.141 ± 0.011	31.31 ± 3.06	0.459 ± 0.081
J8	80	0.114 ± 0.007	28.93 ± 2.04	0.405 ± 0.033
J9	90	0.090 ± 0.011	27.10 ± 2.08	0.332 ± 0.038

Pri **stredných koncentráciách alginátu** (J3–J5; 30–50 %) sa mechanické vlastnosti výrazne zlepšili:

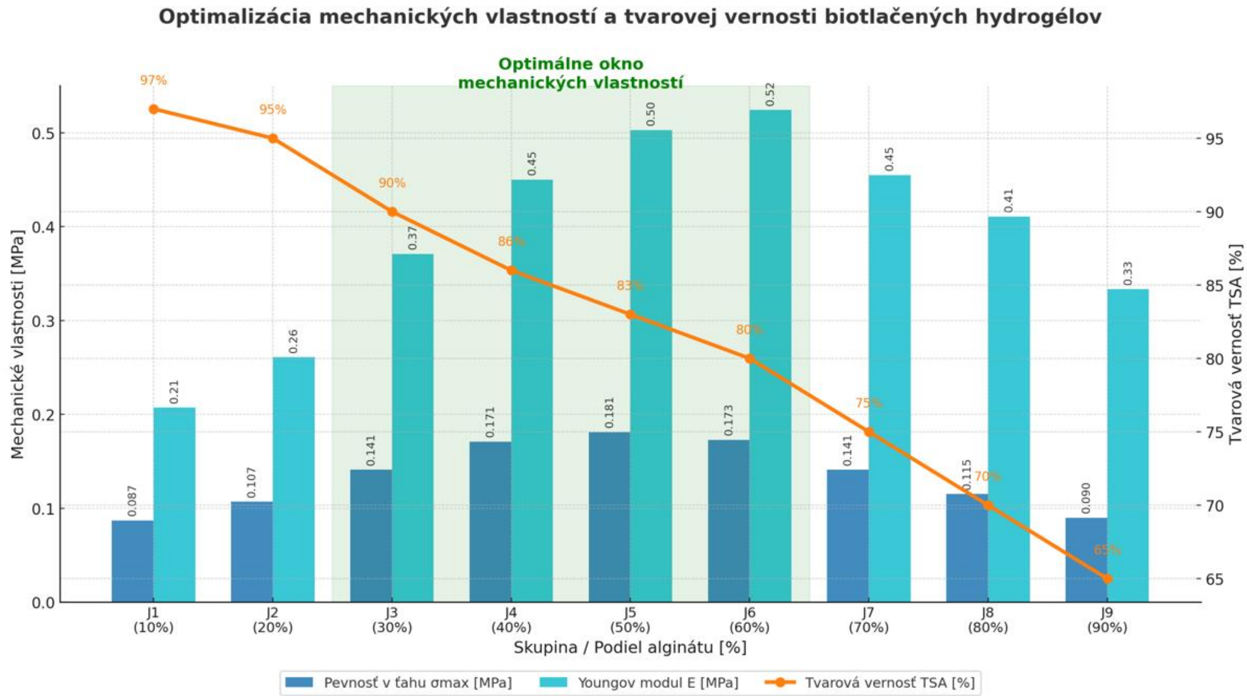
- maximálna pevnosť v ťahu dosiahla hodnoty σ_{max}=0,14–0,18 MPa,
- Youngov modul pružnosti vzrástol na E=0,36–0,51 MPa,
- hodnoty TSA ostali relatívne vysoké (≈85–92 %).

Tieto výsledky poukazujú na to, že rozsah 30–50 % podielu alginátu predstavuje optimálne okno mechanických vlastností, v ktorom je dosiahnutý kompromis medzi pevnosťou, elasticitou a geometrickou presnosťou (pozri obr. 2).

Pri vyšších podieloch alginátu (J7–J9; 70–90 %) sa pozoroval pokles pevnosti v ťahu (σ_{max}≈0,09–0,14 MPa) a Youngovho modulu (E≈0,18–0,26 MPa), pričom TSA výrazne klesla pod

70 %. Tento trend súvisí so zvýšeným zmršťovaním po ionotropnom zosieťovaní, typickým pre materiály s vyšším obsahom alginátu.

Sumarizačný graf (Obr. 2) zobrazuje komplexný graf, kde stĺpcové hodnoty predstavujú pevnosť v ťahu (σ_{max}) a Youngov modul pružnosti (E), zatiaľ čo červená krivka znázorňuje tvarovú vernosť (TSA) hydrogélov v závislosti od podielu alginátu (%).



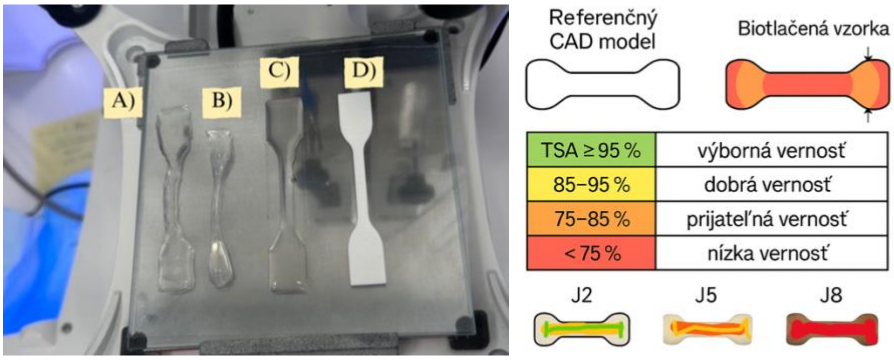
Obrázok 2: Sumarizácia rozloženia hodnôt σmax, E a TSA pre deväť experimentálnych skupín (J1–J9)

Tvarová vernosť biotlačených konštruktov bola hodnotená parametrom Total Shape Accuracy (TSA), ktorý vyjadruje pomer medzi skutočnými a navrhnutými rozmermi vzoriek po zosieťovaní. Výsledky ukazujú silnú závislosť TSA od podielu alginátu:

- pri nízkom obsahu alginátu (J1, J2) boli zaznamenané najvyššie hodnoty TSA (95–98 %),
- v optimálnom rozmedzí alginátu (J3–J5) TSA klesla len mierne (≈85–92 %),
- pri vysokom obsahu alginátu (J8, J9) došlo k výraznému poklesu TSA (≈60–70 %), čo naznačuje významné deformácie vzoriek po sieťovaní.

Kvalitatívne hodnotenie tvarovej presnosti a klasifikácia vzoriek do príslušných tried podľa stupnice TSA sú znázornené na obr. 3. Obrázok dokumentuje porovnanie medzi konštruktmi s vysokou geometrickou stabilitou a vzorkami vykazujúcimi výrazné deformácie.

V niektorých vzorkách s vyšším podielom alginátu bol pozorovaný špecifický fenomén označený ako artefakt terminálneho napučania, ktorý spôsoboval lokálne zväčšenie priemeru skúšobných telies na koncoch a mohol prispieť k poklesu celkovej tvarovej vernosti.



Obrázok 3: 3D biotlač hydrogélových vzoriek označených J. A) Zosieťovaná; hydrogélová vzorka J2; B) Zosieťovaná hydrogélová vzorka J9; C) Nezosieťovaná vzorka J9 (ihneď po tlači); D) dogbone vytlačená z PLA materiálu; Hodnotenie tvarovej vernosti vzoriek

Pred aplikáciou štatistických testov bola overená normalita rozdelenia dát (Shapiro–Wilk test) a homogenita rozptylov (Leveneho test). Parametre $σ_{max}$ a E spĺňali predpoklady pre parametrickú analýzu rozptylu (ANOVA), zatiaľ čo hodnoty TSA boli analyzované pomocou neparametrického Kruskal–Wallisovho testu. Výsledky potvrdili významný vplyv zloženia bioatramentu na všetky skúmané parametre:

- $σ_{max}$: $F(8,81)=48{,}72$, $p<0{,}0001$, $η_2=0{,}83$,
- E: $F(8,81)=56{,}13$, $p<0{,}0001$, $η_2=0{,}86$,
- TSA: $H(8)=52{,}14$, $p<0{,}0001$.

Posthoc analýza (Tukey HSD, $α = 0{,}05$) ukázala, že skupiny J3–J5 tvoria homogénnu podskupinu s optimálnymi vlastnosťami, zatiaľ čo skupiny J1–J2 a J8–J9 sa od nej štatisticky významne líšia ($p < 0{,}001$).

Sumarizačný graf (obr. 3) integruje hodnoty pevnosti v ťahu ($σ_{max}$), Youngovho modulu pružnosti (E) a tvarovej vernosti (TSA) pre všetky skúmané formulácie. Je z neho zrejmé, že rozsah 30–50 % alginátu predstavuje optimálne okno mechanických vlastností, ktoré poskytuje najlepší kompromis medzi požiadavkami na pevnosť, elasticitu a geometrickú stabilitu konštruktov.

4. Diskusia

Táto štúdia sa zamerala na vývoj a mechanickú charakterizáciu biotlačiteľných alginátovo-želatínových hydrogélov so zameraním na optimalizáciu ich zloženia a spracovateľských vlastností. Získané výsledky potvrdili, že pomer alginátu a želatíny zásadne ovplyvňuje mechanické správanie, tvarovú vernosť a potenciálnu využiteľnosť materiálov v biomedicínskych aplikáciách.

Analýza výsledkov ukázala, že nízky obsah alginátu (10–20 %, skupiny J1–J2) vedie k nízkej pevnosti v ťahu ($σ_{max}≈0{,}08–0{,}11$ MPa) a nízkemu Youngovmu modulu pružnosti ($E≈0{,}20–0{,}27$ MPa), čo koreluje s vysokým podielom želatíny v zmesi. Tento jav možno pripísať termolabilnej a menej sieťovanej štruktúre želatíny, ktorá síce podporuje bunkovú adhéziu a proliferáciu [1, 2], no zároveň neposkytuje dostatočnú mechanickú oporu [3].

Naopak, pri stredných koncentráciách alginátu (30–50 %, skupiny J3–J5) došlo k výraznému zvýšeniu pevnosti aj tuhosti konštruktov ($σ_{max}≈0{,}14–0{,}18$ MPa; $E≈0{,}36–0{,}51$ MPa), pričom tvarová vernosť zostala vysoká (TSA≈85–92 %). Tieto hodnoty sú plne porovnateľné s výsledkami uvádzanými v literatúre pre podobné systémy alginát-želatína [4, 5], čo potvrdzuje, že práve tento interval predstavuje optimálne okno mechanických vlastností (pozri obr. 3).

Pri vysokých koncentráciách alginátu (70–90 %, skupiny J8–J9) sa zaznamenal pokles $σ_{max}$(≈0,09–0,14 MPa) a významné zníženie tvarovej presnosti (TSA<70 %). Tento pokles je pravdepodobne dôsledkom výrazného post-sieťovacieho zmršťovania, ktoré je typické pre hydrogély s vysokou hustotou ionotropného zosieťovania [6, 7].

Významnou časťou tejto štúdie bolo hodnotenie tvarovej vernosti konštruktov. Najvyššie hodnoty TSA boli dosiahnuté pri nízkom a strednom obsahu alginátu, zatiaľ čo vyššie koncentrácie viedli k deformáciám a zmršťovaniu vzoriek. Tento trend je vizuálne zdokumentovaný na obr. 2, kde je zobrazené porovnanie konštruktov s vysokou a nízkou geometrickou stabilitou.

Okrem toho bol pri vzorkách s vyšším obsahom alginátu pozorovaný jav označený ako artefakt terminálneho napučania, ktorý spôsoboval lokálne zväčšenie priemeru skúšobných telies na ich koncoch. Tento efekt pravdepodobne súvisí s nerovnomernou distribúciou iónov Ca^{2+} počas procesu ionotropného zosieťovania a môže ovplyvňovať meranie mechanických vlastností aj TSA. Podobný fenomén bol opísaný aj inými autormi [8, 9], čo potvrdzuje, že ide o všeobecný problém pri 3D biotlači alginátových hydrogélov.

Výsledky tejto štúdie sú konzistentné s predchádzajúcimi prácami [4, 5, 10], ktoré poukazujú na potrebu kompromisu medzi mechanickou pevnosťou a biologickou funkčnosťou hydrogélov. Zatiaľ čo vyšší podiel želatíny poskytuje lepšie podmienky pre rast buniek, znižuje stabilitu konštruktu, a naopak, vysoký podiel alginátu zvyšuje tuhosť, ale znižuje tvarovú vernosť a môže viesť k nežiaducim deformáciám.

Nájdené optimálne okno mechanických vlastností v rozsahu 30–50 % alginátu je významné pre vývoj biotlačiteľných lešení mäkkých tkanív a môže byť využité aj pri návrhu systémov pre kontrolované uvoľňovanie liečiv alebo bioaktívnych povlakov implantátov.

Hoci štúdia poskytuje detailnú mechanickú charakterizáciu skúmaných hydrogélov, je potrebné zohľadniť niekoľko obmedzení:

- výsledky sa vzťahujú na vzorky testované in vitro a môžu sa líšiť v in vivo prostredí,
- tvarová vernosť bola hodnotená iba geometrickým porovnaním, bez doplnkovej mikro-CT analýzy,
- nebola skúmaná dlhodobá stabilita konštruktov ani ich biologická odpoveď v kontakte s bunkami.

Budúce práce by mali zahŕňať viacúrovňové modelovanie mechanického správania hydrogélov, kombináciu reologických testov a in vivo validácie, čo umožní komplexnejší návrh funkčných biotlačiteľných lešení.

5. Záver

Táto štúdia ukázala, že pomer alginátu a želatíny výrazne ovplyvňuje mechanické vlastnosti, tvarovú vernosť a spracovateľnosť biotlačiteľných hydrogélov. Optimálne výsledky boli dosiahnuté pri stredných podieloch alginátu (30–50 %), kde vzorky vykazovali najlepšiu kombináciu pevnosti v ťahu, Youngovho modulu a geometrickej stability. Naopak, vysoký obsah alginátu (> 70 %) viedol k zníženiu tvarovej vernosti a zvýšenej náchylnosti k deformáciám. Tieto zistenia potvrdzujú potrebu precíznej optimalizácie zloženia a výrobného postupu pri návrhu bioatramentov pre aplikácie v tkanivovom inžinierstve a biofabrikácii.

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ITMS2014+: 313011BWQ1, spolufinancovaný zo zdrojov Európskeho fondu regionálneho rozvoja. Táto práca bola vypracovaná za podpory projektov KEGA 018TUKE-4/2023 Implementácia metód fyzikálno-chemických analýz v študijnom programe Biomedicínske inžinierstvo a VEGA 1/0403/25 Analýza biomateriálov v biotlači sféroidov z mezenchymálnych kmeňových buniek využívaných v tkanivovom bioinžinierstve.

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NEUROMODULATORY INTERVENTION BY BRIGHT LIGHT EXPOSURE: EFFECT ON SLEEP DEPRIVATION STATE

Marek, Piorecký[1,2], Kateřina, Skálová[2], Jana, Kopřivová[2]

[1]Faculty of Biomedical Engineering, CTU in Prague

[2]National Institute of Mental Health

Abstrakt

Sleep deprivation negatively affects several cognitive functions, including vigilance, attention, memory, and emotional regulation, creating a substantial risk for individuals who frequently experience insufficient sleep. In particular, prolonged wakefulness can lead to deficits in both mood and cognitive performance, which can impair daily functioning. Bright light exposure has been suggested as a promising non-pharmacological intervention to mitigate these negative effects. In this study, we quantitatively assessed the effects of acute intense light exposure following sleep deprivation on EEG biomarkers, specifically focusing on spectral power changes. Our results demonstrated that a single session of bright light exposure led to significant modulation of EEG spectral power, particularly in frequencies associated with alertness and cognitive processing. These findings highlight the potential of bright light as a neuromodulatory intervention that could enhance cognitive function and improve mood states following sleep deprivation. Moreover, our results suggest that bright light could serve as an effective strategy for counteracting the deleterious effects of insufficient sleep, with potential applications in occupational settings and clinical populations affected by sleep disturbances.

Key words

Sleep deprivation, Light exposition, EEG, Neuromodulaiton

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PROTOTYP VOLANTU PRE ELEKTRICKÉ VOZIDLO EDISON

Branko Babušiak[1], Maroš Šmondrk[1], Ladislav Janoušek[1], Štefan Borik[1], Tomáš Gajdošík[2], Igor Gajdáč[2], Rudolf Madaj[2]

[1]Katedra teoretickej elektrotechniky a biomedicínskeho inžinierstva, Fakulta elektrotechniky a informačných technológií, Žilinská univerzita v Žiline

[2]Katedra konštruovania a častí strojov, Strojnícka fakulta, Žilinská univerzita v Žiline

Abstrakt

Ospalosť za volantom a náhle zdravotné problémy patria medzi významné faktory prispievajúce k dopravným nehodám, čo zdôrazňuje kritickú potrebu nepretržitého a neinvazívneho monitorovania vodiča. Tento príspevok predstavuje návrh a vývoj inovatívneho prototypu volantu s pokročilými monitorovacími schopnosťami, určeného na zvýšenie bezpečnosti vodiča a zmiernenie rizík spojených s ospalosťou počas jazdy. Prototyp integruje fyziologické senzory, vrátane elektrokardiografu (ECG) a fotopletyzmografu (PPG), spolu s kinematickými metrikami, čo umožňuje získavanie multimodálnych údajov v reálnom čase počas jazdy v špeciálnom elektrickom výskumnom vozidle s názvom EDISON. Laboratórne experimenty aj testy v reálnej premávke preukázali, že prototyp úspešne zaznamenával vysokokvalitné signály ECG a PPG vhodné na spoľahlivú analýzu srdcovej frekvencie a jej variability. Testovanie na ceste potvrdilo operačnú funkčnosť systému; napriek zvýšenému šumu spôsobenému pohybovými artefaktmi zostal signál ECG dostatočne robustný na nepretržité detegovanie R-vĺn. Testovanie demonštrovalo funkčnosť a presnosť prototypu pri meraní multimodálnych údajov, čím poskytuje spoľahlivú platformu na hodnotenie jazdnej dynamiky a fyziologických signálov vodiča. Vyvinutý prototyp otvára cestu pre budúce pokroky v systémoch monitorovania vodičov, ktoré môžu integrovať umelú inteligenciu a strojové učenie na analýzu únavy a zdravotného stavu vodiča v reálnom čase.

Kľúčové slová

monitorovanie vodiča, ospalosť, elektrokardiografia, fotopletyzmografia, volant

Poďakovanie

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IMPEDANČNO-FREKVENČNÉ CHARAKTERISTIKY POVRCHOVÝCH SUCHÝCH EEG ELEKTRÓD S POUŽITÍM AGAROVÉHO FANTÓMU

Ľubomír Trpiš, Maroš Šmondrk, Branko Babušiak

Katedra teoretickej elektrotechniky a biomedicínskeho inžinierstva

Fakulta elektrotechniky a informačných technológií, Žilinská univerzita v Žiline

Abstrakt

Kľúčom k spoľahlivému snímaniu biosignálov je správna vodivosť na prechode medzi elektródou a kožou. Táto štúdia je venovaná problematike kontaktnej impedancie pri suchých EEG elektródach. Na merania boli použité dve špeciálne elektródy zo zlatej zliatiny a jedna elektróda z vodivého polyméru od spoločnosti g.tec medical engineering GmbH (Rakúsko). Ako referenčný štandard bola na porovnanie použitá mokrá adhézna Ag/AgCl elektróda. Bol vytvorený umelý model rozhrania elektróda–koža, ktorý zabezpečil opakovateľnosť a stabilné meracie podmienky. Veľkosť a fáza elektrickej impedancie sa určovali v rozsahu frekvencií od 0,5 Hz do 1100 Hz s použitím harmonického generátora so signálom o amplitúde 5 V. Namerané impedančno-frekvenčné charakteristiky potvrdili, že suché elektródy vykazovali zreteľné rezistívno-kapacitné správanie, ktoré môže byť limitujúcim faktorom pri meraní biosignálov s vyššou frekvenciou (napr. EEG). Výsledky zároveň preukázali, že impedancia elektród zo zlatej zliatiny bola vo väčšine frekvencií porovnateľná s hodnotami mokrej adhéznej Ag/AgCl elektródy. Navrhnutá meracia metodika je opakovateľná a umožní v budúcnosti porovnávanie rôznych typov elektród.

Kľúčové slová

rozhranie elektróda–koža, snímanie biosignálov, impedancia, suché EEG elektródy

Poďakovanie

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SURFACE RECONSTRUCTION USING LOW-COST PHOTOGRAMMETRY

Teodor Tóth[1], Lucia Bednarčíková[1], Richard Staško[1]

[1]Technical University of Košice, Faculty of Mechanical Engineering, Department of Biomedical engineering and Measurement, Letná 9, 042 00 Košice

Abstrakt

Photogrammetry is a method of digitizing objects often used in cartography, archaeology, architecture, and other fields where, in addition to the shape of the object, information about its surface is also important.

This paper focuses on the use of photogrammetry in digitizing technical objects with various surface textures, which influence the scanning and reconstruction of the object's surface. For scanning, the Walk-Around Method and the Turntable Method were tested. The selected dimensions and deviations were evaluated in the software GOM Inspect 2019 and VGStudio MAX and compared with measurements taken using a digital caliper. On the created models, the texture of the object is visible, producing a pronounced relief on the surface and thus affecting the creation of planes for measurement. This influence is confirmed by the flatness deviation of selected elements, which is less than 0.2 mm. The results show that the Turntable Method is methodologically simpler to implement, while the Walk-Around Method shows an average deviation from the actual dimensions of -0.211 mm, and the Turntable Method 0.022 mm.

Key words

photogrammetry, measurement, Walk - Aroun Method, Turnable Method

Acknowledgement

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THE VALIDATION OF THE CLICK TRAIN STIMULI RISKS IN NEUROSCIENTIFIC HUMAN ASSR EXPERIMENTS WITH A FOCUS ON THE STIMULUS TRANSDUCTION ARTIFACT ORIGIN FROM HEADPHONES IN HDEEG

Jan, Štrobl[1,2], Marek, Piorecký[1], Vlastimil, Koudelka[2]

[1]CTU in Prague, Faculty of Biomedical Engineering

[2]National Institute of Mental Health, Klecany

Abstrakt

The ASSR experiments are EEG or MEG experiments eliciting a periodic response to auditory stimulation. This study is focused on the click train stimulation with a repetition frequency of 40 Hz, which is widely used in neuroscientific ASSR experiments with human subjects. Our previous original study discovered the potential existence of stimulus transduction artifacts (stimulus artifacts) during this experiment design. A stimulus artifact is a technical artifact originating from the headphones. The frequency characteristics of stimulus artifacts are similar to the ASSR response frequency characteristics. For this reason, it is very complicated to separate stimulus artifacts from the ASSR response. The main goal of this study is to investigate the possible risks during neuroscientific ASSR experiments and to focus on the stimulus artifact. We designed two types of experiments with hdEEG. The first experiment type used a human head phantom. So, the non-existing brain response couldn't be confused with the stimulus artifact, and we could investigate the stimulus artifact's existence and potential characteristics. The records from 15 human subjects were analyzed in the second type of experiment. Every subject underwent click train stimulation by headphones and speakers with the same stimulation settings right after each other. We investigated potential risks in ASSR experiments with click train stimuli. Risks arise by analyzing the higher harmonic frequency of 40 Hz, stimulation by speakers, and the existence of stimulus artifacts. The results show the potential risk of analyzing a higher harmonic frequency of 40 Hz caused by a low signal-to-noise ratio and higher ITPC of stimulus artifact. The experiments with speaker stimulation can induce ASSR response, but the signal-to-noise ratio is highly sensitive to the experimental design. Stimulus artifact existence or intensity is variable. The headphone cable can originate the stimulus artifact. We also found some noise with characteristics typical for stimulus artifacts in experiment design verifying the headphone transducer as an artifact source. We didn't prove stimulus artifacts' influence in ITPC of 40 Hz in experiments with human subjects after average re-referencing. However, we discovered some noise with stimulus artifact properties in these records. Based on our results from the human head phantom, the average re-reference can highlight stimulus artifacts in case of stimulus artifacts with high intensity and focal spatial distribution. For this reason, we recommend checking some analyses, like topographic analysis, before applying average re-referencing. This process can protect authors before the false positive results.

Key words
Stimulus transduction artifact, stimulus artifact, electromagnetic artifact, EEG, ASSR

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3D TECHNOLÓGIE V POPÁLENINOVEJ DIAGNOSTIKE: POROVNANIE PRESNOSTI DVOCH SKENOVACÍCH ZARIADENÍ

Katarína Dudová[1], Bibiána Ondrejová[1], Branko Štefanovič[1], Lucia Bednarčíková[1], Richard Staško[1], Peter Szedlák[1] , Jozef Živčák[1]

[1]Katedra biomedicínskeho inžinierstva a merania, Strojnícka fakulta, Technická Univerzita v Košiciach

Abstrakt

Presné stanovenie rozsahu popálenín je kľúčovým faktorom pri plánovaní liečby pacienta, rozhodovaní o chirurgickom zákroku, nastavení fluidnej terapie a dlhodobej rekonvalescencii. [1,2] Tradičné klinické metódy, ako napríklad „pravidlo deviatok“ alebo Lund-Browderov diagram, sú v praxi stále široko používané, ale ich presnosť je obmedzená, pretože sú založené na vizuálnom hodnotení a sú náchylné na subjektívnu variabilitu medzi posudzovateľmi. [2,3] Štúdie ukazujú, že variabilita v odhadoch TBSA medzi skúmanými nemocnicami bola až 8,8 % [6], zatiaľ čo odhad plochy popálenín prostredníctvom moderných 3D skenovacích technológií bol zistený s priemernou chybou 1,9 %. [7] 3D skenovanie získava v súčasnosti na popularite, pretože dokáže presne, objektívne a reprodukovateľne merať povrch popálenia [4-8]. Okrem zlepšenia presnosti dokáže efektívnejšie zdokumentovať proces hojenia a podporiť využitie telemedicíny [9-13].

Táto štúdia sa zameriava na porovnanie presnosti merania povrchovej plochy popálenín medzi referenčným zariadením Artec Eva (profesionálny skener založený na štruktúrovanom svetle s vysokým rozlíšením a submilimetrovou presnosťou) a novším, cenovo dostupnejším zariadením Revopoint Miraco, ktoré je prenosné, kompaktné. [5,11] Do výskumu bolo zaradených 11 pacientov s klinicky viditeľnými hranicami popálenín rôzneho rozsahu a stupňa. Celkovo bolo analyzovaných 26 anatomických oblastí, zahŕňajúcich horné a dolné končatiny, hrudník, tvár a krk. Skenovanie prebiehalo v kontrolovaných svetelných podmienkach, pričom pacienti boli polohovaní tak, aby bola dosiahnutá čo najlepšia viditeľnosť postihnutých oblastí.

Získané dáta boli exportované vo formáte .obj a spracované v softvéri Meshmixer (Autodesk). Pre zabezpečenie jednotného postupu, segmentáciu vykonávala jedna osoba. Z popáleninových oblastí boli vytvorené samostatné 3D modely, na základe ktorých sa vypočítala plocha poranenia v mm². Následne boli výsledky vyhodnotené porovnaním absolútnych rozdielov, relatívnych percentuálnych rozdielov a prostredníctvom lineárnej regresnej analýzy.

Obr. 1. Segmentácia a výpočet veľkosti plochy popáleniny

Výsledky štúdie ukázali vysokú mieru zhody medzi meraniami. Priemerná absolútna odchýlka predstavovala 660,5 mm² a priemerný relatívny rozdiel bol 4,1 %. Vo väčšine prípadov sa odchýlky pohybovali pod hranicou 5 %, čo je v klinickej praxi akceptovateľná úroveň presnosti. Najväčší rozdiel, 16,3 %, bol zaznamenaný pri meraní pravej hornej končatiny pacienta, čo súvisí s komplikovanou topografiou povrchu končatiny. Najnižšia odchýlka, len 0,02 %, bola dosiahnutá pri meraní hrudníka nakoľko ide o topograficky jednoduchšiu oblasť. Lineárna regresná analýza potvrdila veľmi dobrú koreláciu medzi meraniami získanými oboma zariadeniami s koeficientom determinácie $R^2 = 0,99$. Okrem presnosti meraní, štúdia hodnotila aj praktické aspekty používania zariadení v klinickej praxi a vizuálne porovnanie odobratých 3D modelov s fotografiou.

Autori štúdie dospeli k záveru, že Revopoint Miraco dokáže poskytnúť spoľahlivé a klinicky použiteľné merania povrchovej plochy popálenín. Napriek menším odchýlkam je presnosť meraní dostatočná na využitie v praxi a zariadenie predstavuje vhodnú alternatívu k drahším profesionálnym riešeniam.

Kľúčové slová

3D skenovanie, popáleninové rany, meranie povrchu, Artec Eva, Revopoint Miraco

Poďakovanie

Tento výskum bol podporený národným projektom APVV-22-0340 – Vývoj a testovanie ortéz na podporu liečby popálenín pomocou 3D skenovania a aditívnej výroby, ktorý bol financovaný Kultúrnou a vzdelávacou grantovou agentúrou Ministerstva školstva Slovenskej republiky

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AI-BASED APPROACHES FOR DEFECT LOCALIZATION IN BIOCOMPATIBLE MATERIALS

Erika, Slušňáková[1], Michal, Gála[1]

[1]Dept. of Electromagnetic and Biomedical Engineering, Faculty of Electrical Engineering and Information Technology, University of Žilina, Slovakia

Abstrakt

The aim of this work was to design and experimentally verify the application of artificial intelligence algorithms for defect classification in biocompatible materials. Two neural network architectures were examined: a multilayer perceptron (MLP) for processing numerical signal parameters, and a convolutional neural network (CNN) for evaluating image-based representations derived from topological maps. The performance of the models was compared in terms of classification accuracy and computational efficiency.

The results demonstrated that both architectures were capable of effectively classifying defects according to predefined categories. The MLP exhibited high processing speed, low computational requirements, and simpler implementation, while the CNN achieved higher accuracy, particularly for classes that were more difficult to distinguish. Among the tested models, the ResNet-50 architecture achieved the best results, showing high accuracy and stability.

A limiting factor was the dataset size, which included only three defect types and a fixed number of measurement points. Expanding the dataset to include additional defect types, varying geometries, and different spatial distributions could enable a more thorough assessment of the models' capabilities. The findings confirm that the set objectives were successfully met and provide a basis for further research on the application of artificial intelligence for defect analysis in biocompatible materials.

Key words

artificial intelligence algorithms, multilayer perceptron, convolutional neural network, defect classification, biocompatible materials, SFECT

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APPLICATION OF BIOCOMPATIBLE MATERIALS BASED ON MAGNESIUM ALLOYS FOR IMPLANTS MANUFACTURED BY ADDITIVE MANUFACTURING. DESIGN OF A SYNDESMOTIC SCREW FOR STABILIZATION OF THE TIBIA AND FIBULA IN LIGAMENT TISSUE INJURIES

MUDr. Richard Staško[1,2], Dr.h.c. mult. prof. Ing. Jozef Živčák[2], PhD. MPH., prof. Ing. Radovan Hudák[3], PhD., Ing. Monika Michalíková[4], PhD., doc. Ing. Schnitzer **Marek[5], PhD., MUDr. Peter Szedlák,[2,6]**

[1]CAMPUS Rhön Klinikum Bad Neustadt, Von Guttenberg Str. 11, 97616, Bad Neustadt

[2, 3, 4, 5]Technická Univerzita Košice, Katedra biomedicínskeho inžinierstva, Letná 1/9, 042 00 Košice-Sever

[6]Rehanova, Neurologische Rehabilitation, Ostmerheimer Straße 200, 51109 Merheim

Abstract

For the purpose of this work, the distal ligamentous connection between the bones of the lower leg, the tibia and fibula – the syndesmosis (syndesmosis tibiofibularis) – was chosen. This is a common injury that currently requires two surgical procedures: implantation followed by the removal of the osteosynthesis after six weeks. This is the main cause of frequent complications. If the proposed resorbable screw is used, the need for surgical removal of the osteosynthetic material is eliminated, along with the associated risks for the patient. Biodegradable implants based on magnesium offer undeniable advantages in terms of reducing surgical load, minimizing complications, and, not least, reducing the financial burden on the healthcare system.

Polymeric biomaterials are widely used in tissue engineering because they allow for the variable production of implants with complex geometries, and their surface properties can be easily modified. Their goal is to improve the mechanical strength, biocompatibility, and biological activity of implants while eliminating the disadvantages of metal implants. For example, polymer-ceramic composites provide better bioactivity and higher strength, while metal-ceramic composites offer higher resistance to wear and corrosion. The selection of an appropriate biomaterial for bone implants depends on mechanical strength, biocompatibility, corrosion resistance, and the ability to support bone growth. Biodegradable magnesium alloys degrade over six to eight weeks, which is sufficient for the healing of the syndesmotic ligament.

In an evaluation of patients treated at the Trauma Surgery, Orthopedics, and Endoprosthetics Clinic in Bad Neustadt, Germany, a high complication rate of up to 17.9% was found for syndesmosis surgeries. A bioresorbable implant was proposed that would not need to be surgically explanted. This would significantly reduce surgical risk. Clinical and preclinical studies, including long-term follow-up in sheep models and initial human implantations, confirm that ceramic composites degrade gradually while maintaining sufficient mechanical stability during

the first weeks to ensure healing, and subsequently disappear without the need for a second surgery for removal.

The main goal in developing the new implant was to reduce the occurrence of complications, thereby accelerating the therapeutic process and the patient's return to normal function. To date, there is no superior treatment method, which leaves room for innovation in current implants using new bioabsorbable materials. The proposed resorbable screw made of magnesium composite is manufactured through additive manufacturing and has a porous structure. This enables rapid osteointegration and stabilization of the injury. The required healing time for the syndesmosis is six weeks, after which the patient can fully bear weight on the limb, regardless of the screw's stability or stage of resorption.

Key words

Syndesmosis, Osteosynthesis, Polymeric biomaterials, Ceramic composites, Bioresorption

Acknowledgement

Projekt KEGA 012UPJŠ-4/2023

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INTEGRATION OF DATA MINING METHODS IN MEDICAL INFORMATION SYSTEMS

Jana, Schwarzerova[1,2,3,4], Michal, Nohel[4,5], Valentyna, Provaznik[4,6,7], Wolfram, Weckwerth[2,8], Stefan, Reguli[9]

[1]Department of Molecular and Clinical Pathology and Medical Genetics, University Hospital Ostrava, Ostrava, Czech Republic

[2]Molecular Systems Biology (MOSYS), University of Vienna, Vienna, Austria

[3]Department of Control and Instrumentation, Faculty of Electrical Engineering and Communication, Brno University of Technology, Czech Republic

[4]Department of Biomedical Engineering, Faculty of Electrical Engineering and Communication, Brno University of Technology, Czech Republic

[5]Department of Deputy director for science, research and education, University Hospital Ostrava, Ostrava, Czech Republic

[6]Czech Institute of Informatics, Robotics and Cybernetics, Czech Technical University in Prague

[7]Faculty of Medicine, University of Ostrava, Ostrava, Czech Republic

[8]Molecular Systems Biology (MOSYS), University of Vienna, Vienna, Austria

[9] Department of Neurosurgery, University Hospital Ostrava, Ostrava, Czech Republic

Abstrakt

The rapid expansion of medical, clinical, and biological data requires advanced computational methods to ensure their efficient processing, integration, and interpretation [1]. Data mining approaches offer powerful tools to identify hidden structures, detect clinically relevant trends, and construct predictive models that can significantly support both clinical decision-making and biomedical research. In this work, we focus on the integration of data mining techniques into medical information systems to enhance their analytical capabilities and to support the transition towards more precise and personalized patient care. We apply a wide range of techniques, including classification, regression, clustering, and association rule mining, complemented by machine learning algorithms and statistical modeling. These methods are used to analyze heterogeneous datasets comprising clinical records, laboratory findings, diagnostic imaging, and omics data.

A central part of our research is the development of the panOMICs app [1], a platform designed for the integration and analysis of multi-omics datasets (genomics, transcriptomics, proteomics, metabolomics, and others). The application offers user-friendly tools for visualization,

comparison, and interpretation of complex biomedical datasets and is prepared for direct interaction with medical information systems. By linking routine clinical data with high-resolution omics information, the platform enables advanced diagnostics, personalized treatment strategies, and translational research.

In addition, our pilot studies highlight the application of data mining in precision oncology, particularly in patients undergoing CyberKnife radiotherapy [1]. The combination of clinical data mining and advanced algorithms shows promising results in predicting treatment outcomes, identifying potential risk factors, and supporting the optimization of individualized therapeutic plans. This demonstrates how integrative analytical frameworks can bridge the gap between medical information systems, omics technologies, and clinical practice.

Our vision suggests that the use of data mining methods, followed by the application of integrative software solutions such as the panOMICs app, has the potential to significantly improve the efficiency and quality of medical information systems. Furthermore, it opens new avenues for precision medicine by uncovering novel clinical insights, enhancing treatment accuracy, and providing better tools for patient stratification and outcome prediction.

Key words

data mining, medical information systems, panOMICs, multi-omics integration, precision medicine

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CONVOLUTIONAL NEURAL NETWORKS FOR DETECTION AND SEGMENTATION OF BRAIN METASTASES

Michal Nohel[1,2], Stefan Reguli[1,3], Romana Kaplanova[1,4], Jana Jackaninova[4], Jiri Chmelik[2], Lukas Knybel[1,4]

[1] Department of Deputy director for science, research and education, University hospital Ostrava, Ostrava, Czech Republic

[2]Department of Biomedical Engineering, Faculty of Electrical Engineering and Communication, Brno University of Technology, Brno, Czech Republic

[3] Department of Neurosurgery, University Hospital & Faculty of Medicine, Ostrava, Czech Republic

[4] Department of Oncology, University Hospital & Faculty of Medicine, Ostrava, Czech Republic

Abstrakt

Accurate detection and segmentation of brain metastases on MRI are crucial for radiotherapy planning but remain highly time-consuming when performed manually. In this work, we developed and validated a convolutional neural network based on the nnU-Net framework [1], trained on a newly created dataset of 140 patients with expert-annotated brain metastases. Of these, 112 patients were used for training and 28 for testing in a 5-fold cross-validation setting, achieving an average Dice score of 0.82. On the test set, the model reached a Dice score of 0.87.

To further evaluate clinical applicability, we trained the final nnU-Net model on all available data and tested it retrospectively on an independent set of 16 patients. For each case, the manual segmentation time by a radiologist was recorded and compared with the model's prediction time. Manual annotation required on average 30 minutes per patient (median 23 minutes), while the automated prediction was generated within 1–2 minutes. Although expert review and occasional corrections were necessary, these adjustments typically took only a few additional minutes. In practice, 8 out of 16 segmentations required no corrections, 5 needed only minor refinements, and 3 missed very small lesions. Importantly, in two cases the model revealed previously unreported metastases at the navigation MRI, which were absent from the preceding diagnostic report.

These results indicate that deep learning–based segmentation could substantially accelerate clinical workflows by providing reliable initialization masks for radiologists, reducing the overall annotation time while maintaining accuracy. Nevertheless, larger studies are required to further validate the robustness of the method across different clinical settings.

Key words

Brain metastases, Radiotherapy, Convolutional Neural Networks, nnU-Net, Image segmentation,

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PŘÍLOHA 1 – PŘEDSTAVENÍ PRACOVIŠŤ BME V CZ A SK

1. **Biomedicínské inženýrství na VŠB – TU Ostrava**
   prof. Ing. Marek Penhaker, Ph.D.

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   prof. Ing. Ladislav Janoušek, Ph.D.

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   Ing. Martin Mézl, Ph.D.

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   doc. Ing. Teodor Tóth, Ph.D.

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