Instruments & Methods for Biology & Medicine

Student conference

17 June 2021 • Faculty of Biomedical Engineering CTU in Prague • Kladno

Book of Abstracts

Instruments and Methods for Biology and Medicine

June 17, 2021

FACULTY
OF BIOMEDICAL
ENGINEERING
CTU IN PRAGUE

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09:00	**Registration**
09:30	**Conference opening**
09:35	**Invited lecture:** *Bespoke fluorescent nanoprobes for detecting biomaker RNA in liquid biopsies* **Dr. Yu Chen, Ph.D., Department of Physics, University of Strathclyde, Glasgow, UK**
Physical methods and instruments for application in medicine 10:15 – 11:30	*Preparation and testing of a specific bionanosensor for detection of Staphylococcus aureus* **Leontýna Varvařovská**
	Experimental analysis of model hepatocellular carcinoma cell lines **Bibiana Kvasnicová**
	Analyse of fluorescence spectra of healthy cells as a function of carcinoma cell concentration, pH and temperature environment **Jan Svoboda**
	Regional microwave hyperthermia system **Matouš Brunát**
	Prediction and visualization of protein secondary structures on genomic data **Petr Adámek**
11:30	**Lunch Break**
13:00	**Invited lecture:** *Cherenkov imaging in radiotherapy: A journey from bench to bedside* **Ing. Petr Brůža, Ph.D., Thayer School of Engineering, Dartmouth College, USA**
Biomedical imaging and advanced analyses of biomedical data and signals 13:45 – 15:00	*Functional differences of the brain in patients in the presymtomatic and manifestic phases of Parkinson's disease* **Jana Kukačková**
	Neuromelanin quantification in the substantia nigra defined by atlases in magnetic resonance images **Vendula Lhotáková**
	Feasibility study on novel microwave imaging system for hypoxic-ischemic encephaopathy detection in neonates **Jan Rédr**
	Detection of the onset zone of epileptic seizures by intracranial electrophysiological monitoring using convolutional neural networks **Kamila Lepková**
	Prehospital head stroke detection stroke using machine learning algorithm **Tomáš Pokorný**
15:00	**Coffee break**
Materials and optics for application in medicine 15:30 – 16:45	*Doped diamond-like carbon coatings prepared by hybrid deposition systems for biomedical applications* **Petr Písařík**
	Intraocular correction of astigmatism **Martin Fůs**
	Study of material properties of titanium alloy Ti6Al4V used for hip arthroplasty after laser treatment **Lucie Košinová**
	Tribological properties of contact and spectacle lenses **Alena Škubníková**
	Low fractionalized nanofibers significantly modify structural-functional parameters of dead space agarose fillers after rectal extirpation **Simona Stuchlíková, Aleksei Pashchenko**
17:00	**Conference closing & awards the best contributions**

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Invited lectures

Bespoke fluorescent nanoprobes for detecting biomaker RNA in liquid biopsies

Yu Chen
Department of Physics, SUPA, University of Strathclyde, John Anderson Building, 107 Rottenrow, Glasgow G4 0NG, UK

Cancer is the second leading cuase of death globally and a tremendous burden on society. Despite the existence of screening and biopsies, the lack of sensitive and affordable tools for early diagnosis and prognosis of cancer remains key obstacles to reducing cancer mortality. Liquid biopsy offers a promising solution, but current methods are proving to be technically challenging and are yet to be optimised for the clinic. This drives the search for a rapid, cost-effective, easily implemented, sensitive and reliable solution. We are developing bespoke nanoprobes for sensitive and reliable cancer biomarker RNA analysis at single cell level to facilitate rapid cancer detection. Nanoprobes targeting cancer biomaker RNAs have been designed and demonstrated in varies cell lines. Nanoprobes were also applied in intracelluar imaging using fluorescence microscopy. Furthermore, the ability of the nanoprobe to detect cancer cells in cell model and clinical samples has been demonstrated. This leads to the potential of nanoprobes as a diagnostic tool against a range of RNA biomarkers to detect circulating tomour cells in liquid biopsies.

Cherenkov imaging in radiotherapy: A journey from bench to bedside

Petr Brůža

Thayer School of Engineering, Dartmouth College, 1 Medical Center Dr, Lebanon NH 03756, USA and DoseOptics LLC, 16 Cavendish Ct, Lebanon NH 03766, USA

Cherenkov imaging is a novel technique that captures light emissions during radiation therapy, allowing for real-time visualization of radiation treatments on the patient. Despite extensive quality assurance tests of the linear accelerator and treatment plan, no existing method can directly verify relation of the beam with respect to patient's anatomy for every fraction of a therapy course. This open-loop approach can lead to deviations from treatment plan, or even inadvertent mis-delivery of dose to unplanned healthy tissue. Recognizing that megavoltage X-rays and electrons incite Cherenkov radiation in tissue, a time-gated, intensified camera was specifically developed to image this weak radiation, provide visualization to the therapist, and analyze day-to-day delivery variations. This presentation will cover the development from early discoveries to clinical deployment, in order to highlight the importance of translational approach in biomedical engineering.

Physical methods and instruments for application in medicine

10:15 – 11:30

Preparation and testing of a specific bionanosensor for detection of *Staphylococcus aureus*

Leontýna Varvařovská
Faculty of Biomedical Engineering, Czech Technical University in Prague

Today, the detection of bacteria is mainly performed using metabolic tests, PCA and ELISA. However, these methods are time consuming, so new methods of so-called online detection are being sought. Biosensors are very fast, sensitive and accurate devices that enable the mentioned online detection.

The aim of this work was to design and create a prototype of the biosensor that would be used to detect Staphylococcus aureus from the air. This sensor was made of PAN nanofibers (polyacrylonitrile) as a carrier and an antibody as a biosensitive layer. Furthermore, a system for an air filtration was created, by means of which detection was realized. The formed system was tested using PVA nanofibers (polyvinyl alcohol) of 1 g/m2 and fluorescein (spectroscopy). Subsequent detection of the bacteria was performed using the already mentioned immobilized PAN nanofibers and pure PAN nanofibers as a control. The assays were evaluated by measuring the optical density (OD) of a bacterial suspension formed from bacteria captured on the sensor. Finally, the measurement of electrical properties (resistance, capacity) of the model case (PAN nanofibers and cigarette smoke particles) was also described.

Detection Experimental analysis of model hepatocellular carcinoma cell lines

Bibiana Kvasnicová
Faculty of Biomedical Engineering, Czech Technical University in Prague

The measurement of cellular mechanical properties offers a different point of view in many fields. It has a huge importance in cancer research, where cell mechanics can reveal about invasive potential of the cancerous cells or about stage of a tumour progression. The aim of the project is to elaborate a comparative study of two different cell lines of hepatocellular carcinoma

(Snu475 and Huh7) during epithelial-mesenchymal transition (EMT) induced by TGF-β1 treatment, focusing on mechanical properties analysis via atomic force microscopy (AFM). The AFM method called force mapping is used for the mechanical analysis, the evaluation is then processed by JPK software, allowing to display and interpret information given by a matrix of force curves. The unified measuring protocol has been established on wildtype (WT), non-modified single cells. Results show, that nuclear regions tend to have higher stiffness than cytoplasm in both WT cell lines – mean stiffness of SNU475 : (733±59) Pa in nucleus, (393±44) Pa in cytoplasm; mean stiffness of HuH7: (422±30) Pa in nucleus, (199±15) Pa in cytoplasm. The process of EMT in WT changes cell stiffness distribution and cell stiffness itself – in SNU475: (589±52) Pa in nucleus, (624±45) Pa in cytoplasm; in HuH7: (416±38) Pa in nucleus, (430±42) Pa in cytoplasm.

Analyse of fluorescence spectra of healthy cells as a function of carcinoma cell concentration, pH and temperature environment

Jan Svoboda
Faculty of Biomedical Engineering, Czech Technical University in Prague

Cancer disease belongs among common causes of death all along the world. For their effective treatment an early detection of the disease is necessary. This study focuses on the option of detecting the cancerous cells by comparing the fluorescence spektra of biofluorofores NADH (free and bound), FAD and LR in healthy cells 3T3, cancerous cells CT26 and cancerous cells SNU475 and in mixture of 3T3 and CT26 cells in concentrations ranging from 100 % 3T3 and 0 % CT26 to 0 % 3T3 and 100 % CT26. Fluorescence spektra are measured at laboratory temperature and at 37 °C in normal pH of 7,2 and low pH of 6,2 with excitation of 365 and 460 nm in ranges between 400 – 700 nm. Fluorescence spectra are analyzed with software GASpeD, which is based on genetic algorithm. This software breaks down the spectra into contributions of specific biofluorofores of the cells according to literature. I tis shown that the presence of both free and bound NADH and the position of their fluorescences´ maximum intensities are different for healthy and cancerous cells and change based on temperature and pH of the environment.

The point of this study is to prove the possibility of distinguishing cancerous cells on the basis of their fluorescence spectra from healthy cells and the possibility of detecting presence of cancerous cells in a mix of healthy and cancerous cells 3T3 and CT26. The point is also to prove the feasibility of using this method on a different kind of cancerous cells, for which are used SNU475. The results show that there is a possibility to distinguish healthy and cancerous cells based on broken down spectra of their fluorescence for both pure cells and for their mixtures and at different temperatures and pH.

Regional microwave hyperthermia system

Matouš Brunát
Faculty of Biomedical Engineering, Czech Technical University

Regional microwave hyperthermia is a therapeutic method for heating up tumors as a complementary therapy for radiotherapy and chemotherapy. It renders tumors more susceptible to damage while hindering its reparative mechanics. This work creates systems with four or eight microwave applicators around a patient, each creating an electric field inside the patient. These fields interfere with each other creating an electric field with maximal heating losses inside the tumorous tissue and leaving healthy tissue relatively cold. In order to achieve an optimal electric field pattern a metamaterial theory is used. Applicators based on metamaterial transmission line theory can achieve better electric field size and depth,while simultaneously untying electric field properties from geometrical constraints, which is major factor for applicators such as waveguides and dipoles. A success of the system is measured using standard parameters such as electric field size, electric field depth, temperature field, SAR and scattering parameters.

Prediction and visualization of protein secondary structures on genomic data

Petr Adámek
Faculty of Biomedical Engineering, Czech Technical University

The diploma thesis describes a tool for a search for candidate genes of the tetherin/bst2 gene family in vertebrates. The search is based on three different characteristic motifs found in all members of this gene family. The defined protein motifs are: transmembrane regions, coiled-coil structure and GPI (glycophosphatidylinositol) modification/anchor.

The tool developed in this work takes as an input region of a DNA and automates search and identification of motifs, than creates clear textual and graphical output in a form of HTML page. Because of a relatively broad definition of characteristic motifs the tool is meant as a helper for an expert and is focused on presenting complex outputs from standard algorithms in a user friendly way.

Biomedical imaging and advanced analyses of biomedical data and signals

13:45 – 15:00

Functional differences of the brain in patients in the presymtomatic and manifestic phases of Parkinson's disease

JanaKukačková
Faculty of Biomedical Engineering, Czech Technical University in Prague

Parkinson's disease (PD) is one of the most common neurodegenerative diseases. It has been found, that the presymptomatic stage of this disease is REM sleep behavior disorder (RBD). Because Parkinson's disease is currently incurable, efforts are being made to detect early PD and enable more effective treatment. Magnetic resonance imaging was used for the research. Processing functional and anatomical images can obtained parameters such as regional homogeneity and other. These parameters are potential biomarkers.

We compared data from three groups - 50 healthy controls, 57 patients with RBD and 60 patients with PD without treatment. Preprocessing, processing and statistical analysis were performed in the supplementary library DPABI of the MATLAB program. The investigated parameter was regional homogeneity, activation maps were subjected to ANCOVA testing and t-test with two samples. ANCOVA confirmed the difference between the groups of patients. Three types of corrections after two-sample t-tests were used on the resulting activation maps to compare the effect of the selected correction - cluster analysis at $p = 0.001$ and cluster size = 95 voxels, FDR correction at $q = 0.05$ and Bonferroni correction $p = 0.05$. Activation maps corrected in this way were provided to the doctors for further analysis.

Neuromelanin quantification in the substantia nigra defined by atlases in magnetic resonance images

Vendula Lhotáková
Faculty of Biomedical Engineering, Czech Technical University in Prague

Parkinson's disease is one of the most common neurodegenerative diseases that cannot be cured. There is a gradual loss of dopaminergic neurons and at the same time a loss of neuromelanin. RBD behavior disorder in REM sleep is reported as an early symptom of Parkinson's disease and later onset motor symptoms of the disease. It is an effort to diagnose the disease in time, for

this purpose an MRI sequence sensitive to neuromelanin NM-MRI is used, it is a biomarker.

The aim of the study was to create a chain of MRI processing of the brain and to determine the amount of neuromelanin and to compare the results between groups of patients with Parkinson's disease, patients with RBD and healthy individuals. The freely available software SPM12 was used for processing, it is a set of functions and programs for MATLAB. Within the created processing chain for determining the amount of neuromelanin, an algorithm for automatic image alignment was developed and a suitable subcortical atlas Human Motor Thalamus was selected to define the substantia nigra region.

Feasibility study on novel microwave imaging system for hypoxic-ischemic encephaopathy detection in neonates

Jan Rédr
Faculty of Biomedical Engineering, Czech Technical University in Prague

The aim of this study was to develop a feasibility study of novel imaging system based on microwave imaging technology for monitoring of hypoxic-ischemic encephalopathy in newborns. The feasibility study was realized using COMSOL Multiphysics software for numerical simulations and MATLAB for image reconstruction using differential imaging based on Born's approximation. From analytical 1D model of transmission coefficient and from the results of reconstructed images on anatomically accurate transversal cut of neonatal head were determined the dielectric parameters of matching medium and optimal operational frequencies. For the purpose of 3D imaging, H-slot antenna was geometrically optimized for frequency band from 2 to 2,5 GHz. For 3D image reconstruction, several imaging systems were proposed and anatomically accurate head model with ischemia lesions were implemented. The results of this work suggest that such microwave imaging system would help in the monitoring and treatment of hypoxic-ischemic encephalopathy which is the significant cause of mortality and severe neurologic disability in newborn children.

Detection of the onset zone of epileptic seizures by intracranial electrophysiological monitoring using convolutional neural networks

Kamila Lepková
Faculty of Biomedical Engineering, Czech Technical University in Prague

Epilepsy is a chronic severe neurological disease. Approximately one-third of people with seizures are resistant to antiepileptics. The primary solution for resistant patients is the surgical removal of the parts of the brain that cause epilepsy. The exact location of the pathological tissue has to be found. The gold standard for localization is monitoring a patient for several days using intracranial electroencephalography (iEEG) by electrodes implanted deep into brain structures and subsequent manual zone determination by a team of physicians. Even then, the results of the resection cannot be predicted with high certainty. Application of convolutional neural networks to iEEG can help detect epileptic activity measured at electrodes and find the exact location of the pathological zone more accurately and faster. The Kohen kappa coefficient was calculated from the confusion matrix, equal to 0.89 in the test dataset. The model's accuracy was determined using sensitivity (SEN), the positive predictive value (PVV) and F1 score calculated from the confusion matrix. SEN reached 90.07 % in the test iEEG set; the positive predictive value was 88.60 %, and the F1 score

reached 90.03 %. The neural network extracts essential information from signals and categorizes them into pathological or physiological classes. The study results suggest that the use of artificial

intelligence can make the diagnosis of epilepsy more objective, more accessible, faster and cheaper. The new approach can overcome diagnostic problems, help physicians determine the exact location of pathological zones, thereby help plan brain resection and improve the quality of life for patients with epilepsy.

Prehospital head stroke detection stroke using machine learning algorithm.

Tomáš Pokorný
Faculty of Biomedical Engineering, Czech Technical University in Prague

A brain stroke is the second most common cause of death all around the world. There are two main types of strokes, ischemic and hemorrhagic. About 85% of strokes are ischemic, where a quick diagnostic is a key factor in reducing the consequences of a stroke. Microwave stroke detection system could be small, portable, and suitable for fast stroke detection in an ambulance car. Machine learning algorithms appear to be able to detect stroke and distinguish between ischemic and hemorrhagic stroke.

People who have suffered a stroke are in direct risk of their lives. Obtaining data for training and testing, the algorithm must be performed in the first phase of research with numerical simulations or phantom measurements. Using simplified 2D numerical models of the microwave system, we simulated different sizes and positions of the stroke in the phantoms of the human head. The Support Vector Machine algorithm achieves a detection and classification accuracy of over 99 percent.

Materials and optics for application in medicine

15:30 – 16:45

Dopped diamond-like carbon coatings prepared by hybrid deposition systems for biomedical applications

Petr Písařík
Faculty of Biomedical Engineering, Czech Technical University in Prague

Nowadays there are materials having excellent properties for use in medicine (Diamond-like carbon, Titan dioxide, Hydroxyapatite, …). Diamond-like carbon (DLC) is a metastable form of amorphous carbon containing bonded carbon atoms of sp2 and sp3 hybridized orbital. DLC layers are semiconductors with high mechanical hardness, chemical inertness, low coefficient of friction, high thermal conductivity, good electrical and optical properties, biocompatibility and no cytotoxicity. All properties of the films are not always ideal, so it is necessary to modify the layer. One example of how to modify the properties of thin layers are dopations. The incorporation of dopants in films may lead to greater multifunctionality and much improved properties. Most modifications were made to modify contact angle and surface energy, to reduce internal stresses, to decrease surface roughness, coefficient of friction or wear, to increase the adhesion to the substrate, biocompatibility, electrical conductivity and resistivity. Silver, titanium and chromium doped diamond-like carbon (Ag-DLC, Ti-DLC, Cr-DLC) and gradient layers (Ti/DLC and Cr/DLC) were deposited on silicon (Si 100) and titanium substrates (Ti 6Al 4V) by hybrid system - pulsed laser ablation (PLD) and magnetron sputtering (MS). Laser energy density was 8 J·cm-2 (C target for deposition Ti and Cr doped layers) and 10 J·cm-2 (for Ag doped layers) using KrF excimer laser. The topology, mechanical and antibacterial properties of films were investigated. The composition was analysed using wavelength-dependent X-ray spectroscopy. Mechanical properties of DLC films with various dopant and gradient layers were evaluated. Hardness (reduced Young's modulus) was determined by nanoindentation. Films adhesion was studied using scratch test and was decreasing with concentration of dopant. In vivo measurement (using gram positive and negative bacteria) of antibacterial properties of the Ag-DLC films. This result opens further possibility for application of doped and gradient DLC films in medicine.

Intraocular Correction of Astigmatism

Martin Fůs
Faculty of Biomedical Engineering, Czech Technical University in Prague

A certain group of patients diagnosed with cataracts has corneal astigmatism and its compensation is a prerequisite for optimal postoperative visual acuity. Using modern calculation formulas and a virtual image-guided system, the surgeon is able to compensate for this ametropia by implanting a toric intraocular lens (TIOL) into the correction axis. In addition to the angular position, the resulting visual acuity of the patient is affected by the tilt, centering and axial displacement of the implanted lens. The aim of this work is to develop a methodology for objective evaluation of factors influencing intraocular correction of astigmatism. The solution consists in creating a methodology for preoperative diagnostics and calculation of toric lens parameters, virtual navigation of implantation, postoperative evaluation of visual functions and creation of software for analysis of postoperative lens position. The current state of solving a wide range of diploma thesis issues, including the design of a 3D model of the eye, will be presented.

Study of material properties of titanium alloy Ti6Al4V used for hip arthroplasty after laser treatment

Lucie Košinová
Faculty of Biomedical Engineering, Czech Technical University in Prague

Hip replacement is currently one of the most common orthopedic surgeries, although short-term and long-term patient satisfaction is very different. It is a surgical procedure in which the hip joint is replaced by a prosthetic implant. Titanium alloy Ti6Al4V is one of the materials used for this purpose. It is very important to investigate and improve its material properties. One of the possible methods is the laser treatment of the material by the Laser Shock Peening (LSP). This method is an established technology for the induction of compressive residual stresses in metallic materials. These compressive residual stresses increase the fatigue life of components in high reliability applications when failure is caused by surface-initiated cracks.

In this paper are presented results of measurement residual stress distribution on X-ray diffraction and the measurement of hardness before and after LSP

treatment. We found that the twice-affected surface of Ti6Al4V by the LSP method reaches hardness to a greater depth. The residual compressive stress extends to a greater depth of the material, which should result in better fatigue resistance of the material than with only one LSP effect. Longer implant life could be achieved using the LSP method.

Tribological properties of contact and spectacle lenses

Alena Škubníková
Faculty of Biomedical Engineering, Czech Technical University in Prague

This paper deals with tribological properties of contact and spectacle lenses, especially the friction coefficient. Friction coefficient in contact lenses is bound with comfortable wear and in spectacle lenses is this coefficient dependant on the durability of teh lens. Three types of contact lenses – 2 siliconhydrogel and 1 hydrogel contact lenses, and two spectacle lenses from different manufacturers (OMEGA and ZEISS) were measured.

Wearability test was performed by Tribometr Pin-on-Disk (TRB³ - Anton Paar) with linear movement – trajectory was 8 mm for spectacle lenses, and 3 mm for contact lenses. Chromium steel testing ball (Ball type: Ac 100 Cr6) with a 6 mm diameter was used during both of measurement.

The outcome of our measurement of contact lenses was, that with increasing sliding speed during measurement the friction coefficient increases as well and with constant sliding speed and increasing applied force the friction coefficient decreases. Measurement of spectacel lenses showed that spectacle lenses with enhanced surface are not being scratched for 0,25 N of applied force. The damage of this type of spectacle lenses occurs with bigger applied force (0,5 N; 0,1 N). Each spectacle lens was evaluated under microscope and the scratch width was measured.

Low fractionalized nanofibers significantly modify structural-functional parameters of dead space agarose fillers after rectal extirpation

Simona Stuchlíková, Aleksei Pashchenko
Faculty of Biomedical Engineering, Czech Technical University in Prague

Dead space after rectal resection in colorectal surgery is an area with an increased risk of complications. There are a small number of optimal methods for avoiding complications of the given type of surgery. Our research aims to develop and appropriately modify a suitable implanted material with optimal characteristics, which improves the healing process and meeting all safety criteria of an abdominal implant. Our study evaluates the characteristics of agar, agarose gels, and gels functionalized with crushed PCL and PVA nanofibers. A biomechanical analysis was carried out for the samples under study. Young's modulus of elasticity was measured at different temperature conditions, with different concentrations, and assessed the effect of the maturity of the sample on its characteristics.