Committee of Biocybernetics and Biomedical Engineering of the Polish Academy of Sciences

Polish Society of Biomedical Engineering

AGH University of Science and Technology, Kraków

20-th Polish Conference

on Biocybernetics and Biomedical Engineering

With the honorary patronage

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Abstract Book

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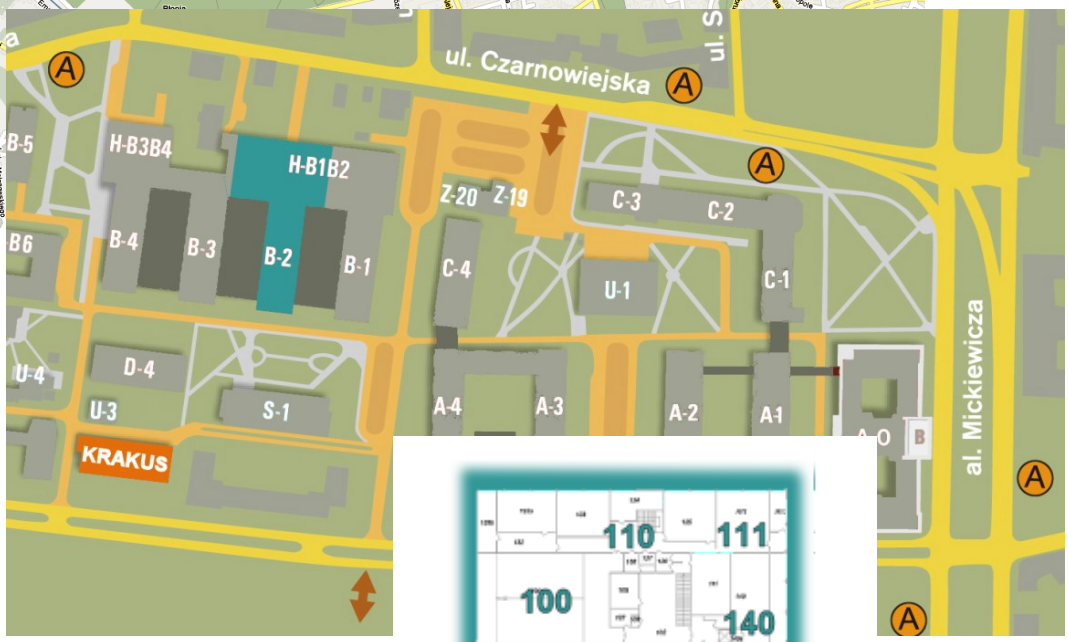
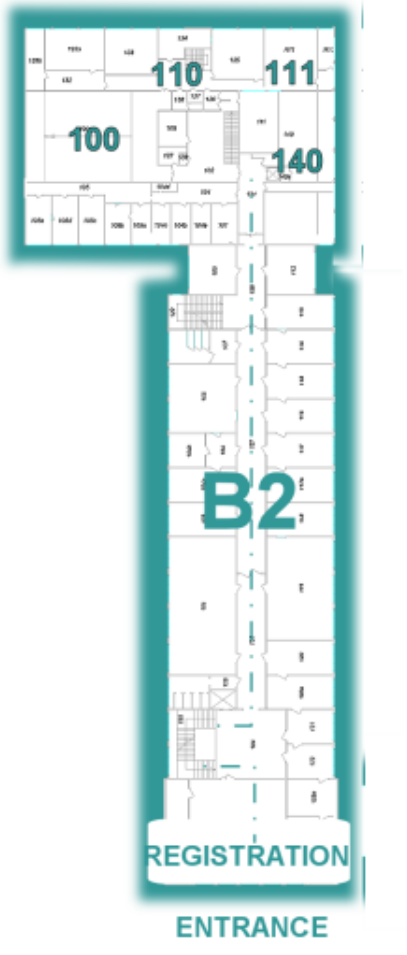
We express our gratitude for their involvement and hope that they will soon submit as presenting authors to next editions of the Polish Conference on Biocybernetics and Biomedical Engineering.

Program at a glance

Wednesday, Sep. 20	8:30	Registration	bldg. **B-2** entrance hall
	10:00	Opening ceremony	bldg. **B-2** auditory **100**
	10:15	Plenary lecture	bldg. **B-2** auditory **100**
	11:00	Coffee break	
	11:30	Scientific sessions **O1**, **O2**	bldg. **B-2** aud. **100**, **140**
	13:00	Lunch break	
	14:00	Scientific sessions **O3**, **O4**	bldg. **B-2** aud. **100**, **140**
	14:00	Visit to Krakow Cardiac Research Institute Core Lab	meeting at registration
	15:30	Coffee break	
	16:00	Scientific sessions **O5**	bldg. **B-2** auditory **100**
	16:00	Special Session on certification system for clinical engineers	bldg. **B-2** auditory **140**
	17:30	Special Session, 70 anniversary of prof. Ryszard Tadeusiewicz	bldg. **B-2** auditory **100**
	19:00	reception and regional dance show	Krakus building
Thursday, Sep. 21	9:00	Plenary lecture	bldg. **B-2** auditory **100**
	10:00	Scientific sessions **O6**, **O7**	bldg. **B-2** aud. **100**, **140**
	10:00	Open lecture on *Integrated Structural and Functional Research on Nervous System* by prof. Ewa Zalewska	bldg. **B-2** room **110**
	11:30	Coffee break	
	12:00	Scientific sessions **O8**	bldg. **B-2** auditory **100**
	12:00	PSBE (PTIB) award nomination	bldg. **B-2** auditory **140**
	13:30	Lunch break	
	14:30	Poster session **P1**	bldg. **B-2** room **111**
	16:00	PSBE (PTIB) members meeting	bldg. **B-2** room **110**
	17:30	Social event	
Friday, Sep. 22	9:00	Plenary lecture	bldg. **B-2** auditory **100**
	10:00	Scientific sessions **O9**, **O10**	bldg. **B-2** aud. **100**, **140**
	10:00	Open course *How to write a successful scientific paper* by prof. Adam Liebert	bldg. **B-2** room **110**
	11:30	Coffee break	
	12:00	Poster session **P2**	bldg. **B-2** room **111**
	13:30	Conference closing ceremony	bldg. **B-2** auditory **100**
	14:00		

Conference rooms





Detailed session plan

session id	title	room	time	presentations (submission no.)
K1	Plenary lecture *Molecular Imaging Today* by prof. Leszek Królicki:	bldg. **B-2** aud. **100**	Wed. Sep. 20, 10:15 – 11:00	
O1	Medical imaging and image processing I	bldg. **B-2** aud. **100**	Wed. Sep. 20, 11:30 – 13:00	12, 17, 22, 106, 112
O2	Biomaterials and tissue engineering	bldg. **B-2** aud. **140**	Wed. Sep. 20, 11:30 – 13:00	19, 33, 36, 39, 42, 98
O3	Biomedical signal processing	bldg. **B-2** aud. **100**	Wed. Sep. 20, 14:00 – 15:30	7, 10, 14, 41, 49, 54
O4	Medical optics	bldg. **B-2** aud. **140**	Wed. Sep. 20, 14:00 – 15:30	43, 50, 57, 87, 92, 104
A1	Visit to Krakow Cardiac Research Institute Core Lab.	meeting at registration	Wed. Sep. 20, 14:00 – 15:30	
O5	Measurements in biology and medicine I	bldg. **B-2** aud. **100**	Wed. Sep. 20, 16:00 – 17:30	51, 63, 74, 97, 99
SS1	Special Session on certification system for clinical engineers	bldg. **B-2** aud. **140**	Wed. Sep. 20, 16:00 – 17:30	109
SS2	Special Session, 70 anniversary of prof. Ryszard Tadeusiewicz	bldg. **B-2** aud. **100**	Wed. Sep. 20, 17:30 – 19:00	
K2	Plenary lecture *Transcranial Optical Measurement of Brain Perfusion and Oxygenation* by prof. Adam Liebert:	bldg. **B-2** aud. **100**	Thu, Sep. 21, 9:00 – 9:50	
O6	Biomechanics and artificial organs	bldg. **B-2** aud. **100**	Thu. Sep. 21, 10:00 – 11:30	76, 79, 82, 108
O7	Education in biomedical engineering	bldg. **B-2** aud. **140**	Thu. Sep. 21, 10:00 – 11:30	58, 88, 90, 107
A2	Open lecture on *Integrated Structural and Functional Research on Nervous System* by prof. Ewa Zalewska	bldg. **B-2** room **110**	Thu. Sep. 21, 10:00 – 11:30	
O8	Modeling and computers in medicine	bldg. **B-2** aud. **140**	Thu. Sep. 21, 12:00 – 13:30	15, 26, 68, 31, 96
SS3	PSBE (PTIB) award nomination	bldg. **B-2** aud. **100**	Thu. Sep. 21, 12:00 – 13:30	
P1	poster session I	bldg. **B-2** room **111**	Thu. Sep. 21, 14:30 – 16:00	5, 9, 13, 27, 29, 37, 45, 46, 47, 48, 55, 60, 70, 75, 77, 83, 92, 93, 100, 101, 102, 103, 104, 111, 115
K3	Plenary lecture by prof. Metin Akay (title will be announced later)	bldg. **B-2** aud. **100**	Fri. Sep. 22, 9:00 – 9:50	
O9	Measurements in biology and medicine II	bldg. **B-2** aud. **100**	Fri. Sep. 22, 10:00 – 11:30	67, 69, 89. 91, 94
O10	Medical imaging and image processing II	bldg. **B-2** aud. **140**	Fri. Sep. 22, 10:00 – 11:30	6, 11, 32, 20, 116
A3	Open course *How to write a successful scientific paper* by prof. Adam Liebert	bldg. **B-2** room **110**	Fri. Sep. 22, 10:00 – 11:30	
P2	poster session II	bldg. **B-2** room **111**	Fri. Sep. 22, 12:00 – 13:30	4, 18, 23, 25, 34, 44, 52, 53, 59, 61, 62, 64, 65, 66, 71, 73, 78, 80, 81, 84, 85, 86, 95, 110, 113

Practical hints about your stay in Kraków

The conference is being held in lecture rooms of the AGH-University of Science and Technology as outlined below

registration desk	building B2, entrance hall
regular oral sessions	building B2, rooms 100, 140 and 111 (1-st floor)
poster sessions	exhibition area (1-st floor)

Please refer to the map of the AGH-UST campus and to the detailed conference program to be sure you are on time at the session of your interest. The buildings and lecture rooms will be clearly marked with the Computing in Cardiology signs.

We wish to recommend you using public transportation (trams and busses), in particular within Krakow center. A 20 min single journey ticket (cost 2,80 zl) or 40 min single journey ticket (cost 3.80 zl). Both allow changes in transportation means within the specified time following the first validation. Tickets can also be purchased at newspaper stands and in vending machines on board. Hiring a taxi is easy everywhere and any driver will bring you to the AGH-UST campus. Before taking the taxi on the street, please be sure the taxi displays a price list and uses the meter. It is a good idea to have your hotel name and address printed with you.

Within the conference rooms in B2 building, a wireless network will be available free of charge. Those of you already registered at 'Eduroam' may login with the credentials of origin and enjoy a full speed connection (4Mbps/1Mbps). Alternatively, in all AGH-UST buildings the network 'AGH-guest' is available free of charge without a password but with a speed and content limitation (256kbps/64kbps, www, mail and ssh are allowed).

In order to keep up the meeting timetable, the attendees are kindly asked to present timely and quickly proceed between session rooms.

Regular coffee breaks with tea, coffee, soft drinks, cakes and fruits are planned as follows:

Wednesday, Sep. 20	11:00 – 11:30 and 15:30 – 16:00
Thursday, Sep. 21	11:30 – 12:00
Friday, Sep. 22	11:30 – 12:00

Accompanying events

As it is usual for nearly all scientific meetings, we consider accompanying events as an important part of the conference. This year we are glad to highlight the following:

Visit to KCRI Core Lab (**Wednesday, September 20, 14:00 – 15:30**). Let's just meet at the registration desk and go for a short walk to visit KCRI. KCRI is a full-service clinical research and education organization launched in 2004 by interventional cardiologists and clinical personnel from Krakow University Hospital. Its original mission was to support a burgeoning field of clinical research in Poland and Central Europe. Initially it was focused on interventional cardiovascular medicine and devices, which to this day remains its key specialty. For this purpose, it included from the very beginning a cardiovascular imaging core laboratory, the first of its kind in Poland and Eastern Europe, and the only one to this day in the region.

Celebrate with us 70-th birthday of Professor Ryszard Tadeusiewicz – one of founding fathers of biocybernetics and biomedical engineering in Poland - with personal recollections from his colleagues, (**Wednesday, September 20, 17:30 – 19:00,** bldg B-2 room 100). The special session will be immediately followed by reception in Krakus restaurant which comes from Poland's oldest student folkloristic ensemble with over 60 years of tradition and many spectacular successes in Poland and abroad. Those who selected this option are invited to see a show of regional dances and music given by Krakus Ensemble. The regional dance show will commence at 19:15 at the Krakus Restaurant and will last for approximately 1 hour.

Attend to open lecture on *Integrated Structural and Functional Research on Nervous System* by prof. Ewa Zalewska (**Thursday, September 21, 10:00 – 11:30,** bldg B-2 room 110). The lecture will present latest achievements and advances in simultaneous fMRI and electrophysiological research of brain functions. The lecture is open to general public.

Meet with us at traditional Jewish District surrounding (**Thursday, September 21, 18:30 – 21:30**) for a dinner in Szara Kazimierz restaurant (Kraków ul. Szeroka 39). Those who selected this option will have an opportunity to network and relax in a more informal setting away from the scientific sessions. A guided tour may precede the dinner if requested in advance.

Attend to open course on *how to write a successful scientific paper* by prof. Adam Liebert (**Friday, September 22, 10:00 – 11:30,** bldg B-2 room 110). The course will reveal some common hints for authors of scientific papers from an editor point of view. Recommended in particular for young scientist planning their professional university or research career. The lecture is open to general public.

Content

Chapter 1. Measurements in biology and medicine

Chapter 2. Biomedical signal processing

Chapter 3. Telemedicine

Chapter 4. Biomedical imaging and image analysis

Chapter 5. Biomaterials and tissue engineering

Chapter 6. Modeling in medicine

Chapter 7. Artificial organs

Chapter 8. Biomechanics

Chapter 9. Medical decisions support

Chapter 10. Medical optics

Application of the method of estimation of afterhyperpolarization duration to assessment of bilateral changes in motoneurons of stroke survivors

Bożenna Kuraszkiewicz, Hanna Goszczyńska, Maria Piotrkiewicz
Nalecz Institute of Biocybernetics and Biomedical Engineering, Polish Academy of Sciences
02-109 Warsaw, Trojdena 4
mpiotrkiewicz@ibib.waw.pl

Aim: It has been recently shown by McNulty et al. [1] that the discharge rates of the motoneurones (MNs) supplying muscles on the non-paretic side of stroke survivors were different not only from those on paretic side, but also from the control MNs. Our study is aimed to verify and extend the findings mentioned above. With this purpose, we computed estimates of afterhyperpolarization (AHP) duration of motoneurons (MNs) supplying muscles of stroke survivors and control subjects and determined their dependencies on subject's age and duration of the disorder.

Materials and Methods: The study population included 11 post-stroke patients and 8 healthy volunteers. The patients (aged 30-77 years), all suffering from spasticity and seeking for BOTOX treatment, were recruited from Department of Rehabilitation in Chi-Mei Hospital, Tainan, Taiwan. The control group consisted from 8 subjects aged 22-64 years without any record of neuromuscular disorder. The experiments were performed in agreement with the declaration of Helsinki and approved by Ethical Committee at Chi-Mei Hospital, Tainan. The motor unit (MU) potentials were recorded from the *brachial biceps* at paretic and non-paretic side in patients and at the left, non-dominant side in control subjects. The signals were picked up by a bipolar concentric electrode, amplified by an electromyograph, sampled by an A/D converter and stored on a computer for data analysis. The AHP duration was estimated by the method developed in our Institute based on the analysis of interspike interval variability [2]. The statistical analysis of data was performed by the tools built into the program Microsoft Excel 2007.

Results: The estimated AHP duration for patients' MNs supplying more-affected muscles was significantly longer than control values and the prolongation decreased with patient age and disorder duration. For MNs supplying less-affected muscles dependency on age was closer to the control data, but the scatter was substantially bigger. The AHP duration estimate of less-affected MNs, when corrected for the factor of age, tended to be higher than that of control for the short times after stroke and lower than control for the longer times.

Conclusion: Our results confirm the recent observation that the MUs of the muscles at the non-paretic side are also affected. Thus, the non-paretic side does not provide a valid control for motor unit activity on the paretic side and control data should always be recorded in healthy subjects. Additionally, our data indicate the possibility that the spinal MNs respond to the cerebral stroke with prolongation of AHP duration, which tends to recover after the accident. These changes occur in parallel in more- and less- affected muscles.
Our results allow us to assume that the spinal MNs on both sides respond to the cerebral stroke very soon and to suppose that the subsequent changes may be accelerated by the rehabilitation.

References:
[1] P.A. McNulty et al. Single motor unit firing rate after stroke is higher on the less-affected side during stable low-level voluntary contractions, *Frontiers in Human Neuroscience*, 2014, vol. 8, article 518, pp. 1-12
[2] M. Piotrkiewicz An influence of AHP on the pattern of motoneuronal rhythmic activity. *Journal of Physiology*, (Paris), 1999, vol. 93, pp. 125–133.

The relationship between baroreflex sensitivity and cerebral autoregulation during controlled breathing

Agnieszka Uryga[1], Agnieszka Kazimierska[1], Arkadiusz Mielczarek[2], Michał M. Placek[1], Paweł Wachel[3] Magdalena Kasprowicz[1]
1.Department of Biomedical Engineering, Faculty of Fundamental Problems of Technology, 2. Department of Cybernetics and Robotics, Faculty of Electronics, 3. Department of Control Systems and Mechatronics, Faculty of Electronics, Wroclaw University of Science and Technology, Wybrzeze Wyspianskiego 27, 50-370 Wroclaw, Poland
e-mail: agnieszka.uryga@pwr.edu.pl

The stability of cerebral blood flow is maintained by baroreflex and cerebral autoregulation (CA). It is known that CO_2 can alter CA, however, the influence of different respiratory rates (RRs) on CA has not been well established [1]. In addition, it is still not clear whether baroreflex and CA are two independent mechanisms or there is a relationship between them. Moreover, due to non-stationarity of physiological signals, traditional spectral method based on Fourier transform can be insufficient to examine CA and baroreflex. The purpose of this study was to investigate the correlation between baroreflex sensitivity (BRS) and CA in time–frequency (TF) domain.

Non-invasive measurement of arterial blood pressure (ABP), cerebral blood flow velocity (CBFV) in the left middle cerebral artery, and end-tidal CO_2 ($EtCO_2$) was performed in 38 healthy volunteers (22 females, 16 males, median age 22, range 18-31 years) during controlled breathing at 6, 10, and 15 breaths/minute. Ethical approval was obtained from Wroclaw Medical University (permission no. KB – 170/2014). Time–frequency baroreflex sensitivity (TFBRS) was calculated using modified TF algorithm [2] and CA was assessed by slow wave TF phase shift (TFPS) between ABP and CBFV. In order to determine the effect of respiration rate on CA, partial TF phase shift (pTFPS) between slow waves of ABP and CBFV was estimated within the partial TF coherence mask which reduces the influence of $EtCO_2$. TF analysis was performed in the very low frequency range (VLF, 0.02-0.07 Hz) using Zhao-Atlas-Marks distribution.

Controlled breathing with growing rate caused a decrease in $EtCO_2$ ($p << 0.001$) and an increase in ABP ($p << 0.001$). The increase of CBFV was statistically unimportant. TFPS was rising with breathing frequency (Friedman's ANOVA $F = 14.58$, $p = 0.0007$), but changes in pTFPS were insignificant. TFBRS decreased with increasing breathing frequency (Friedman's ANOVA $F = 9.00$, $p = 0.01$). Analysis of pooled data at all RRs showed a negative and relatively weak relationship between TFPS and TFBRS ($R_{partial} = -0.22$, $p = 0.03$). When the influence of $EtCO_2$ was removed, there was no correlation between pTFPS and TFBRS.

The TF method is appropriate for analyzing non-stationary signals, like fluctuations in ABP and CBFV. TF approach could be also effectively applied to BRS calculations. Our results suggest that different RRs influence CA estimates. Removing the influence of $EtCO_2$ caused a decline of the relationship between TFPS and TFBRS. Moreover, BRS calculated using TF method showed an inverse relationship between CA and BRS and the impact of controlled breathing on baroreceptor activity, which is in accordance with recent research [3].

Research supported by National Science Centre, Poland (no. DEC-2013/10/E/ST7/00117).

References:
[1] Uryga A., Placek M.M., Wachel P., Szczepański T., Czosnyka M., Kasprowicz M. Phase shift between respiratory oscillations in cerebral blood flow velocity and arterial blood pressure, *Physiol Meas.*, vol.38, no. 2, pp. 310-324, 2017.
[2] Orini M., Laguna P., Mainardi L.T., Bailón R. Assessment of the dynamic interactions between heart rate and arterial pressure by the cross time-frequency analysis, *Physiol Meas.*, vol.33, no. 3, pp.315-31, 2012.
[3] Nasr N., Czosnyka M., Pavy-Le Traon A., Custaud M.A., Liu X., Varsos G.V., Larrue V. Baroreflex and cerebral autoregulation are inversely correlated, *Circulation Journal*, vol. 78, no. 10, pp. 2460-7, 2014.

Baroreflex sensitivity estimation during postural change in joint time and frequency domain

Agnieszka Kazimierska[1], Agnieszka Uryga[1], Michał M. Placek[1], Paweł Wachel[2], Magdalena Kasprowicz[1]
[1] Department of Biomedical Engineering, Faculty of Fundamental Problems of Technology,
[2] Department of Control Systems and Mechatronics, Faculty of Electronics,
Wroclaw University of Science and Technology, Wybrzeze Wyspianskiego 27, 50-370 Wroclaw, Poland
e-mail: agnieszka.kazimierska@pwr.edu.pl

Arterial baroreceptors constitute a subclass of neurons sensitive to changes in arterial blood pressure (ABP). Their function is directly connected to baroreceptor – heart rate reflex (baroreflex), an autoregulatory mechanism whose role is to prevent large short-term fluctuations of ABP through changes of heart rate (HR), vascular resistance, and cardiac contractility. Diminished baroreflex response was reported in several pathological states, such as hypertension, myocardial infarction, and chronic heart failure. Baroreflex function is commonly assessed using baroreflex sensitivity (BRS), a parameter defined as the change in HR caused by a unitary change in ABP. In the clinical setting, BRS is estimated using a variety of invasive and noninvasive techniques, including approaches based on artificially-induced acute changes in ABP and the assessment of spontaneous oscillations in ABP and electrocardiogram (ECG) [1]. One of the most common methods of spontaneous BRS estimation is the spectral method based on calculation of power spectra of systolic blood pressure (SAP) and ECG R-R peak interval (RR) signals. This approach, however, does not take into account the nonstationary nature of physiological signals. Therefore, we proposed a joint time-frequency domain (TF) method of BRS assessment (TFBRS), which allows for more accurate estimation of time-variant parameters. The TF method is a modification of a recent algorithm [2] using Zhao-Atlas-Marks representations of SAP and RR interval signals. In this work we aimed to present the ability of our approach to correctly identify the relationship between BRS values obtained in different physiological circumstances.

ABP and ECG signals were measured noninvasively in a group of 25 young, healthy volunteers. Two 30-minutes-long recordings were obtained from each volunteer: one in the sitting and one in the supine position. Ethical approval was obtained from Wroclaw Medical University (no. KB – 170/2014). BRS was estimated using the standard spectral method and the TF method in two frequency ranges: low (LF, 0.04–0.15 Hz) and high (HF, 0.15–0.40 Hz) for both body positions. The result of TF method is a time course of BRS values, so the median for each recording was used as final BRS estimate.

All methods showed a statistically significant increase in BRS after laying down as compared to the sitting position (Wilcoxon signed-rank test, $p<0.001$). Moreover, the only statistically significant difference between TFBRS and spectral BRS occurred in the LF range for the supine position ($p=0.001$). However, Bland-Altman analysis of agreement between methods revealed that in both positions the spectral and TF methods show better concurrence for the LF range than the HF range, and the agreement is moderate (±1.96 SD from 3 ms/mm Hg up to 10 ms/mm Hg).

Our results demonstrate that the new TF approach accurately determines the relationship between BRS in sitting and supine position, in accordance with previous studies conducted using well established methods [3]. This observation confirms the validity of applying TF analysis to baroreflex response, which may in turn allow for more precise study of baroreflex as a time-variant mechanism, especially in relation to other nonstationary phenomena. The limitations of using traditional spectral techniques for nonstationary signals may also be the cause of moderate agreement between selected methods.

Presented research was supported by National Science Centre, Poland (no. DEC-2013/10/E/ST7/00117).

References:
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Identification of the parameters of lung during recruitment maneuver.

J Glapinski, J. Mroczka [1] A Fijalkowska-Nestorowicz [2] ;
[1] *Wrocław University of Technology, Chair of Electronic and Photonic Metrology, Wroclaw, Poland,*
[2] *Medical University, Department of Anaesthesiological and Intensive Care Nursing, Lublin, Poland,*

The recruitment maneuver (RM) is a part of clinical strategy of respiration supporting. One of promoted strategy to prevent ventilator-induced lung injury is to open the lung and keep it open [1]. The subject of the research was to monitor the phenomena occurring during recruitment maneuver when the artificial ventilation is applied at the mouth of animal ARDS model, using low frequency forced oscillation technique.

The phenomenon of the opening alveoli was modelled according to the estimations made in the complex mathematical and physical-mathematical model of alveolar zones of respiratory system. The complex model structure was reduced into its simpler, identifiable analog of nonlinear resistance and capacitance of the lung.

A large white pig weighing 50±5 kg were included into the study. Under general anaesthesia the animal was tracheostomised, intubated and ventilated in a volume-controlled mode (Puritan Bennett 840) at RR–18/min, with VT– 8-10 ml/kg, I:E ratio -1:2 and FIO2–1.0. Lungs injury was induced by repetitive lavages with 1.5-1.8 l warm 0.9% NaCl. The low frequency (0,5Hz) sinusoidal flow oscillations were induced at the intubation tube by means of mechanically controlled syringe. The flow and pressure changes were monitored by pneumotachograph (Hans Rudolph) while the external negative pressure (eNP) in the whole body size-box was changing.
For the estimation of time-varying mechanical parameters (Rest and Cest) of the lung the Kalman filter method of data analysis was used.

Application of the proposed method in the identification of the parameters of lung changes during the vacuum in the chamber as in the example figure (Fig. 1). There were significant differences in R and in C at the body size-box negative pressure -4, -8, -12, and -16 cmH2O compared to baseline (no negative pressure).

The research program aimed at designing of non-invasive procedure for monitoring of alveolar recruitment-derecruitment based on pressure and flow signals measured at the mouth. The low frequency forced oscillation technique allows observation of changes in the parameters typical for recruited lungs and assess the possibility of monitoring of changes of physiological parameter values when the RM is applied in artificially ventilated lungs.

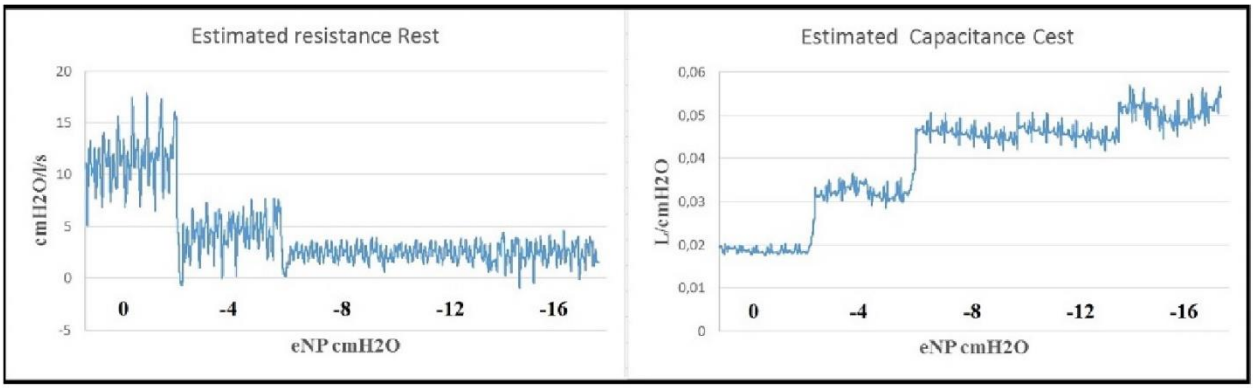

Fig. 1 Estimated lung parameters.

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Multimodal data acquisition in monitored biopsy procedure

Jan Juszczyk, Bartłomiej Pyciński, Joanna Czajkowska, Agata Wijata,
Marta Galińska, Aleksandra Juraszczyk, Ewa Piętka
Department of Computer Science and Medical Equipment, Faculty of Biomedical Engineering,
Silesian University of Technology, (ul. Roosevelta 40, 41-800 Zabrze, Poland)
jan.juszczyk@polsl.pl

Aims

Core needle biopsy is one of the diagnostic techniques in breast cancer. Usually the biopsy is performed under ultrasonographic control. During biopsy procedure 3-5 samples of tissue are obtained from different places of the tumor. Different localizations of the samples are crucial to determine heterogeneity of the tumor. The aim of proposed system is to record locations of the samples relative to a fixed structure like breast or the patient's torso. During a biopsy procedure several types of image and surface data are recorded. The proposed system brings each dataset into a common coordinates system. The system automatically records a moment of the needle shot. The use of the tracking system and 3D breast model allows determining biopsy sites and the visualization of the procedure, which increases the effectiveness of the biopsy.

Methods

The multimodal data acquisition system consists of the following elements: optical and electromagnetic tracking devices, Time-of-Flight (ToF) camera, thermovision camera and video camera. The system is prepared for cooperating with any ultrasound machine. Electromagnetic tracker has been used for US probe tracking. The marker is very small and can be attached directly to the probe without disturbing the physicians. US probe tracking is needed to determine the position of the US image. Optical marker was used for biopsy gun tracking. The only important moment of biopsy gun tracking is time around biopsy insertion. Optical tracker was used because the biopsy gun is made of ferromagnetic metal and it disrupts electromagnetic marker work. Position of the needle is determined by position of biopsy gun and needle detection on US image, if it is visible on the US image. The ToF was used for skin surface reconstruction. The reference point is associated with this model. ToF data can be recorded during biopsy constantly or only before and after biopsy. A dynamic model can be obtained in the former case, whereas a static one in the latter case. Video and thermovision cameras were used for collecting texture images. These images complement the information about surface reconstruction. For collecting the data a plug-in for 3DSlicer software was developed. The system automatically detects a moment of the biopsy gun shot.

Results

Testing of the system has been divided into two phases - laboratory tests and *in vivo* tests. During laboratory phase the accuracy of the needle detection and US image position was determined. Inter-compatibility of all system components was confirmed. During *in vivo* procedures 44 patients were examined included 35 patients during the biopsy procedure. In all system tests ?? datasets were recorded.

Conclusion

This paper presents a 1,5 year work of developing the multimodal data acquisition system. The system was tested in clinical unit. The most important feature of the system is the lack of interference in the biopsy procedure and there is no direct contact of the system with a patient. System calibration can be carried out after or before the biopsy. If more than one biopsy are carried out during one day, only one calibration is sufficient. The accuracy of the needle tracking is 3 - 5mm and the accuracy of the US probe is 0.7mm.

Acknowledgements

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The assessment of Shear Wave Elastography (SWE) application in research of liver mechanical properties

Matylda Żmudzińska[1], Marcin Inglot[2], Ewelina Świątek–Najwer[1], Urszula Zaleska-Dorobisz[2], Celina Pezowicz[1]
[1]Wroclaw University of Science and Technology, Department of Biomedical Engineering, Mechatronics and Theory of Mechanisms, ul. Lukasiewicza 7/9, 50-371 Wroclaw; [2]General and Paediatric Radiology Facility, Independent Public Teaching Hospital No. 1, ul. M. Sklodowskiej - Curie 58, 50-369 Wroclaw
matylda.zmudzinska@pwr.edu.pl

Among all of kinds of sonoelastography, Shear Wave Elastography (*SWE*) is considered as the most objective method. It is used not only for diagnostics but also for simulation purposes. With the development of haptic techniques, tactile laparoscopic simulators are becoming more popular. However, in recent years, several publications have appeared, indicating that haptic feedback provided in haptic simulators is insufficient for surgeons training [1]. Possible source of this limit may be a series of simplifications applied in *SWE* algorithms. There is limited number of studies on determining objective values of liver mechanical parameters by *SWE*. The aim of this study is to correlate the values of Young's modulus (*E*) of liver, obtained with *SWE* and indentation test.

Material consisted of 8 fresh porcine livers. Each of them was divided into four lobes, according to organs anatomy. At least three *SWE* examinations, using Aixplorer by SupersonicImagine® were conducted on each of them. Subsequently, indentation test was conducted, again at least three times on each of the lobes, using spherical indenter, d = 10 mm. *E* values obtained by indentation were counted by different strain rates [2], using the same simplifications as in *SWE* method algorithms.

Presented results show statistically significant difference ($p<0.05$) between *E* obtained by *SWE* and indentation, at $\varepsilon_A=0.025\div0.075$ and $\varepsilon_B=0.05\div0.1$, in contrast to $\varepsilon_C=0.1\div0.2$, what is shown on the figure below.

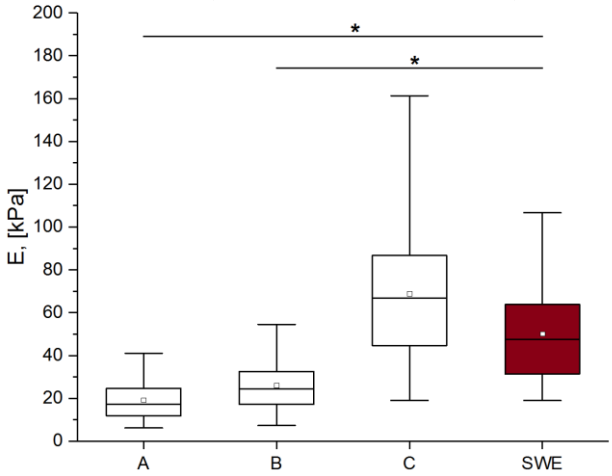

Fig. Mean Young's modulus for different strain rates and SWE.
A: ε = 0.025 ÷ 0.075, B: ε = 0.05 ÷ 0.1, C: ε = 0.1 ÷ 0.2 (t-student, *p<0.05)

According to presented results, it is substantial to focus on strain rate, in which moduli values are calculated. *E* values obtained for ε_A may be biased by measurement resolution. On the other hand, even though *E* values obtained for ε_C are consistent with *SWE* results, they should not be connected, due to the *SWE* measurement methodology. Performed research is an introduction to the development of a methodology for human liver testing. In future study, it is considered to use e.g. media simulating abdominal environment, and different models to count the moduli values.

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The atomic sensors in the Magnetocardiography

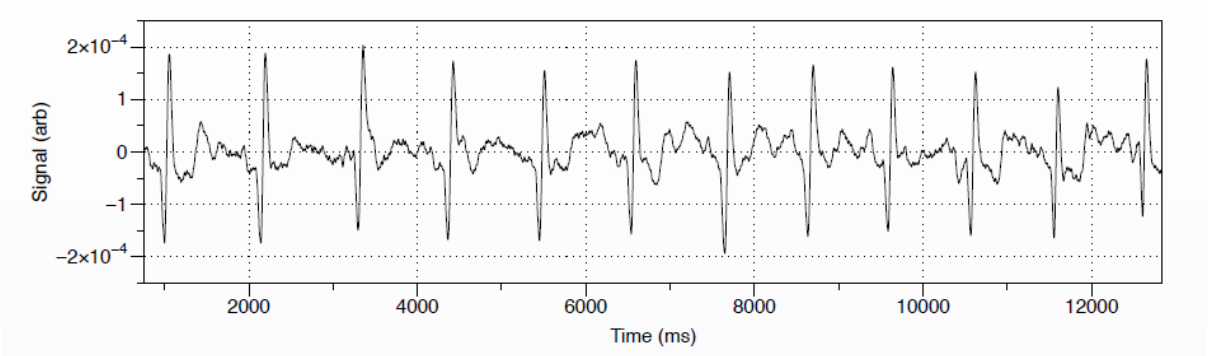
K. Peczalski
Institute of Metrology and Biomedical Engineering WUT, Warsaw 8 Boboli st.
K.Peczalski@mchtr.pw.edu.pl

Introduction of non cryogenic atomic sensors for assessment of magnetic fields of human organs encourage scientists to return to study on its diagnostic applications. Nowadays recognize as a so called gold standards superconductive SQUID sensors are very expensive as a diagnostic tool mostly due to its big dimensions referred to helium cooling system and need for magnetic shielded room (MSR). The atomic significantly smaller magnetometers with simple resistance heating systems despite of still existing needs for magnetic shielding let to avoid some appliance problems.

The atomic magnetometers are designed for assessment of induction of small magnetic fields. The main components of the sensor is a glass cell consisting of vapors of alkali metals such as cesium, rubidium or potassium. The atoms of alkali metals are characterized by one valence electron. The two perpendicular laser beams: pumping and measuring passing through the vapor stored in the sensors cell. The magnitude of the magnetic induction depends on changes of the Larmor precession angle of atoms with polarized spin.

The sensitivity of atomic magnetometers is limited by the density of alkali metals in the cell and the time of spins coherence. The atomic magnetometers working in the SERF regime, according to the higher energy of atoms in the vapor and thus avoiding of spin exchange effect, are able to maintain sufficient sensitivity. The second requirements for suitable for biosignals sensitivity of SERF sensor is to compensate an external magnetic DC field close to zero. This task is realized by the compensation systems incorporated in the MSR.

The two systems of the Helmoholz coils, global for whole MSR capacity and local each consists of three sets of coils dedicated for X, Y, Z axes were tested. The compensation system is intend to produce magnetic induction vector opposite to existing in the MSR earth induction vector. In the laboratory of sensors, ultrasound techniques and low amplitude biosignals of Warsaw University of Technology the examinations stand were designed and preliminary study of magnetic field of the heart action were performed. In the below figure the MCG record of healthy volunteer is presented. According to knowledge of the author this is the first in Poland MCG record performed in the dedicated MSR with use of the non cryogenic sensor.



Conclusions:

1. The noncryogenic magnetometer SERF provides sufficient sensitivity for the MCG study,
2. The necessity of applying of MSR still limiting the wider clinical application of the method.

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Impact of hemodialysis on cardiovascular system

Malgorzata Debowska[1], Jan Poleszczuk[1], Alicja Wojcik-Zaluska[2], Wojciech Dabrowski[3], Mauro Pietribiasi[1], Andrzej Ksiazek[4], Wojciech Zaluska[4], Jacek Waniewski[1]
[1]Nalecz Institute of Biocybernetics and Biomedical Engineering, Polish Academy of Sciences, Ks. Trojdena 4, 02-109 Warsaw, Poland
Departments of [2]Physical Therapy and Rehabilitation, [3]Anesthesiology and Intensive Therapy, and [4]Nephrology, Medical University of Lublin, Jaczewskiego 8, 20-954 Lublin, Poland
mdebowska@ibib.waw.pl

Aims. The body homeostasis of patient on *hemodialysis* (HD) is periodically disturbed. During interdialytic time patient gains water, which is quickly removed during the treatment. The rapid reduction of body overhydration and blood volume during HD affects the cardiovascular system. We aimed to investigate the pulse wave profile and the volume changes of body fluid compartments during HD sessions performed after interdialytic breaks of different lengths.

Methods. Two consecutive HD sessions (duration time 240 ± 10 min) after long (3 days) and short (2 days) interdialytic breaks were monitored in 25 prevalence HD patients (60% females, age 64.8 ± 13.3 years, weight 70.1 ± 15.4 kg, median dialysis vintage 9.6, range 1.3 - 29.8 years). Parameters of the central pulse wave were derived from the pressure waveform recorded at the radial artery using applanation tonometry (SphygmoCor, AtCor Medical, Australia). Overhydration, *total body water* (TBW) and *extracellular water* (ECW) were measured using Body Composition Monitor (Fresenius, Germany). Blood volume changes were measured online during dialysis by CritLine (Hema Metrics, Utah) and stroke volume was assessed by cardioimpedance (PhysioFlow, Manatec Biomedical, France). Statistical differences were assessed using two-sided Wilcoxon signed rank test.

Results. The patients were more overhydrated before HD after long than after short interdialytic break (overhydration: 3.0 ± 1.8 vs. 2.4 ± 1.9 L, respectively, $p < 0.01$). ECW significantly decreased during HD by 2.4 ± 0.7 and 2.0 ± 1.1 L ($p < 0.001$) after long and short break, respectively, but intracellular water remained at the same level. The drop of blood volume in the sessions after long break (596.6 ± 380.4 mL) was higher than in the sessions after short break (482.5 ± 316.7 mL, $p < 0.05$). Stroke volume remained the same during HD, whereas ejection duration decreased and the drop of ejection duration correlated with the drop of blood volume (rho = 0.49, p-value < 0.01). During HD session peripheral and central (*systolic*, SP, and *diastolic*, DP) blood pressures as well as the time (T1) and value of the peak of the left ventricular ejection pressure (P1) decreased, Tab 1. HD affected also the *augmentation index* - the amount of aortic pressure augmented by the reflected waves, Tab 1.

Tab. 1. Parameters of cardiovascular system (p-value after vs. before HD: *** < 0.001, ** < 0.01).

	Before HD	*After HD*
Aortic SP (mmHg)	128.7 ± 22.7	117.6 ± 20.8***
Aortic DP (mmHg)	78.1 ± 11.7	71.9 ± 12.4**
Aortic P1 (mmHg)	110.6 ± 18.0	103.2 ± 16.7**
Aortic T1 (ms)	108.2 ± 16.1	103.7 ± 14.9**
Ejection duration (ED, ms)	328.0 ± 33.4	298.7 ± 36.4***
Stroke volume (SV, mL)	82.1 ± 31.7	80.7 ± 34.2
Augmentation index (%)	159.7 ± 28.9	147.6 ± 25.0**

Conclusions. During interdialytic time the volumes of body fluid compartments increase with higher fluid content after the long, three-days, compared to two-days break between HD sessions. During HD: ECW and blood volume decrease. The volume changes of body fluid compartments during HD contribute to the modification of the cardiovascular system. No change in stroke volume and decrease of ejection duration during HD indicate that after HD the heart is working under smaller workload. Blood pressure, time of the characteristic waveform points and augmentation index significantly change during HD.

Influence of smartphones usage on the surface temperature distribution of parotid region

Joanna Bauer[1], Ignacy Górecki[1], Maria Litwin[1], Agnieszka Migasiewicz[2], Halina Podbielska[1]

[1] Wrocław University of Science and Technology, Faculty of Fundamental Problems of Technology, Department of Biomedical Engineering, Wybrzeże Wyspiańskiego 27, 50-370 Wrocław, Poland
[2] Wrocław University School of Physical Education, Faculty of Physiotherapy, Department of Cosmetology, al. I. J. Paderewskiego 35, 51-612 Wrocław, Poland
Corresponding Author: joanna.bauer@pwr.edu.pl

Mobile phones are commonly known to emit radio frequency and microwave nonionizing electromagnetic waves to provide the service, nevertheless the long-term health effects resulting from their use are still not fully documented. Some authors suggest that they can affect human biology and thus increase the risk of several diseases e.g. brain tumors, eye/ear tumors, neurobehavioral problems, immune system problems, infertility, high blood pressure etc. [1]. The International Agency for Research on Cancer (IARC) based on these reports classified in 2013 mobile phones radiation as "possibly carcinogenic to humans" (group 2B on the IARC scale) [2].

However, it has to be underlined that most of the existing literature is devoted to the elderly cordless phones technologies, whereas nowadays the leading apparatuses on the market are smartphones. Consequently, there is an urgent need for further research, especially on the thermal effects of mobile phone usage that are considered as one of the principal factors causing some physiological effects in head tissues [3].

The aim of this study was to examine the thermal effects caused by chosen smartphones on the parotid region. An experiment was carried on 32 healthy volunteers. Research programme was accepted by the Senate Ethics Committee for Scientific Research at the University School of Physical Education in Wroclaw. Superficial temperature changes were recorded by use of thermal camera FLIR T335. During the measurements the guidelines given by the European Association of Thermology were strictly followed. Participants were adapted for a period of 20 minutes before recording of thermal images. For each participant altogether 8 images were taken: before phone call, immediately after 5 minutes call and then after every 10 minutes till one hour. Experiment was conducted using smartphones with different specific absorption rates (SAR) values, as well as for two operating modes (working mode vs flight mode). In total, the data base of 256 thermal images was recorded and analyzed.

It was found that there are statistically significant differences between mean temperatures of the parotid region dependent on SAR value and operating mode. The heating of parotid region was caused by both, absorption of radiofrequency electromagnetic waves and activity of phone battery. Moreover, it was observed that the duration of the thermal response is gender depended.

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Estimation of brain hemodynamic parameters using multiwavelength time-resolved NIRS technique combined with ICG bolus-tracking method

Martyna Lachowska[1], Anna Gerega[1], Piotr Sawosz[1], Laura B. Morrison[2], Keith St Lawrence[2], Eric Wright[2], Adam Liebert[1]
[1]Nalecz Institute of Biocybernetics and Biomedical Engineering Polish Academy of Sciences Ks. Trojdena 4 st. 02-109 Warsaw, Poland
[2]Imaging Division, Lawson Health Research Institute, London, Ontario, Canada
mlachowska@ibib.waw.pl

Near-infrared spectroscopy (NIRS) is a non-invasive optical method for assessing changes in concentrations of oxy- and deoxy-hemoglobin in a tissue, which enables local tissue oxygenation to be measured. Combining NIRS with an intravenous contrast agent, such as indocyanine green (ICG), also provides a means of measuring cerebral hemodynamic parameters, such as cerebral blood flow (CBF), cerebral blood volume (CBV) and mean transit time (MTT), which are valuable for monitoring brain perfusion disorders [1]. However, accurate measurement of these parameters by NIRS is challenging due to the substantial light absorption in superficial tissue. Application of a unique time-resolved spectral technique may provide even grater sensitivity to absorption changes in the intracerebral compartment, avoiding contamination of the measured signals caused by changes in the perfusion of extracerebral tissues [2]. Analysis of the optical signal measured on the surface of the head with a simultaneous registration of ICG concentration in the artery leads to calculating of brain hemodynamic parameters with a very good precision.

The purpose of the study was to develop a technique for quantifying cerebral hemodynamics from dynamic spectral data based on the inflow of ICG to the brain. Quantification also requires measuring the arterial ICG concentration, which was performed by dye densitometry, and applying a model to these two ICG concentration curves to extract the CBF-scaled residual function (RF), which has an area equal to CBV [1,3]. The MTT value is given by the ratio CBV/CBF.

In the present study, time-resolved diffuse reflectance measurements were acquired with probes placed on the surface of the pig's head during inflow and washout of an intravenous injections of ICG. Dynamic data were acquired simultaneously at 16 wavelengths across the near-infrared region (650-850 nm). The attenuation curves from NIRS were converted to tissue ICG concentration curves (C_T) based on the Beer-Lambert Law. The non-linear least squares method was then used to extract RF, C_T and the corresponding arterial ICG concentration curve. Various models describing RF were investigated, including a 2- and 4-parametric models and a Fermi function. For validation CBF, CBV and MTT values were also estimated by perfusion computed tomography (pCT). The hemodynamic estimates varied between the different models, but were in good agreement with the results from pCT.

In this work various models to characterize the residual function were examined in order to select the model that provided the best agreement to the estimates from pCT. The bolus-tracking method is minimally-invasive and may not only assess the values of brain perfusion indicators but also monitor these values at bedside which is extremely important for patients with impaired cerebral circulation.

The study was financed by the National Science Centre - the project number UMO-2014/15/B/ST7/05276.

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Duration of untreated psychosis is associated with low-frequency functional connectivity in patients with first-episode schizophrenia

Kamil Jonak[a,b*], Paweł Krukow[c], Justyna Morylowska-Topolska[c], Hanna Karakuła-Juchnowicz[b,c]

[a] Department of Biomedical Engineering, Lublin University of Technology, ul. Nadbystrzycka 6, 20-618, Lublin, Poland
[b] Chair and I Department of Psychiatry, Psychotherapy and Early Intervention, Medical University of Lublin, Poland, ul. Głuska 1, 20-439 Lublin, Poland
[c] Department of Clinical Neuropsychiatry, Medical University of Lublin, ul. Głuska 1, 20-439 Lublin, Poland
* Corresponding author: k.jonak@pollub.pl

Aims: The duration untreated psychosis (DUP) is the time interval between the first occurrence of symptoms such as hallucinations and delusions, and the initiation of pharmacological treatment. Prolonged DUP is considered to worse functional outcome, which might be related to the neurotoxic effect of untreated psychosis. The current state of knowledge regarding the main neural mechanisms regulating human behaviour and cognition refers to the connectivity hypothesis, according to which the exchange of information inside the nervous system is the main form of brain's activity and its effectiveness translates into normal or distorted behaviour. It seems likely that the DUP should be correlated with the functional connectivity parameters, especially with FC at lower frequencies, associated with pathological neural activity. Majority of previous studies regarding relations between DUP and brain was focused on brain's structure (measured with CT or MRI) (Anderson et al., 2015), but not with electrochemical activity, which can be assessed with quantitative EEG. Our goal was to explore the hypothetical impact of DUP on functional connectivity (measured in delta and theta frequencies) in first-episode schizophrenia patients

Methods: A group of 30 demographically homogenous sample of first-episode schizophrenia patients was enrolled in the study. DUP was estimated on the basis of patients and his relative's information gathered by specialized clinical psychiatrist. For neurophysiological examination, for each participant 10 minute of resting state EEG (19 electrode) record where collected. Sampling frequency was set on 500 Hz. For further analysis 25 artefact free and 8.19s time duration epochs were selected (4096 samples). Functional connectivity values were calculated using the phase lag index (PLI), between all 19 electrode-pairs. Statistical analysis of FC data were calculated using the Pearson's two-tailed correlation coefficient.

Results: Duration of untreated psychosis was directly correlated with PLI results in delta frequency in pairs of relatively remote cortical areas localized in frontal, temporal and parietal lobes. This result mean, that DUP affects the effectiveness intra-brain synchronization, which might in turn generate cognitive impairments and psychopathological symptoms.

Conclusion: According to Lehmann et al. (2014), delta frequency is associated with inhibition of neural activity. Therefore structures with are connected at very low frequency are thought to be in fact disconnected. Our results suggested, that DUP might impede the functional outcome of patients by disturbing their brain's effective synchronization.

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Processing and Analysis of EEG Signal for SSVEP Detection

Marcin Kołodziej, Andrzej Majkowski, Łukasz Oskwarek, Remigiusz J. Rak, Paweł Tarnowski

Warsaw University of Technology, Warsaw, Poland
marcin.kolodziej@ee.pw.edu.pl

The aim of the article is to provide a systematic presentation of basic tools that are most commonly used to analyze electroencephalography signals (EEG) in brain -computer interfaces for detection of steady-state visually evoked potentials (SSVEP). We use a database of EEG signals containing SSVEP and demonstrate the desirability of the use of selected methods, showing their benefits. Methods such as independent components analysis (ICA), frequency analysis (DFT), and time-frequency analysis (STFT) are presented. For SSVEP, the features of EEG signal should be stable with time. Short-Time Fourier Transform (STFT) allows to confirm this stability. Independent Component Analysis is used to extract pure SSVEP components. The advantages of each method are described and the obtained results are discussed. Further, source location by the use of low-resolution electromagnetic tomography algorithm is demonstrated.

Full text of this paper can be found at:

Marcin Kołodziej, Andrzej Majkowski, Łukasz Oskwarek, Remigiusz J. Rak, Paweł Tarnowski, Processing and Analysis of EEG Signal for SSVEP Detection in: Augustyniak P., Maniewski R., Tadeusiewicz R. (eds.) *Recent Developments and Achievements in Biocybernetics and Biomedical Engineering, Proc. of. 20-th Polish Conference on Biocybernetics and Biomedical Engineering*, Springer International Publishing AG, Series: Advances in Intelligent Systems and Computing, 2017, pp. 3-21

Steady State Visually Evoked Potentials and Their Analysis with Graphical and Acoustic Transformation

Sławomir Kotyra and Grzegorz M. Wójcik

Department of Neuroinformatics, Institute of Computer Science,
Maria Curie-Sklodowska University
5 M. Curie-Sklodowska Sq. 20-031 Lublin, Poland
slawomir.kotyra@umcs.lublin.pl

In this paper we present the experimental set-up that was constructed to study Steady State Visually Evoked Potentials (SSVEP). It is based on the DSM-51 unit that works as a hard real-time controller, connected with goggles containing blinking tricolor (RGB) LED diodes. The EEG system used in our experiments was Mindset-1000 with 16 channels, 16 bit Analog to Digital Converter (ADC) manufactured by Nolan Computer Systems. The EEG signal extracted from the Mindset- 1000 EEG device was recorded synchronously with the stimulating signal from the DSM-51 controller.

Full text of this paper can be found at:

Sławomir Kotyra and Grzegorz M. Wójcik, Steady State Visually Evoked Potentials and Their Analysis with Graphical and Acoustic Transformation in: Augustyniak P., Maniewski R., Tadeusiewicz R. (eds.) *Recent Developments and Achievements in Biocybernetics and Biomedical Engineering, Proc. of. 20-th Polish Conference on Biocybernetics and Biomedical Engineering*, Springer International Publishing AG, Series: Advances in Intelligent Systems and Computing, 2017, pp. 22-31

The Station for Neurofeedback Phenomenon Research

Sławomir Kotyra and Grzegorz M. Wójcik

Department of Neuroinformatics, Institute of Computer Science,
Maria Curie-Sklodowska University
5 M. Curie-Sklodowska Sq. 20-031 Lublin, Poland
slawomir.kotyra@umcs.lublin.pl

This paper presents the basic research station for the testing of neurofeedback phenomena. The most important part of the system is a hardware module driving a pair of tricolor goggles. This part of the system covers the full 24-bit (RGB) color palette. The goggles used by us eliminate external stimuli and significantly distinguish our station from the station used previously in similar studies. The entire system, including the software, was designed specifically for the planned research, including a neurofeedback loop, where the goggles are responsible for providing the feedback signal to the sense of sight.

Full text of this paper can be found at:

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Influence of Skin Tone on Efficiency of Vision-Based Heart Rate Estimation

Aleksandra Królak

Lodz University of Technology, Institute of Electronics
90-924 Łódź, ul. Wólczańska 211/215
aleksandra.krolak@p.lodz.pl

Non-contact methods of human heart rate (HR) facilitate medical assessment of this most important vital sign and increase patient comfort. Videoplethysmograpy (VPG) can be applied not only in healthcare units but also at homes and remote locations. In this paper the efficiency of an algorithm for pulse rate detection based on face image is analyzed. The correspondence between patient ethnicity and various color components used for HR estimation is examined. The results suggest that analysis of color components related to red provide better performance in case of darker skin tone, while green-related components are more accurate for persons of Caucasian origin.

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Localization of Noise Sources in a Multilead Electrophysiological Record

Piotr Augustyniak

AGH University of Science and Technology
30 Mickiewicza Ave. 30-059 Kraków
august@agh.edu.pl

Electrophysiological recordings from brain, heart, stomach or muscles usually contain noise, which decreases the clarity of desired signal. The term 'noise' is commonly applied to a variety of extrinsic factors: spontaneous muscle activation, skin response, interferences or limitations in electrical circuits. Usually the noise is identified by its temporal or spectral characteristics provided by statistical models. This paper proposes a two-compartment model of noise allowing for rough localization of its source with a search of coincidence in a multilead record. Accordingly to characteristics of noise sources expected in each of these compartment, the algorithm performs correlation, coherence and principal component analysis to distinguish equipment-related noise from a possible extra physiological activity taking place within the body. Physiological activities can be then localized with use of the independent component analysis with regard to the electrode position and, with applying of extra knowledge, classified as noise or signal. The proposed algorithm was tested with synthetic and original ECG and shows 43-95% of detection efficiency, depending on the source and amplitude of noise. It can be beneficial for assessment of physiological record quality, studying coincident physiological processes and research on noise characteristics.

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Influence of Preterm Birth, BPD and Lung Inhomogeneity on Respiratory System Impedance - Model Studies

Barbara Stankiewicz, Marek Darowski, and Krzysztof Jakub Pałko

Nalecz Institute of Biocybernetics and Biomedical Engineering, Polish Academy of Sciences,
Department of Biomedical Systems and Technologies
ul. Ks. Trojdena 4, 02-109 Warszawa
bstankiewicz@ibib.waw.pl

The influence of preterm birth, bronchopulmonary dysplasia (BPD) and lung inhomogeneity on respiratory system impedance (RSI) was studied. The simulation of spontaneous breathing in full term newborns (FT), very low birth weight (VLBW) and extremely low birth weight (ELBW) preterm infants was carried out using a developed linear RLC respiratory system model. Besides BPD, four types of lung inhomogeneity: 1) one-lung obstruction (OBSTR), 2) one-lung restriction (RESTR), 3) one-lung obstructive-restrictive disturbance (OBSTR-RESTR I), 4) bilateral obstructive-restrictive disturbance (OBSTR-RESTR II), with obstruction of one lung and restriction of the second, were studied. The impact of preterm birth on infant RSI was stronger than the BPD impact. The differences in the real and imaginary parts of RSI, between full term, VLBW and ELBW infants, were much greater than between preterm infants with and without BPD. The shift of resonant frequency between full terms and ELBW amounted to 20 Hz, but between ELBW with and without BPD only 5 Hz.
The bilateral obstructive-restrictive lung inhomogeneity (OBSTR-RESTR II) with obstruction of one lung (R1 = 10 R2) and restriction of the second lung (C2 = 0.1 * C1), appeared to have the most adverse influence on RSI. In ELBW with OBSTR-RESTR II, both the real and imaginary parts of RSI increased several times compared to healthy ELBW.
However, severe one-lung obstruction (R1 = 10 * R2) or one-lung restriction (C1 = 0.1 * C2) in preterm infants prompted significant increases of RSI compared to healthy infants. The 20% difference in airway resistance (R1 = 1.2 * R2) or lung compliance (C1 = 1.2 * R2) between the left and right lung seemed to be clinically unimportant.

Full text of this paper can be found at:

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Information coding and decoding using Discrete Wavelet transform

Agnieszka Świerkosz
AGH- University of Science and technology
Mickiewicza Avenue 30
30-059 Cracow
aswierk@agh.edu.pl

The subject of the study is to encode additional information to the ECG signal. This is a kind of novelty, because it is not a commonly used method. Advantages are:
1) possibility to additional data,
2) use the existing channels for transmission and archiving for ECG with encoded data,
There are several publications on coding information for ECG [1-3]. Methods are different e. g. [3]:.

- LSB,
- QIM [3].

Data encoding is performed in the time-frequency domain. The information is encoded in several steps:
1) we convert the signal from the time domain to time-frequency by wavelet transform.
2) Then we should analyze where we can encode the information. It is best to do this in the band gap that occurs most often from the end of the QRS complex to the beginning of the T wave. To do this, we need to measure the noise that results in the depth of coding.
3) Additional information has to be converted into bit strings.
4) In the 1-st scale, we encode data (bitstreams) of the appropriate bit depth of coding.
3) In the 2-nd scale, the location of the above mentioned data container is described.
4) Finally, we return to the time domain using inverse wavelet transform.

The author managed to encode the sample text string at a example 3-bit encoding depth. The word encoding was based on ASCII codes. The Matlab software, in which wavelet transformation was implemented, was helpful in this interference. The author has proved that virtually any encoding depth, within the ECG bandwidth gap is practically possible. The author research area is to explore the encoded signal at depths of 1-5 bits and check if the signal does not change its value at such encoding values.

Cryptography is quite an old field of computer science. While encoding information is not new, the encoding of additional information in the ECG signal itself is no longer obvious. It is, however, economically viable for two reasons. First, the additional data should not change the diagnostic value of the signal. Secondly, the way of transmitting and archiving such information along with ECG values is very economical. The analysis of this method shows yet another property. Additional data are placed in the signal stream, meaning there is no way to accidentally lose descriptive data.

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Parkinson's disease progression monitoring based on voice recordings

Daria Hemmerling[1], Magdalena Wójcik-Pędziwiatr[2],
Michalina Malec-Litwinowicz[2], Natalia Grabska[2], Michał Michalski[2]
[1]AGH University of Science and Technology
Department of Measurement and Electronics
Al. Mickiewicza 30, 30-059 Krakow,
[2] The John Paul II Specialist Hospital in Cracow
Department of Neurology with Unit of Stroke
and Unit of Neurological Rehabilitation
hemmer@agh.edu.pl

The Parkinson's disease (PD) is the second most frequent neurodegenerative disorder affecting about 2% of the population above 65 years old. Speech disorders of people with Parkinson's disease are mainly caused by: functional deficits in the larynx, weakened mimic muscles, decreased lung capacity and reduced speech velocity. Such changes lead to a number of voice and speech abnormalities including: volume reduction, lower voice intensity, limited voice modulation (monotonous speech), difficulty with volume changes, reduced voice tone, rough and hoarse tone, and improper articulation (speech becomes blurred) and change of expression pace [1]. The aim of this paper was the prediction of the patient's state in 3 hours after taking the medication based on voice analysis and present the results in UPDRS scale (*Unified Parkinson Disease Rating Scale*), which is a reliable tool for monitoring disease progression both in symptomatic and non-symptomatic disease monitoring [2]. The impact of Parkinson's disease on speech is included in III part of the UPDRS scale, and the most often the analysis of patients' speech is limited to the description of the score only from this section. In this case, the number of points can range from 0 to 108 (27 issues x 4 = 108).

The first step concerned voice recordings, which were done in the period when the Parkinson's symptoms return (*OFF* state), 30, 60, 120 and 180 minutes after taking the medication (l-DOPA). Just after each voice recording every patient was evaluated using UPDRS scale. The voice analysis was done in time, frequency and mel-cepstal domain to get fragility during phonation, prosody and articular deficits that affect voice production. The first goal of this work was to predict the voice course in 180 minute after taking the medication based on previous recordings. The second goal was to develop a model to translate the results of signal processing to the neurological state of the patient according to the UPDRS scale, III part. A higher UPDRS score indicates a more advanced stage of the disease. The prediction was done based on Feed-Forward Back Propagation Neural Network. The training function was updated using Levenberg-Marquardt algorithm in optimization manner. Back propagation is a feed forward neural network and it propagates the error in backward direction to update the weights of hidden layers. To map UPDRS value based on voice signal we have used *Support Vector Regression* (SVR) [3]. The experiments performed following the leave-one-out validation strategy consider recordings of sustained phonations of polish vowels. The data consists of 10 patients who phonated 4 vowels: /a/, /e/, /i/ and /u/.

The lowest mean absolute difference between calculated UPDRS points and points given by a physician was achieved for /a/ vowels and amounts to 4.78 ± 5.62. This is a preliminary study that considers a new approach of voice signal processing to make prediction of patient's state and to express the results in understood by physicians scale. The proposed system enables to follow the course of Parkinson's fluctuations noninvasively based on voice analysis with high accuracy.

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Analysis of EHG signals to prediction of preterm labor using joint recurrence plots

Iwona Gruszczyńska[1*], Sławomir Grycuk[1], Marta Borowska[1], Paweł Kuć[2], Piotr Laudański[2]
[1]Faculty of Mechanical Engineering, Bialystok University of Technology, Wiejska 45C, 15-351 Białystok, Poland
[2]Department of Perinatology, Medical University of Bialystok, M. Skłodowskiej-Curie 24A, 15-276 Białystok, Poland
Email of Corresponding Author: iwonag94@wp.pl

Modern knowledge about the physiology and pathophysiology of human uterine contractile activity in pregnancy and childbirth is not yet one hundred percent and a new diagnostic methods that can improve or accelerate the diagnosis of premature birth are still needed. The aim of the study is to analyze the uterine contractions obtained by electrohysterography using joint recurrence quantification analysis. The analysis of the biopotential measurements of uterine contractions was performed for 8 channels, in which the electrode 1 and 4 were analyzed on the outside of the abdomen. The work is supposed to check if the joint recurrence plot technique can identify regions with the same dynamics, and this will enable detecting disorders in the early stages of pregnancy.

The material of this study consists of uterine contractions extracted from EHG signals received from women at risk of pregnancy. These women were in 24th week of pregnancy, one of them delivered within 7 days, second delivered after 7 days. During research the signals were recorded from 8 channels, but this work focuses on the analysis of the electrodes 1 and 4 because at an early stage of pregnancy they are placed on the stomach directly above the myometrium.

The study of uterine contractions was based on the analysis of recurrence plots (RP), joint-recurrence plots (JRP) for uterine contractions and the joint-recurrence quantitative analysis (JRQA) from the received RPs for all EHG signals. In Fig. 1a the JRP is shown for both electrodes uterine contraction for first woman, Fig. 1b JRP for second woman. The JRP and RPs were obtained from signals of uterine contraction containing 2000 samples. Values of time delay, embedding dimension and threshold were chosen for the signal from these both electrodes. The embedding dimension was chosen using the method of false nearest neighbors and the time delay by the method of mutual information. The threshold value was set by the size of the reconstructed attractor.

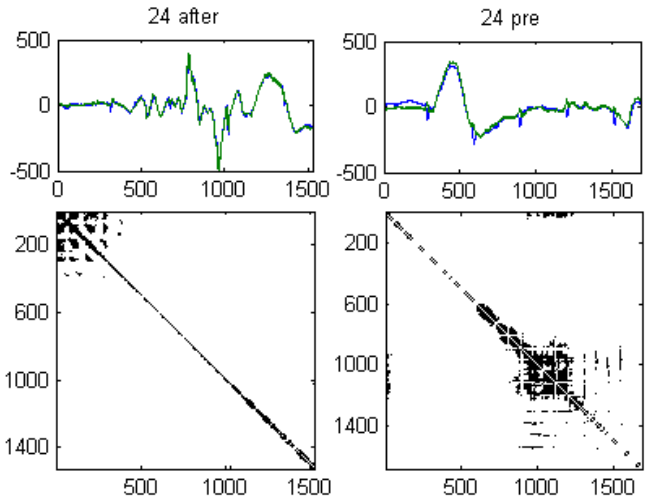

Fig.1. Joint Recurrence Plot of signals under consideration, (a) Joint Recurrence Plot for woman which delivered after 7 days, (b) Joint Recurrence Plot for woman which delivered within 7 days.

Result shows that Joint Recurrence Quantification Analysis of the EHG signals can be used to identify synchronisation between two electrodes and this fact can be helpful in detecting disorders in the early stages of pregnancy.

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Acoustic analysis of phoneme /s/ mispronunciations for sigmatism diagnosis

Michał Kręcichwost, Zuzanna Miodońska, Paweł Badura.
Faculty of Biomedical Engineering, Silesian University of Technology in Zabrze, Poland
michal.krecichwost@polsl.pl

Variety of speech disorders can be found in Polish language speakers. One of the most common disorders is sigmatism, which is non-normative realization of sibilant phonemes (/s, z, ts, dz/, /ʃ, ʒ, ʧ, ʤ/, /ɕ, ʑ, tɕ, dʑ/). The most popular types of this phenomenon are interdental and lateral sigmatism. The effectiveness of the speech therapy depends on the correct diagnosis of the pathology and selection of appropriate exercises. Unfortunately, this task often requires many years of experience. The diagnosis is also not objective.

Speech processing may allow the therapy to be more objective. According to our knowledge, only few approaches to computer-aided sigmatism diagnosis can be found in literature [1, 2]. These projects focus on a general assessment of pronunciation (normative/pathology), without any detailed analysis of the disorder.

The proposed methodology allows the phoneme [s] to be classified into one of 3 groups. The database recorded for this pilot study contains 1308 [s] phoneme occurrences (444 normative, 432 interdental, 432 lateral). All analyzed recordings come from 15 adult speakers with proper pronunciation who were simulating the pathologies. Pseudo-words containing phoneme [s] surrounded by vowels were suggested by speech therapists and recorded (ASA, ESE, ISI, OSO, USU, YSY. SAS, SES, SIS, SOS, SUS, SYS).

A feature vector was calculated for each frame of analyzed phonemes. The feature vector contained 13 Mel-Frequency Cepstral Coefficients (MFCC), their first derivative, 26 Shifted Delta Coefficients (SDC), Root Mean Square (RMS), and 3 fricative formants with corresponding amplitudes. Random Forest algorithm was used for classification of phoneme [s] into one of 3 groups (normative, interdental, lateral).

Classification results obtained with Random Forest (RF) were compared with multi-class Support Vector Machine (nu-SVC) with polynomial kernel function. The efficiency of the classification using the proposed feature vector and the RF algorithm was 77%. For SVM, 70% was obtained. By using MFCC coefficients (a basic feature set for speech assessment [3]), classification yielded 67% and 62% for RF and SVM, respectively. The proposed feature vector improved classification results by approximately 10 percentage points.

Obtained results showed the possibility to recognize the type of sigmatism. For this task, MFCC coefficients may be insufficient. The proposed feature vector associated with the nature of the sibilant phonemes allows for improving classification efficiency. Also, RF is intrinsically suited for multiclass problems, while SVM is intrinsically two-class. The nature of the speech defect also suggests that the use of only one channel during registration may be insufficient.

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Estimating phase shift using matching pursuit algorithm to assess cerebral autoregulation

Michał M. Placek[1*], Marek Cygan[2], Paweł Wachel[1,2], Magdalena Kasprowicz[1]
[1] Department of Biomedical Engineering, Faculty of Fundamental Problems of Technology
[2] Department of Control Systems and Mechatronics, Faculty of Electronics
Wroclaw University of Science and Technology (Wybrzeże Wyspiańskiego 27, 50-370 Wrocław)
[*]michal.placek@pwr.edu.pl

Aims

Cerebral autoregulation (CA) is a physiological control mechanism responsible for adjustment of cerebral blood flow (CBF) in response to changes in arterial blood pressure (ABP) in order to provide adequate blood supply to the brain. For diagnosis and management of patients with cerebral circulation pathologies a detailed assessment of CA is of great importance. A popular method for assessing CA is a transfer function analysis [1]. It yields the spectral coherence function and the phase shift between ABP and transcranial Doppler cerebral CBF velocity (CBFV). Serious restriction of the spectral method is that it assumes stationarity, whereas ABP as well as CBFV exhibit time-varying nature, and CA is considered to be a non-stationary mechanism [2]. Moreover, phase shift might not be a reliable measure when corresponding coherence is low. To overcome these limitations, we aim to investigate the ABP-CBFV relationship using algorithm based on multichannel matching pursuit (MMP).

Methods

Non-invasive measurement of ABP, CBFV in the left middle cerebral artery, and end-tidal CO_2 ($EtCO_2$) was performed in 50 healthy volunteers (29 females, 21 males, median age 23, range 18–31 years) during normocapnia and hypercapnia. Hypercapnia is a state of abnormally elevated $EtCO_2$, and it is known to impair CA. All volunteers provided written informed consent before participation. Ethical approval was obtained from the Commission of Bioethics at Wroclaw Medical University before commencing the study (permission no. KB–170/2014). Raw signals were first decimated to the frequency 2 Hz and then detrended by removing regression line. MMP with Gabor dictionary was employed to find common time-frequency atoms in slow fluctuation of ABP and CBFV for each recording. Phase shifts calculated individually between each pair of common atoms yielded the distribution of ABP-CBFV phase shift weighted by fitting power. We evaluated standard deviations and kurtoses of distributions obtained for all recordings. Wilcoxon signed rank test was used to assess the differences between the parameters during normocapnia and hypercapnia.

Results

Hypercapnia led to the increase in $EtCO_2$ of 30.5%, CBFV of 28.4%, and ABP of 10.6% ($p < 10^{-8}$ for all). The following results are provided as median [Q1–Q3]. Standard deviation of phase distribution was significantly reduced during hypercapnia in comparison with normocapnia (36.6° [25.0–43.2]° vs 53.3° [40.2–68.3]°, $p < 10^{-5}$), whereas kurtosis was higher (5.49 [4.52–8.04] vs 3.98 [3.09–5.12], $p < 0.0005$).

Conclusion

We presented an alternative method for CA assessment that accounts for time-varying nature of signals used for its assessment. Algorithm based on MMP is capable of finding regions of high coupling between ABP and CBFV to estimate phase shift without using auxiliary measures like coherence. New parameters describing CA can discriminate between normo- and hypercapnia.

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Coupling of oxy- and deoxy-hemoglobin concentrations with EEG rhythms during motor task

P. Lachert[1]*, P. Pulawski[1], D. Janusek[1], D. Milej[1], P. Sawosz[1], M. Kacprzak[1], K.J. Blinowska[1]
[1] Nalecz Institute of Biocybenetics and Biomedical Engineering, Ks. Trojdena 4 st.
02-109 Warsaw, Poland

**e-mail: plachert@ibib.waw.pl*

Introduction

The evidence concerning coupling between hemodynamic processes and EEG rhythmical activity is rather scarce, especially in the context of functional Near Infrared Spectroscopy (fNIRS). The aim of our study was gaining information on neurovascular coupling by means of simultaneous measurement of fNIRS and EEG during motor task. Specific time-frequency pattern accompanying this task gives an opportunity to study the relation between oxyhemoglobin (HbO), deoxyhemoglobin (HbR) and EEG rhythms

Material and methods

Simultaneous measurement of fNIRS and EEG was performed on ten healthy subjects (mean age 28 years), during right index finger tapping. EEG activity was recorded from 32 active Ag/AgCl electrodes. Time-resolved fNIRS system operating at 690 and 832 nm consisted of two sources and 8 detectors placed symmetrically on both hemispheres over the sensorimotor cortex. Distributions of times of flights of photons (DTOF's) were measured. Changes in the concentrations of HbO and HbR were calculated according to Beer-Lambert law from changes in the total number of photons of DTOF's and using molar extinction coefficients for assumed differential path length factor value.

Results

Kolmogorov-Smirnov test revealed high significance $p<0.0001$ of concentration changes of HbO and HbR except for 2 subjects in case of HbR. The increase of HbO during movement in the left motor cortex of hand and decrease of HbR were accompanied by the decrease of the amplitudes of alpha and beta rhythms (desynchronization). The hemodynamic changes onsets were delayed in respect of electrophysiological changes. Namely, the delays were: 2.87±2.02 for HbO-alpha, 2.74±1.82 for HbO-beta, 2.79±1.80 for HbR-alpha, 2.67±1.60 for HbR-beta. In order to quantitatively evaluate relations between the hemodynamic parameters concentration changes and alpha and beta amplitudes during motor task evolutions Person coefficients between the time series were calculated. For all subjects (but two who showed insignificant changes of HbR during the task) the statistical significance was below 0.0001. The respective averaged values of correlation coefficients were: -0.69±0.16 for HbO and alpha, -0.54±0.32 for HbO and beta, 0.59±0.29 for HbR and alpha and 0.49±0.22 for HbR and beta.

Discussion

Usually brain activation during particular tasks is connected with an increase of HbO. The negative correlations between HbO and EEG amplitudes in the α and β bands may be explained by the fact that during motor action the decrease of α and β rhythms is accompanied by an increase of high frequency gamma rhythm (with a spectrum extending to 100Hz), which is difficult to observe in scalp recordings, yet is prominent in cortical measurements [1]. We have observed gamma activity around 40 Hz during a motor task involving single voluntary movements. EEG reflects synchronized neural activity, gamma rhythm is less synchronized than α and β rhythms and is strongly damped by extracerebral structures. fNIRS detects brain activity regardless of its synchronization. High frequency brain activity hardly detected in EEG is reflected in fNIRS as an increase of blood oxygenation level.

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Application of Entropy Measures for the Detection of Preterm Labor

Marta Borowska[1], Paweł Kuć[2]
[1]Faculty of Mechanical Engineering, Bialystok University of Technology, Wiejska 45C, 15-351 Białystok, Poland
[2] Department of Perinatology, Medical University of Bialystok, M. Skłodowskiej-Curie 24A, 15-276 Białystok, Poland
Email of Corresponding Author: m.borowska@pb.edu.pl (M. Borowska)

Premature labor is still the biggest worldwide challenge, because, despite the progress of medicine has not sufficiently effective methods for its diagnosis. The uterine electromyography (EMG) is the promising method of predicting preterm labor. Evaluation of the nonlinear dependence and the complexity of uterine EMG signals by using entropy measures could help in the early detection of premature labor.

Originally, entropy comes from thermodynamic property that is the measure of the degree of disorder within a system. A statistical interpretation of thermodynamic entropy is the amount of information stored in the system [1]. Entropy is a measure of the complexity of the time series [2]. Material of the study consists of 186 uterine contractions extracted from EHG signals received from patients with threatened preterm labor between the 24th and the 36th week of pregnancy. The women were divided into two groups: those delivering within 7 days from presenting of threatened preterm labor symptoms - group A and women delivering after 7 days - group B. The system allowed 8-channel signal registration in 8 different points of abdominal wall over the pregnant uterus. The sampling frequency was 500 Hz. The analysis concerned the recorded signals from the electrode 4 for this analysis. The entropy measures, namely, approximate entropy (*ApEn*), sample entropy (*SpEn*), permutation entropy (*PermEn*) and fuzzy entropy (*FuzzyEn*) are computed of group A and group B. Entropy measures were evaluated with the dimension $m = 3$ and time delay $\tau = 1$. Statistical analysis was performed by means of a two-sided Wilcoxon rank sum test.

Table 1. The The values of entropy measures for the patients in group A and B (mean ± std).

	SpEn	***ApEn***	***PermEn***	***FuzzyEn***
Group A (N=57)	0.103±0.065	0.169±0.104	1.551±0.185	0.035±0.026
Group B (N=129)	0.203±0.180	0.312±0.222	1.620±0.179	0.087±0.093
	p<0.0001	p<0.0001	p<0.01	p<0.001

For entropy measures significant decrease of values of *SpEn*, *ApEn*, *PermEn*, *FuzzyEn* ($p < 0.05$) was found in patients who gave premature birth before completed 7 days (Table 1). The results indicate that contractions are less complex in the preterm state than in the term state. Entropy measures can be useful for quantifying the dynamical changes of EMG signals.

The study confirmed differences in uterine contraction between patients delivering prematurely within 7 days and after from the EMG registration for all analyzed measures.

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Analysis of EHG signals in order to predict preterm labor using nonlinear dynamics methods

Sławomir Grycuk[1*], Iwona Gruszczyńska[1], Marta Borowska[1], Paweł Kuć[2], Piotr Laudański[2]
[1]Faculty of Mechanical Engineering, Bialystok University of Technology, Wiejska 45C, 15-351 Białystok, Poland
[2] Department of Perinatology, Medical University of Bialystok, M. Skłodowskiej-Curie 24A, 15-276 Białystok, Poland
Email of Corresponding Author: gslawe@gmail.com

Due to the development of new life, monitoring of pregnancy as well as labor should be a priority. Pregnancy in the first two trimesters requires the most attention because during this period the largest number of miscarriages occurs. After about 24 weeks of pregnancy, the baby has a chance to survive outside of the mother's body. By contrast, before this term comes to miscarriage. Therefore, registration of contractions may be a clinical procedure that becomes necessary in situations of fetal heart disease.
The aim of the study is to analyze EHG signals registered for women at risk of pregnancy who gave birth within 7 days or after 7 days using nonlinear dynamics methods. An analysis of uterine contractions for women in pregnancy between 24th and 28th weeks with single channel of EHG signals performed using the Recurrence Quantification Analysis (RQA) sliding window analysis and other nonlinear dynamics methods.

The material of this study consists of 20 uterine contractions extracted from EHG signals received from women at risk of pregnancy between 24th and 28th weeks of pregnancy. Women were divided into 2 groups: group A who gave birth within 7 days and group B after 7 days. The signals analyzed in this study were raw, that is without using any pre-processing. During research the signals were recorded from 8 channels distributed in 8 different muscles on the outside of the abdomen, but this work focuses on the analysis of the electrode 4, because at an early stage of pregnancy this particular electrode is placed on the stomach directly above the myometrium.

The values of RQA coefficients have been calculated using the CRP package applied by Marwan (Marwan et al. 2007). The time delay τ for the generated phase space was calculated using the method of mutual information and the embedding dimension m was obtained by the method of false nearest neighbors. Value of threshold ε is defined by the size of the area in which points are being searched for on the neighboring trajectories. The window analysis for RQA factors and the parameters of τ, m and ε were performed by shifting window containing 500 samples by the step equal to 250 samples along the signal. The entire procedure was repeated 7 times. In this way, the RQA coefficients and the parameters of τ and m allowed to evaluate changes in system dynamics over time. In Table 1 is shown averaged values of chosen RQA coefficient are shown such as: recurrence rate (RR), determinism (DIM), entropy (ENTR), laminarity (LAM), recurrence period density entropy (RPDE) for A and B group. These parameters have been selected to determine pregnancy welfare, each of all the variance of samples was divided by the mean. It was reported that values of RR, DIM, ENTR for each uterine contractions were higher for group A than group B, whereas values of LAM and RPDE for group B.

Table 1. Averaged RQA coefficient values such as: RR, DIM, ENTR, LAM, RPDE for A nad B group

RR		DIM		ENTR		LAM		RPDE	
in 7	After 7	in 7	After 7	in 7	After 7	in 7	After 7	in 7	After 7
0.0684	0.0807	0.7272	0.7799	3.0297	3.2083	0.5119	0.5403	0.3474	0.2576
±0.052	±0.076	±0.155	±0.200	±0.534	±0.655	±0.295	0±.331	±17.199	±16.647

Therefore, biomedical signals could be analyzed by a nonlinear dynamical process (Hassan et al. 2010) and due to the lack of similar studies using nonlinear dynamics methods to the early detection of preterm labor the RQA method is used in this work. The analysis carried out in this study allowed to observe differences in the dynamics of EHG signals between groups A (delivered after 7 days) and B (delivered within 7 days). This results indicates that EHG recording can be helpful in defining patients with preterm labor symptoms.

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Data acquisition and preprocessing software for high-density near-infrared spectroscopy device

Petro Guchek, Karolina Bejm , Piotr Sawosz, Adam Liebert
Nalecz Institute of Biocybernetics and Biomedical Engineering, Polish Academy of Sciences, Warsaw,
pguchek@ibib.waw.pl

Optical spectroscopy methods are widely used in medical practice for diagnostic purposes and occupy one of the leading positions next to X-ray, acoustic, nuclear magnetic resonance, radionuclide, endoscopic, etc. Light in near infrared wavelength range penetrates into biological tissue, interacts with various structural and dynamic components of tissues and carries information about tissue oxygenation changes. Nalecz Institute of Biocybernetics and Biomedical Engineering developed a high density diffuse optical tomography (HD-DOT) device capable of imaging of an adult human head [1, 2].
Aim of the study was to develop a software for optical data collection and preprocessing of the results of measurements. The software will also allow to diagnose the hardware problems and visualize the results obtained in real time.

To develop the proposed subsystem allowing for data acquisition from the HD-DOT device, methods of object-oriented programming, computer graphics and set theory were used. Microsoft Visual Studio and the C # programming language were used as a development environment tool. In order to integrate the developed application with the MATLAB system, for further stages of the data analysis, MATLAB Builder for .NET (MATLAB Compiler) was applied (Fig.1).

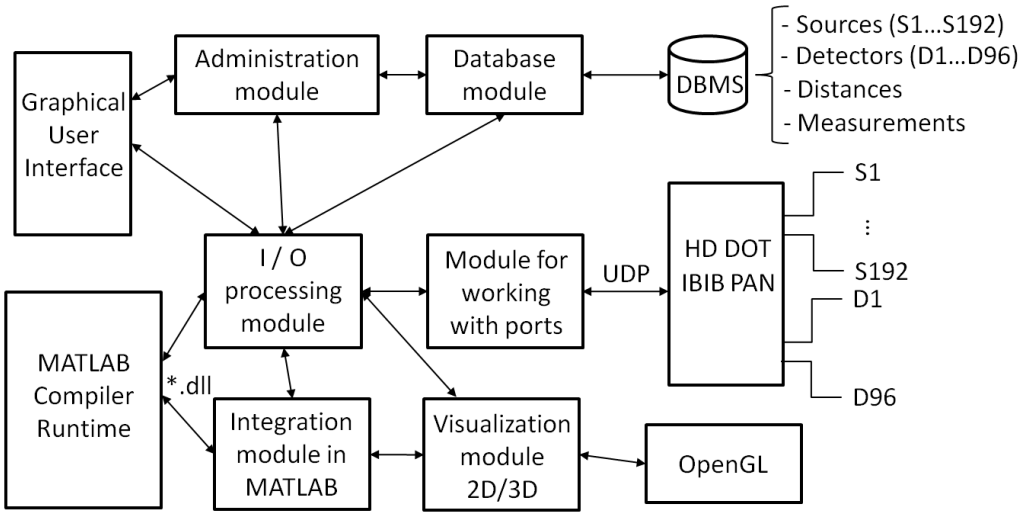

Fig. 1. Structure of the software controlling data acquisition from HD-DOT device (DBMS- *database management system*, UDP - *User Datagram Protocol*, I/O - *Input/Output*)

The developed software allows to (1) record the data provided by the HD-DOT device, (2) store the data in a database and (3) analyze the quality of the optical signal diffusely reflected from human tissues in real-time based on various geometric parameters for different sources and detectors grids. The quality of the optical signal is presented as SNR maps for combinations of all nearest and all second-nearest source-detector pairs. These maps visualize uncertainties related to poor optical coupling of light emitted from the source fiber bundles into the tissue as well as light reemitted from the tissue into the detecting fiber bundles. Real-time mapping allows for detection of optical signal issues during fixation of the optodes on the head.

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Wireless communication infrastructure for smarter medical monitoring

Szymczyk Piotr, Szymczyk Magdalena
AGH University of Science and Technology,
The Faculty of Electrical Engineering, Automatics, Computer Science and Biomedical Engineering,
Department of Automatics and Biomedical Engineering,
al. A. Mickiewicza 30, 30-059 Krakow, Poland
Piotr.Szymczyk@agh.edu.pl

1. Introduction

The fast-growing Internet of Things gives the opportunity to create cheap and universally available intelligent medical monitoring systems [3]. This will enable a significant expansion of the use areas of such services and their standardization in the near future. The main aim of this study is to present a proposal for such a system.

1.1. Current state-of-the-art

Currently, there are a number of incompatible communication protocols such as:

- ZigBee, RF4CE, MiWi, WirelessHart, SimpliciTI, TI-MAC, LoRa,
- 6LoWPAN, Thread (IP6 on IEEE 802.15.4),
- Blutooth, Bluetooth Smart, Blutooth 5.0,
- WiFi, LiFi (Light Fidelity),
- ANT/ANT+ and proprietary 2.4GHz protocols,
- GSM, LTE, Sigfox, LoRaWAN,
- Dedicated communication on free bandwidth ISM i SRD (169, 315, 433, 868, and 915 MHz).

Most manufacturer prefers their own solution, which, unfortunately, results in the lack of integration of communication and the creation of coherent systems.

2. Motivation

There is an urgent need to select and standardize communication technology in medical services, both technically and economically optimal.

3. Methods and concept

At the current stage of wireless communication, the most promising solution to the problem of wireless communication in smart medical monitoring systems is Bluetooth 5 technology in combination with WiFi. The structure of such an infrastructure is shown in the figure below:

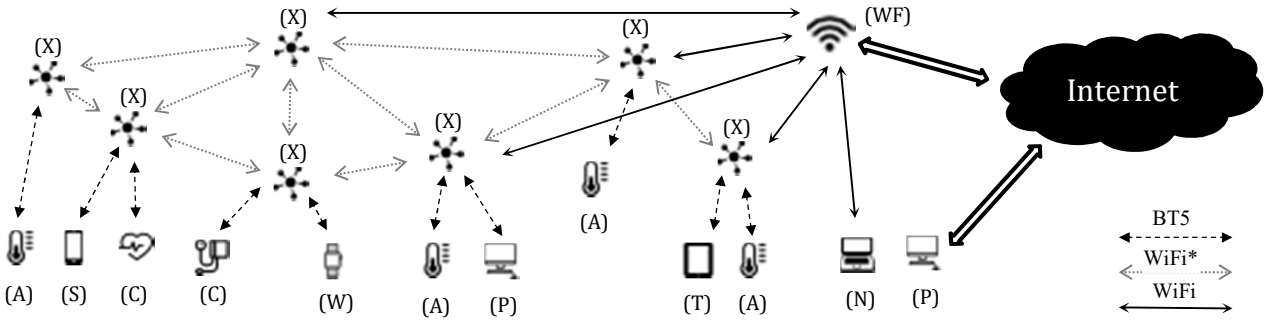

Figure 1. Wireless communication infrastructure for smarter medical monitoring

4. Results and conclusion

Communication between sensors located in the environment (A) or on the human (C) and the aggregation point (X) is carried out using Bluetooth 5 (BT5) and the communication between aggregation points (X) is done by modified WiFi with mesh routing (WiFi*). On the other hand, the communication between aggregation points (X) and WiFi access point (WF) is of course implemented by standard WiFi. The proposed and described solution is cheap and can be widely available in a short time. The nRF52840 (Advanced Multi-protocol System-on-Chip Supporting: Bluetooth Low Energy, Bluetooth 5) [1] and WiFi Module - ESP8266 [2] are used here. The smartwatch (W), smartphone (S), tablet (T), notebook (N), or PC (P) equipped with WiFi or Bluetooth 5.0 with the appropriate software can be used on the user's side. Such equipment is cheap and widely available and service is simple and well known.

Acknowledgment

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Innovative solutions in telecare - activity monitoring of the elderly - summary of the project

Paula Stępień, Zuzanna Miodońska, Michał Kręcichwost, Paweł Badura,
Piotr Zarychta, Marcin Rudzki, Jacek Kawa, Ewa Piętka
Department of Computer Science and Medical Equipment, Faculty of Biomedical Engineering,
Silesian University of Technology, Roosevelta 40 st., 41-800 Zabrze, Poland
Paula.Stepien@polsl.pl

Introduction

As a result of aging modern societies face specifc challenges. One of them is the necessity for elderly care. In order to prolong their well-being as well as lighten the duties of their relatives innovative solutions for telecare are required [1].

Aims

The project's aims were to provide innovative IT and constructional solutions in the field of medical telecare. Main aspects to be covered were: (1) to develop a device and algorithms for daily activity monitoring of the elderly staying within home environment that would allow measurement of features, whose change in various time periods indicate lowering one's condition, (2) to develop an apparatus providing safety features for outdoor use.

Methods

A measurement system composed of five 3-axial inertial sensors was developed. The sensors are to be placed on one's ankles, hips and back. Such placement permits, not only generic physical activity, yet also several gait features to be extracted and assessed. A large set of primary (acceleration, angular velocities, spectra, etc.) and secondary features (number of steps, stance and swing times and angles, etc.) have been proposed.
For the second part a GPS localizer with the possibility to perform voice calls and help requests was designed. Simple interaction using push-buttons makes it easy to use for almost everyone.

Results

The activity monitoring measurement system was tested in John Paul II Geriatric Hospital in Katowice as well as in residential home st. Elizabeth in Ruda Śląska. Both, the applicability of the system for supporting a typical geriatric tests like the Berg Balance Scale [2] as well as prolonged daily activity monitoring were tested [3]. In total over 100 patients were examined. Results show that the system fulfills its tasks, however several ergonomic improvements could be introduced.

Acqnowledgements

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The Accuracy of H&E Stain Unmixing Techniques when Estimating Relative Stain Concentrations

Paweł Kłeczek, Sylwia Mól, and Joanna Jaworek-Korjakowska

AGH University of Science and Technology, Department of Automatics and Biomedical Engineering
al. A. Mickiewicza 30, 30-059 Krakow

The hematoxylin and eosin stain (H&E stain) is one of the most popular, routine stain in histology. It allows to observe an overall cellular architecture of tissue and is more versatile than such stainings as immunohistochemistry. In this paper, we evaluate performance of state-of-the-art methods for stain unmixing in H&E-stained images. The aim of our study is to measure the degree of conformity of relative stain concentration maps obtained automatically to ground truth, to examine their robustness to variations in staining and illumination between images, and to assess their usefulness for routine usage.

Full text of this paper can be found at:

Paweł Kłeczek, Sylwia Mól, and Joanna Jaworek-Korjakowska, The Accuracy of H&E Stain Unmixing Techniques when Estimating Relative Stain Concentrations in: Augustyniak P., Maniewski R., Tadeusiewicz R. (eds.) *Recent Developments and Achievements in Biocybernetics and Biomedical Engineering, Proc. of. 20-th Polish Conference on Biocybernetics and Biomedical Engineering*, Springer International Publishing AG, Series: Advances in Intelligent Systems and Computing, 2017, pp. 89-99

The Analysis of the Shape of the Genetically Modified Human Skin Fibroblasts in Culture

Anna Korzynska[1], Lukasz Roszkowiak[1], Krzysztof Siemion[1,2], Jakub Zak[1], Karolina Zakrzewska[1,3], Anna Samluk[1], Agnieszka Wencel[1], Krzysztof Pluta[1], and Dorota Pijanowska[1]

[1] Nalecz Institute of Biocybernetics and Biomedical Engineering, Polish Academy of Sciences, Warsaw, Poland
[2] Department of Pathomorphology, Central Clinical Hospital of the Ministry of the Interior and Administration, Warsaw, Poland
[3] Institute of Fundamental Technological Research, Polish Academy of Sciences, Warsaw, Poland
akorzynska@ibib.waw.pl

The aim of this study is the comparison of the morphological parameters of the shape of various types of human dermal fibroblasts, cultured in Laboratory of Tissue Engineering. This investigation compares three groups of fibroblasts: control group and with two kinds of genetic modifications. Those are: fibroblasts isolated from human skin (control group), after transduction with lentivirus bearing EGFP fluorescent marker and transduction with lentivirus bearing DsRed2 fluorescent markers. The experimental sequences of images of a monitored cells' culture have been analyzed using image processing methods, such as image segmentation and morphological feature quantification of cells. The following features: area, perimeter, eccentricity, roundness, elongation ratio, length of the major axis, roundness and Hu and Zernike moments have been analyzed in two types of cells models: lamina model and wire model. It appears that the differences in eccentricity, roundness, elongation ratio between modified human skin fibroblasts and their reference culture are not statistically significant. However, the differences in the area, the length of the major axis and the length of perimeter between the control group of fibroblasts and both groups of transduced fibroblasts are statistically significant. The next feature - roundness of fibroblasts - presents statistically significant difference for both transduced groups and fibroblast control group. There is no statistically significant difference between fibroblasts transduced with EGFP marker and those transduced with DsRed2 marker. Genetically modified fibroblasts after extra gene transduction occupy bigger area and assume more elongated shapes. Their compactness is not affected and seems to be similar in all groups.

Full text of this paper can be found at:

Anna Korzynska, Lukasz Roszkowiak, Krzysztof Siemion, Jakub Zak, Karolina Zakrzewska, Anna Samluk, Agnieszka Wencel, Krzysztof Pluta, and Dorota Pijanowska, The Analysis of the Shape of the Genetically Modified Human Skin Fibroblasts in Culture in: Augustyniak P., Maniewski R., Tadeusiewicz R. (eds.) *Recent Developments and Achievements in Biocybernetics and Biomedical Engineering, Proc. of. 20-th Polish Conference on Biocybernetics and Biomedical Engineering*, Springer International Publishing AG, Series: Advances in Intelligent Systems and Computing, 2017, pp. 100-112

An Automatic Quantitative Evaluation of Ladder Pattern Presented in Intercellular Spaces in Histopathological Images of Reflux Disease Specimen Stained with Desmoglein-3 Antibody

Marek Wdowiak[1], Tomasz Markiewicz[1,2], and Szczepan Cierniak[2]

[1] Warsaw University of Technology, Warsaw, Poland,
[2] Military Institute of Medicine, Warsaw, Poland
marek.wdowiak@ee.pw.edu.pl

Following paper presents automatic method for quantitative evaluation of ladder pattern, which can appear in microscopic images of the esophageal epithelium tissue in a course of gastroesophageal reflux disease (GERD). Studies carried on the electron microscopy biopsy samples, have shown relation between dilated intercellular spaces (DIS) and treatment response. According to the studies, DIS can be classied as 'bubbles' and 'ladders'. Performing electron microscopy diagnosis generates high cost for hospitals, although immunohistochemistry (ihc) offers another cheaper possibility of DIS visualization. Using ihc technique causes problem with less noticeable, therefore harder to evaluate structures. This results in high interobserver verbality, and questionable manual evaluation. Aim of our paper was to design an algorithm, which would allow automated morphometric study of ladder patterns that were visualized by ihc staining techniques. For automatic intercellular binding detection, we designed context based method. Neighborhood mask is divided in two areas: foreground, which should contain line structures and background, where we should not find them. Detection of intercellular binding is done by evaluating location of pixel's collection in respect to mask's background and foreground. Intercellular binding has a shape of curved lines; therefore, mask areas have line characteristic as well. Identified structures were divided on the longest line segment possible, which ware evaluated using morphological covariance. As estimated distance value, we took distance between peaks seen on morphological covariance plot. Our proposed method could grade 77% of segments evaluated by expert with relevant mean squared error of 10%, therefore, showing possibility of automatic quantitative evaluation of ladder pattern.

Full text of this paper can be found at:

Marek Wdowiak, Tomasz Markiewicz, and Szczepan Cierniak, An Automatic Quantitative Evaluation of Ladder Pattern Presented in Intercellular Spaces in Histopathological Images of Reflux Disease Specimen Stained with Desmoglein-3 Antibody in: Augustyniak P., Maniewski R., Tadeusiewicz R. (eds.) *Recent Developments and Achievements in Biocybernetics and Biomedical Engineering, Proc. of. 20-th Polish Conference on Biocybernetics and Biomedical Engineering*, Springer International Publishing AG, Series: Advances in Intelligent Systems and Computing, 2017, pp. 113-123

Stroke Bricks - the Segments of Interests to Localize Early Stages of the Ischemia Evolution

Rafal Jozwiak[1], Ewa Sobieszczuk[2], Bogdan Ciszek[3], Piotr Wolski[1], Michal Szklarski[1], and Izabela Domitrz[2]

[1] Faculty of Mathematics and Information Science, Warsaw University of Technology,
Koszykowa 75, 00-662 Warsaw, Poland,
[2] Department of Neurology, Medical University of Warsaw,
Banacha 1a, 02-097 Warsaw, Poland
[3] Department of Descriptive and Clinical Anatomy, Centre of Biostructure Research,
Medical University of Warsaw,
Chalubinskiego 5, 02-004 Warsaw, Poland
R.Jozwiak@mini.pw.edu.pl

The purpose of neuroimaging in stroke diagnosis is to visualize early phases of brain ischemia evolution. Different forms of computerized support are often affected by the presence of many false overinterpretation areas, thus it is of great interest to provide neurologically verified regions in order to improve the accuracy of ischemia assessment. We propose Stroke Bricks (StBr) as an arbitrary spatial division of brain into the block of tissues associated with specific clinical symptoms of ischemic stroke. Neurological stroke decits are translated into respective areas of possible ischemia on the basis of arbitrarily proposed symptomsregions mapping rules. StBr concept may be useful for an integrated radiological CT-based assessment of suspected stroke cases or can be included into computer-aided tools to optimize the evaluation of stroke site and its extent.
The accuracy of StBr was presented on the basis of experimental simulation with real clinical data.

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Rafal Jozwiak, Ewa Sobieszczuk, Bogdan Ciszek, Izabela Domitrz, Piotr Wolski, and Michal Szklarski, Stroke Bricks - the Segments of Interests to Localize Early Stages of the Ischemia Evolution in: Augustyniak P., Maniewski R., Tadeusiewicz R. (eds.) *Recent Developments and Achievements in Biocybernetics and Biomedical Engineering, Proc. of. 20-th Polish Conference on Biocybernetics and Biomedical Engineering*, Springer International Publishing AG, Series: Advances in Intelligent Systems and Computing, 2017, pp. 124-134

Automatic detection of cells in FISH images using map of colors and three-track segmentation

Tomasz Les[1], Tomasz Markiewicz[1,2] and Janusz Patera[2]

1 Warsaw University of Technology, Warsaw, Poland
[2] Military Institute of Medicine, Warsaw, Poland
lest@ee.pw.edu.pl

The article presents a complex method of recognition nuclei cells areas and of segmentation of nuclei. The evaluation process of the identification and segmentation quality of proposed methods using L2 distance function and sensitivity function is also presented. FISH test is a fluorescence technique used for staining of microscope images of breast cancer. The technique allows visualization of HER2, CEN17 genes and cells nuclei. Fast and efficient microscopy image analysis allows a proper choice of therapy. This article presents a new, complex technique based on the color analysis, morphological transformations and watershed segmentation. The technique allows rapid and efficient identification of nuclei areas, as well as precise detection of the cells nuclei outlines. This step is often overlooked in a computer image analysis, whereas it is extremely important. It allows to increase the accuracy of HER2 / CEN17 gene detection, as well as it allows to exclude fake biomarkers and increase the speed of identification of algorithms for HER2 genes by limiting the searched area. Proper segmentation of nuclei also makes manual evaluation of images easier.

Full text of this paper can be found at:

Tomasz Les, Tomasz Markiewicz and Janusz Patera, Automatic detection of cells in FISH images using map of colors and three-track segmentation in: Augustyniak P., Maniewski R., Tadeusiewicz R. (eds.) *Recent Developments and Achievements in Biocybernetics and Biomedical Engineering, Proc. of. 20-th Polish Conference on Biocybernetics and Biomedical Engineering*, Springer International Publishing AG, Series: Advances in Intelligent Systems and Computing, 2017, pp. 135-144

Usage of ICP Algorithm for Initial Alignment in B-Splines FFD Image Registration in Breast Cancer Radiotherapy Planning

Marek Wodzinski[1], Andrzej Skalski[1], Piotr Kedzierawski[2], Tomasz Kuszewski[3], and Izabela Ciepiela[2]

[1] AGH University of Science and Technology, Department of Measurement and, Electronics
al. A. Mickiewicza 30, PL30059, Krakow.
[2] Hollycross Cancer Center, Department of Radiotherapy
Artwinskiego 3, PL25734, Kielce.
[3] Hollycross Cancer Center, Department of Medical Physics
Artwinskiego 3, PL25734, Kielce
{wodzinski, skalski}@agh.edu.pl

Estimation of a resected tumor lodge localization after a breast cancer surgery is a demanding task for the radiotherapy planning. The image registration techniques can be used to improve the radiotherapy. The initial alignment of two volumes is an important aspect of medical image registration procedure. We propose usage of the iterative closest point in two different scenarios: as a initial alignment, replacing intensity based rigid registration and as a initial transform to speed-up traditional rigid registration process. Two versions of the algorithm are presented: a point matching between bone structures and a line matching between volume edges. The correctness and usefulness are evaluated using: a target registration error, comparison of the computation time and convergence ratios, and visual inspection. The results demonstrate that the usage of iterative closest point algorithm significantly improve the initial alignment process in terms of the computation time.

Full text of this paper can be found at:

Marek Wodzinski, Andrzej Skalski, Piotr Kedzierawski, Tomasz Kuszewski, and Izabela Ciepiela, Usage of ICP Algorithm for Initial Alignment in B-Splines FFD Image Registration in Breast Cancer Radiotherapy Planning in: Augustyniak P., Maniewski R., Tadeusiewicz R. (eds.) *Recent Developments and Achievements in Biocybernetics and Biomedical Engineering, Proc. of. 20-th Polish Conference on Biocybernetics and Biomedical Engineering*, Springer International Publishing AG, Series: Advances in Intelligent Systems and Computing, 2017, pp. 147-156

Basic Concepts of 3D Morphological Spectra - Generation and Applications

Małgorzata Przytulska and Juliusz L. Kulikowski

Nalecz Institute of Biocybernetics and Biomedical Engineering, Polish Academy of Sciences
4 Ks. Trojdena Str., 02-109 Warsaw
{mprzytulska, jkulikowski}@ibib.waw.pl

Morphological spectra are a modified version of orthogonal systems of Walsh functions useful in discrete image analysis. Their application to 2D biomedical image analysis was described in several former papers. In this paper theoretical backgrounds of morphological spectra dened in any multi-dimensional discrete space and their application to 1-, 2- or 3-dimensional signal analysis are presented and illustrated by simple examples.

Full text of this paper can be found at:

Małgorzata Przytulska and Juliusz L. Kulikowski, Basic Concepts of 3D Morphological Spectra - Generation and Applications in: Augustyniak P., Maniewski R., Tadeusiewicz R. (eds.) *Recent Developments and Achievements in Biocybernetics and Biomedical Engineering, Proc. of. 20-th Polish Conference on Biocybernetics and Biomedical Engineering*, Springer International Publishing AG, Series: Advances in Intelligent Systems and Computing, 2017, pp. 157-167

Automatical Syndesmophyte Contour Extraction from Lateral C Spine Radiographs

Karolina Nurzynska[1], Adam Piórkowski[2], Marzena Bielecka[2], Rafal Obuchowicz[3], Grzegorz Taton[4], Joanna Sulicka[5], and Mariusz Korkosz[5]

Institute of Informatics
[1] Faculty of Automatic Control, Electronics and Computer Science, Silesian University of Technology
ul. Akademicka 16, 44-100 Gliwice, Poland
[2] AGH University of Science and Technology, Department of Geoinformatics
and Applied Computer Science
A. Mickiewicza 30 Av., 30-059 Cracow, Poland
[3] Department of Radiology, Jagiellonian University Collegium Medicum, Cracow, Poland
[4] Department of Biophysics, Chair of Physiology, Faculty of Medicine, Jagiellonian University Medical College, Cracow, Poland
[5] Department of Rheumatology and Balneology, Faculty of Medicine, Jagiellonian University Medical College, Cracow, Poland
Adam.Piorkowski@agh.edu.pl

This article describes the problem of segmentation of the spine for lateral C spine radiographs. In this case, the most frequently used approach is the Active Shape Model. The use of the Active Appearance Model is considered in this paper. Segmentation quality of sample data is tested for selected preprocessing and predetecting edge algorithms: Sobel filter, Canny edge detection algorithm, and Statistical Dominance Algorithm . The particularly important issue of precise description of contours is considered and partially tested. The aim is to deliver a good quality preliminary step to syntactic analysis of vertebrae using the generalized shape language.

Full text of this paper can be found at:

Karolina Nurzynska, Adam Piórkowski, Marzena Bielecka, Rafal Obuchowicz, Grzegorz Taton, Joanna Sulicka, and Mariusz Korkosz, Automatical Syndesmophyte Contour Extraction from Lateral C Spine Radiographs in: Augustyniak P., Maniewski R., Tadeusiewicz R. (eds.) *Recent Developments and Achievements in Biocybernetics and Biomedical Engineering, Proc. of. 20-th Polish Conference on Biocybernetics and Biomedical Engineering*, Springer International Publishing AG, Series: Advances in Intelligent Systems and Computing, 2017, pp. 168-178

Detection and classification of pigment network in dermoscopic color images as one of the 7-point checklist criteria

Joanna Jaworek-Korjakowska, Paweł Kłeczek and Ryszard Tadeusiewicz

AGH University of Science and Technology, Cracow, Poland
{jaworek,kleczek,rtad}@agh.edu.pl

Malignant melanoma, which is a dangerous proliferation of melanocytes, is commonly diagnosed in all people, regardless of age, gender, or race. In the last several years an increasing melanoma incidence and mortality rate has been observed worldwide and it is rising faster than other forms of cancer. In this paper we present a new approach to the detection and classification of pigment network, one of the major feature in a widely used diagnostic algorithm 7-point checklist. Accurate assessment of pigment network is clinically important due to a significantly different occurrence in benign and malignant skin lesions. We describe a complex algorithm containing following steps: image enhancement, lesion segmentation, pigment network detection as well as classification. The algorithm has been tested on 300 dermoscopic images and achieved 91% sensitivity and classification accuracy of 85%. Compared to state-of-the-art, we obtain improved classification accuracy.

Full text of this paper can be found at:

Joanna Jaworek-Korjakowska, Paweł Kłeczek and Ryszard Tadeusiewicz, Detection and classification of pigment network in dermoscopic color images as one of the 7-point checklist criteria in: Augustyniak P., Maniewski R., Tadeusiewicz R. (eds.) *Recent Developments and Achievements in Biocybernetics and Biomedical Engineering, Proc. of. 20-th Polish Conference on Biocybernetics and Biomedical Engineering*, Springer International Publishing AG, Series: Advances in Intelligent Systems and Computing, 2017, pp. 179-186

Functional endoscopic sinus surgery with Head Mounted Display and video analysis

Jaromir Przybylo[1], Paweł Dobosz[2]

[1] AGH University of Science and Technology, Faculty of Electrical Engineering Automatics, Computer Science and Biomedical Engineering
Al. Mickiewicza 30, 30-059 Krakow, Poland,
[2] Department of Otolaryngology, Head and Neck Surgery, 5th Military Hospital with Polyclinic, Wroclawska 1-3, 30-901 Krakow, Poland,
przybylo@agh.edu.pl,

Endoscopic sinus surgery (FESS) is the primary approach used today for the surgical treatment of many pathologies localized in the nasal cavity, paranasal sinuses, and, in select cases, in the base of the skull. Most surgeons currently prefer to operate using the video monitor rather than an eyepiece endoscope. Although video monitors have greatly enhanced surgical endoscopy by sharing the operation eld view with nurses and anesthesiologists, video monitors require the operating surgeon to be focused on the screen instead of on the patient. In this article, the use of the Head-Mounted Display (HMD) is examined in functional endoscopic sinus surgery. The integration of imaging information from various sources (i.e. endoscope camera, CT scans) digitally is proposed using an image processing pipeline. The crucial requirement for the construction of a vision system is to ensure minimum video signal latency between the source and the display (HMD). Therefore, effects of various delays were examined during simulated surgical tasks. Also, an eye-tracking-based approach was used to quantitatively assess the time that the surgeon spent focusing on the screen versus observing the patient.

Full text of this paper can be found at:

Jaromir Przybylo, Paweł Dobosz, Functional endoscopic sinus surgery with Head Mounted Display and video analysis in: Augustyniak P., Maniewski R., Tadeusiewicz R. (eds.) *Recent Developments and Achievements in Biocybernetics and Biomedical Engineering, Proc. of. 20-th Polish Conference on Biocybernetics and Biomedical Engineering*, Springer International Publishing AG, Series: Advances in Intelligent Systems and Computing, 2017, pp. 187-197

Glottocorrelographic Visualization of Normal and Pathological Vocal Folds Oscillations from Videolaryngostroboscopic Images

Bartosz Kopczynski[1], Pawel Strumillo[1], and Ewa Niebudek-Bogusz[2]

[1] Institute of Electronics, Lodz University of Technology, Poland,
[2] Department of Audiology and Phoniatrics, the Nofer Institute of Occupational Medicine, Lodz, Poland

Videostroboscopy is a common technique used by phoniatricians for diagnosing vocal folds status by imaging their oscillations. Implementation of image processing methods allows to extract qualitative description and quantitative indices. Such an analysis approach allows to detect glottal pathological changes and monitor the voice quality. Presented analysis of the videostroboscopic sequences were carried for 12 individuals i.e. 6 patients with diagnosed vocal nodules and 6 normophonic individuals classified as a control group. Image pre-processing and image segmentation algorithms were applied to compute the glottal area waveform (GAW) and the glottovibragram during phonation and to build a novel representation of vocal folds oscillations which we called the glottocorrelogram. The obtained results confirm that computer analysis and new representations of the phonation process of the glottis can aid the phoniatricians in diagnosis of voice disorders.

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Bartosz Kopczynski, Pawel Strumillo, and Ewa Niebudek-Bogusz, Glottocorrelographic Visualization of Normal and Pathological Vocal Folds Oscillations from Videolaryngostroboscopic Images in: Augustyniak P., Maniewski R., Tadeusiewicz R. (eds.) *Recent Developments and Achievements in Biocybernetics and Biomedical Engineering, Proc. of. 20-th Polish Conference on Biocybernetics and Biomedical Engineering*, Springer International Publishing AG, Series: Advances in Intelligent Systems and Computing, 2017, pp. 198-208

PYRAMID METHODS IN ANALYSIS OF THE AORTA IMAGES

Ewelina Sobotnicka, Aleksander Sobotnicki, Dawid Roj, Janusz Jeżewski
Institute of Medical Technology and Equipment ITAM Zabrze
118 Roosevelt St., 41-800 Zabrze, Poland
ewelina.sobotnicka@itam.zabrze.pl

The motivation to perform the research was the fact that analysis of biomedical images in one scale only, may cause loss of information contained in the image. The solution is to analyse the image in all scales simultaneously, which is possible through the use of a spatial pyramid representation. Thanks to this method, the obtained images are at different levels of details, including all the relevant information. Image pyramids create hierarchical structure with decreasing or increasing size and geometric resolution. The pyramid can be interpreted as a multi-level smoothing filter, when the unnecessary pieces of information included in the image are gradually eliminated, leaving the most significant objects and structures on the highest level of the pyramid [1]. The current state-of-art in this domain describes the pyramid method as a form of processing which is used for natural scene image analysis [2][3] but not for aorta image, so the authors decided to test the spatial pyramid representation in aorta image processing. During the biomedical images processing (e.g. depicting the aorta structure) attention should be paid to the specific areas, which should be properly detected, with contours correctly outlined.

The experiments were performed in several stages. In the first phase, database of the aorta images was prepared. In the second phase, spatial pyramid representation of the aorta images was determined. The image processing based on a spatial pyramid representation, relied on expansion and reducing scale of the aorta image. The processed images were subjected to segmentation. Additionally, to validate correctness of the segmentation with pyramid method, the Dice coefficient was used. Original authors' solution used in the experiments was the fusion pyramid method with gradient and polynomial approximation for aorta image segmentation. The main aim of the experiment, was to extract the aorta structure from the analysed images, with clearly marked outlines of its occurrence and depicting aortic aneurysms with pathological changes.

Pyramid expansion and reduction method was used for all the 20 different aorta images and the obtained results were similar for each methods. Images on the higher levels of pyramid have a better quality. The structures on the image are smoothed and details are more visible. Thanks to that preliminary treatment, it is possible to get satisfactory results during extracting the aorta structure from the images. We were able to extract the structure of aorta from the background by using three levels of the Gaussian pyramid together with the gradient and polynomial approximation. The pyramid method with segmentation delivered precise outlines of the structures in the images presented in Fig. 1.

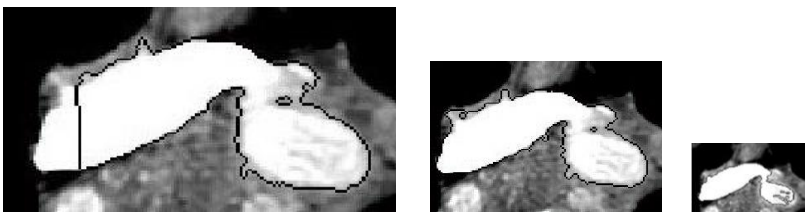

Fig. 1 Results of segmentation – the three images obtained at each level of the pyramid.

Thanks to the pyramid method, the images at different levels of detail including the relevant information are obtained (in a computationally efficient way). In addition, combining pyramid method with the segmentation gives more opportunities for extracting the specific structure of aorta from analysed image, without losing of important information. The developed implementation algorithm of the proposed method may be applied to the illustration of hardly visible pathological changes in the images of the aorta.

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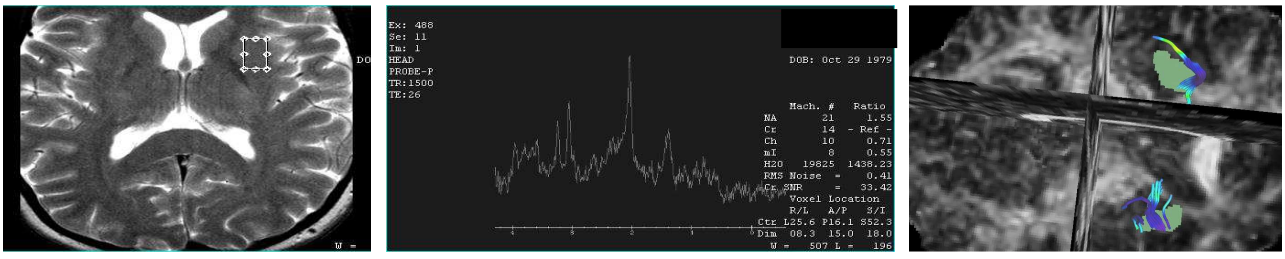
MRS and tractography brain studies in Parkinson's disease – preliminary study

Hanna Goszczyńska[1], Beata Toczyłowska[1], Małgorzata Michałowska[2], Paweł Senator[1], Urszula Fiszer[2]
1. Nalecz Institute of Biocybernetics and Biomedical Engineering Polish Academy of Sciences, Ks. Trojdena 4, 02-109 Warsaw
2. Centre of Postgraduate Medical Education, Marymoncka 99/103, 01-813 Warszawa
hgoszczynska@ibib.waw.pl

Aim: The aim of this study is to investigate *in vivo* patients with Parkinson's Disease and control group - healthy volunteers for evaluation of nerve fibers structure and amino acid concentration using MR tractography and proton spectroscopy studies (MRS). The main goal is to investigate correlation between neurotransmitters observed in MRS and nerve fiber tracts measured in tractography of selected movement brain area (putamen) [1,2]. The work presents the pilot study for examination procedures preparation.

Method: Investigations have been carried out to prepare protocols for proton spectroscopy using single-channel coil with 512 repetition and TE = 26 ms and tractography with 25 direction. Spectroscopy will be performed from one area corresponding to the occurrence of motion area (putamen), with a linewidth of water signal at half-high of approximately 7Hz. Parameters are selected for the proton spectrum from the examined tissue area with a focus on signaling from stimulatory neurotransmitters, ie, glutamine and glutamate (quantitative study of glutamine and glutamate in the putamen against creatine). Analysis of diffusion tensor and its scalar parameters in selected areas will take place after completion of the study, in "postprocessing". This will allow the evaluation of single-hemispheric and inter-hemispheric nerve fibers and their connections.

Results: Pilot studies on healthy volunteers were performed to prepare the protocol for patient examinations. All studies were performed on 3T MRI scanner (Discovery MR750w 3.0T, GE, USA) being the equipment of CNSLab in Nalecz Institute of Biocybernetics and Biomedical Engineering. Postprocessing for diffusion studies were performed using 3D Slicer software which also was used to calculated scalar parameters as ADC (*Apparent Diffusion Coefficient*), MD (*Mean Diffusivity*), FA (*Fractional Anisotropy*), AD (*Axial Diffusivity*) and RD (*Radial Diffusivity*). Below were presented typical control subject images for spectroscopy (scanner software) and tractography for putamen region of interest (Fig. 1a,c) (3D Slicer software).



a b c

Fig. 1

Conclusion: This work was orientated for preparing protocol for Parkinson's Disease patient examinations. Our goal is to find correlations between biochemical changes (primarily Glu and Gln Fig. 1 b) and diffusion tractography parameters (ADC, MD, FA, AD, RD of tracts, Fig. 1c) in diffusion examinations and that should help us explaining the movement disorders.

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Multimodal system for visualisation and monitoring of chronic skin wounds

Jan Juszczyk, Marcin Rudzki, Michał Kręcichwost, Dominik Spinczyk,
Bartłomiej Pyciński, Joanna Czajkowska, Ewa Piętka
Department of Computer Science and Medical Equipment, Faculty of Biomedical Engineering,
Silesian University of Technology, ul. Roosevelta 40, 41-800 Zabrze, Poland
jan.juszczyk@polsl.pl

Introduction

Chronic wounds result mostly from diseases of civilization: diabetes mellitus, atherosclerosis and cancer. The prognoses show that occurrence of chronic wounds in the coming years is going to increase, mainly because of the upward trend of mentioned diseases' morbidity. Therefore, there is a need for the development of new procedures which may decrease frequency of severe chronic wound side-effects. Robust and effective monitoring of wound healing will result in future financial benefits due to lowering treatment and hospitalization costs as well as by lowering the absence time caused by inability to perform vocational duties.

Aims

Aim of a new project is to develop a methodology for comprehensive monitoring of chronic wound healing. Various imaging modalities (i.e. photography, stereoscopy, infra-red imaging, high frequency ultrasonography) are to be utilized in order to develop a 3D computer model of the wound. Such a model should: present thermo map with respect to wound spatial location by the use of colour photography (VIS) and thermography (IR), present depth of the wound by the use of HF ultrasound, enable wound healing monitoring by a specialized data visualization system and a selection of features that quantify the wound description.

Methods

Four main tasks are to be carried during the project:

1. Multimodal image acquisition – is devoted to the development of a method for image acquisition from aforementioned imaging modalities that would be clinically applicable and ergonomic – especially the design of a measurement stand (cameras holder) and acquisition protocols is of main importance;
2. Multimodal image fusion technique – is devoted to the development of methods for image registration and fusion into one common 3D coordinate system, as a result a 3D wound model is to be obtained;
3. Chronic wound monitoring – is devoted to finding relationships and similarities between wound regions in images acquired repeatedly during convalescence in order to select distinctive features that would quantify the healing process;
4. Visualization system and clinical verification method – is devoted to the design of a computer aided diagnosis software that is to be tested in a clinical environment.

Preliminary Results

The acquisition setup for IR-VIS images recording has been assembled and tested. The calibration phantom for IR-VIS fusion has been constructed. Accuracy of IR-VIS fusion is 12px for 320x240 IR image raster for 1 meter acquisition distance. The 3D skin surface reconstruction by using Time-of-Flight camera has been tested. The accuracy of skin surface reconstruction in the direction of the ToF camera optical axis is 2mm for registration of perpendicular surface and decreases for oblique surfaces.

Conclusions

The accuracy of IR-VIS fusion depends on IR image quality primarily. The 3D skin surface quality depends strongly on angle of registered surface. This suggests that the measurements should be carried out from two different positions at least or stereography should be used and two models should be merged.

Acknowledgements

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Statistical approach to the 3D spiral computed tomography with reduced dose absorbed by patients during examinations

Robert Cierniak
Institute of Computational Intelligence, Czestochowa University of Technology
robert.cierniak@iisi.pcz.pl

It has been shown in literature that the number of cancerous diseases for patients who had had a CT scan is 24% higher than in the case of patients who had not had the CT examination. For this reason, manufacturers of CT began a challenge to develop methods of reducing the X-ray dose absorbed by patients without decreasing the quality of the CT images. It is possible to improve the resistance of tomographic images to the measurement noise by using statistical signal processing. This means that it is possible to decrease the radiation intensity applied, and so decrease the dose absorbed by patients. Recently, some commercial solutions of statistical systems are developed, e.g. the most interesting approach called MBIR (Model-Based Iterative Reconstruction) [1]. There a statistical model of the measurement signals is derived, and an iterative reconstruction algorithm is formulated. This algebraic method, however, has some significant drawbacks, namely: the difficulty in establishing the coefficients of the forward model for 3D spiral cone-beam scanners, the huge number of coefficients in the model, and an extremely complex reconstruction problem. Moreover, this system uses a reconstruction problem model that has been shown to be extremely ill-conditioned.

We can avoid those drawbacks by using an analytical strategy for the image processing. I have shown previously how to formulate the analytical reconstruction problem for scanners with parallel geometry [2], and next I have proposed a scheme of reconstruction method for the helical cone-beam scanners. My approach has some fundamental advantages compared with algebraic methodology. Firstly, we can perform the reconstruction process in only one plane in 2D space. Secondly, because of the analytical methodology, we can perform most of the computationally expensive operations in the frequency domain, and we make our reconstruction method practically independent of the dimensions of the reconstructed image. Because the basic methodology is very strongly associated with the parallel geometry of X-ray beams, we preferred to choose an appropriate signal processing strategy among reconstruction algorithms which rely on rebinning, i.e. ASSR (Advanced Single Slice Rebinning) algorithm [3].

During experiments, there were used projections obtained on the commercial CT scanner (Somatom Definition AS+, Siemens Healthcare, *flying focal spot* technique**,** 100 kVp and effective 200 mAs, 70s after iodinated contrast injection). Results of these experiments are depicted in the figure below.

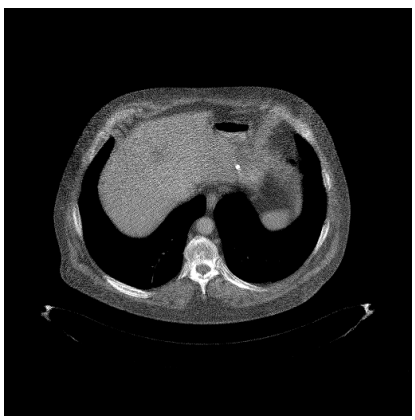
A)  B) 

Figure. A) image reconstructed using a traditional filtration/back-projection algorithm, i.e. the ASSR; B) image reconstructed using the method proposed here, which is based on the analytical statistical formulation of the reconstruction problem and on the ASSR method.

Presented here approach overperforms the algebraic method regarding the better condition number at the level of problem formulation. In this way, my method is more competitive in terms of its resistance to the influence of noise, and it opens up a new perspective for the regularization of the reconstruction problem. The main motivation for this paper is to present a feasible approach to 3D helical tomographic scanners based on the analytical statistical reconstruction method.

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Automatic segmentation of lung cancer cells with the new parameters by using methods of image processing and analysis.

Przemysław Jedrusik[1], Robert Koprowski[1], Ilona Bednarek[2], and Zygmunt Wróbel[1]
1) Dep. of Comp. Biomedical Systems, University of Silesia, ul. Bedzinska 39, Sosnowiec,
2) Dep. of Biotech. and Genetic Eng., Medical University of Silesia, ul. Jedności 8, Sosnowiec, Poland
Email: pjedrusik@o2.pl

This work focused on the development of an algorithm for automatically determining the correct number of lung cancer cells. According to the World Health Organization, lung cancer is the leading cause of cancer death among men and the second of women in the world [2]. The proposed solution is an extension of cell segmentation based on their structure and mutual location. Physical features of the objects were selected, which allowed for proper selection of methods and their parameters of image analysis and processing. The developed tool was able to detect significantly larger cells, determining whether these large cells were a combination of smaller objects, taking into account in addition the level of stretching of objects. In addition, the relative position of the cells, the distance between them, was an important parameter. All these properties have allowed to correct the operation of the algorithm for the best cell segmentation. Previously known articles do not mention the analysis of these individual characteristics for cells segmentation using image processing and analysis methods. The developed algorithm was written using Matlab software.

The study of this work is based on microscopic analysis of medical images A549 lung cancer cells. Cells were visualized under inverted microscope (OLYMPUS BX-60 microscope with DP50 digital camera). The images were saved as a bitmap files with a resolution of 2080x1540 pixels. We were registered 160 different images. Pixel of acquired images was dimension of approximately 10 nanometers in real. The algorithm presented in the paper has been divided into three sub-stages. The first stage included the preparation of input images for binarization. Median filter was used to eliminate artifacts, with a window size of 19x19 pixels[1]. Size of the filter was matched to the size of artifacts. Adaptive binarization and morfological operations: erosion, dilation (structuring element size selected for non matching objects) were a next stage of the algorithm. This paper uses the Sauvola's method of binarization, based on the standard deviation and average value of the pixel at a specified point, with a positive parameter *k* to modular according the analyzed image[3]. Third stage, according to the proposed algorithm, for each of cells were determined following parameters: surface area, the center of gravity, major and minor diagonals. The main loop is repeated until you receive cells of a size that is consistent with the characteristic of biological cells is their growth and division. Therefore finally detected cells had a surface area in the range from half of average of all cells size to 2.5 times of av. of all cells size.

Received data has been partially shown in table bellow. Analyzed table containing the results, it was shown that the selected parameter k is associated with an average size of objects and with the size of the maximum detected object in the image. With the reduction of the average size of the cell area, also decreases the surface area of the maximum field. The shape of the objects was stretched slightly, the ratio of the diagonals was less than 2. It was also observed the close relationship between the detection of a valid objects, and the average distance between them. The distance between the cells was significantly higher than the average cell size, there were blank areas between cells.

no.	k	cells	av. area [px]	max cell area [px]	av. distance [px]	major/minor axis
1	0.32	264	662	658	924	1.67
2	0.36	152	685	677	1026	1.88

The proposed algorithm allows the automatic selection of parameter k in the Sauvola's method of binarization. Therefore it is possible to perform fully automated segmentation of images with additional parameters. The parameters clearly define the appearance of objects obtained and their distribution of the image. All objects of a size significantly different from the average were eliminated. Proposed tool to assist assessment of the behavior of tumor cells can be widely applied not only to lung cancer cells, but also to any other cell line. It allows automatically examine cell confluence, which is a very important determinant in cells behavior analysis.

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The method based on Navier-Lame equation for distortion correction

Paweł Bzowski[1,2], Rafał Panek[3,4], Maria Schmidt[3], Damian Borys[1,2]
[1]*Institute of Automatic Control, Silesian University of Technology, Akademicka 16, 44-100 Gliwice, Poland*
[2]*Biotechnology Centre, Silesian University of Technology, Krzywoustego 8, 44-100 Gliwice, Poland*
[3]*Institute of Cancer Research, 15 Cotswold Road, SM2 5NG, London, United Kingdom* [4]*Nottingham University Hospitals,Darby Road, NG7 2UH, Nottingham, United Kingdom*
Email: pawel.bzowski@polsl.pl

Medical imagining technique, such as magnetic resonance imagining (MRI) and computed tomography (CT) are commonly used in diagnostic medicine. These techniques are able to detect and diagnose different pathologies. Both techniques are complementary and the MRI-CT co-registration is often performed. One of the MRI technique limitations is possibility of geometrical distortion, which is not present in CT. This deformation is usually caused by magnetic field inhomogeneity often observed in the case of large field of view studies or presence of metallic implants. As a result obtained images can be deformed leading to a significant miss match between the two modalities. Mathematical algorithms like rigid and non-rigid algorithms could correct these deformations.

The main aim of this work was to implement an algorithm consisting of rigid and non-rigid registration methods. The algorithm was implemented in MATLAB 2015b (MathWorks, Natick, MA). In this method we used affine transformations with mutual information for rigid co-registration [1], and Navier-Lame equation with mutual information with sum of squared difference as a force value [2,3]. After the registration process the results were compared with study image. We used mutual information as a quality measure. In this work we used two test objects: "Lego" and "Ice" phantoms and medical MRI and CT images. The data sets were acquired with 3T MRI scanner (Philips Achieva, Philips Medical Systems, Best, Netherlands) and CT (General Electric).

As a result we obtained rigid and non-rigid transformations of phantom and medical images. Rigid method was required for initial processing, but remaining inaccuracies were present, especially in the off center areas. . Processing time for pair of 128x128x30 data sets was approximately 20 minutes (Intel i7, 4 cores, 8 threads, 16 GB RAM). All images (study, template, after rigid transformation and after non-rigid transformation) were compared. An increased match between the result distortion corrected MRI and CT images was observed, which was also consistent with obtained MI values. Sometimes the rigid transformation had some problems with found the correct position, because the algorithm stopped in local minimum. In this case the changing initial values for rigid transformation were necessary.

Implemented algorithm provided good results for mono-modal and multi-modal image sets. Using mathematical transformations the final image fusion can be much more accurate. The proposed method can be relatively easily implemented in a routine medical practice and has potential to enable reliable fusion of distorted clinical images.

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Volume estimation of normal and pathological brain structures

Antonina Młynarczyk-Kochanowska[1], Michał Strzelecki[1], Ernest Jan Bobeff[2], Dariusz Jan Jaskólski[2]
[2]Medical Electronics Division, Institute of Electronics, Technical University of Lodz,
211/215 Wolczanska St., Lodz 90-924, Poland
[2]Department of Neurosurgery and Neuro-oncology, Medical University of Lodz,
Norbert Barlicki Memorial Teaching Hospital No. 1, Kopcinskiego St. 22, Lodz 90-153, Poland
Email of corresponding author: antonina.mlynarczyk@gmail.com

This work is aimed at development of a software tool useful for neurosurgeons. The idea emerged in a group of clinicians investigating various methods of analysis of brain pathologies on computed tomography (CT) scans. Most software tools described in the literature are dedicated for data acquired by the magnetic resonance imaging (MRI). On the other hand, the former imaging technique is less expensive and faster, moreover it is a daily routine in diagnosis of neurological patients. Thus, it is reasonable to develop an image processing tool for CT data as well. It will be mostly used to distinguish between normal and pathological brain structures and provide physicians their volumetric data. Such quantitative information will significantly improve diagnosis and treatment of acute brain pathologies.

Spiral Computed Tomography technique was applied during examination on SIEMENS Somatom CT Sensation, syngo CT 2006A. Greyscale images of 512x512 pixels of patients having intracranial hemorrhages were investigated using MATLAB software. Slice thickness was equal to 1.0 mm while mean pixel size was 0.44x0.44 mm. After image acquisition, the following image processing steps were taken. First, every slice of the image data was segmented to distinguish the brain structure from the skull. Next, based on Hounsfield Units (HU) it was possible to separate cerebrospinal fluid (CSF), brain matter and hemorrhage. Finally, the morphological erosion and dilation were applied to remove unnecessary structures [3]. Finally, the calculation of structures was performed. Each image processing step was evaluated by an expert to verify how accurate brain structures were segmented.

As a result, it was possible to separate abovementioned brain structures and calculate their volume. Calculations were based on the number of pixels obtained during segmentation of selected region in each slice, pixel dimensions, and slice thickness. Sample analyzed CT slice and extracted regions are presented in Figure 1. Images (b, d, f) show raw segmentation results, while (c, e, g) – segmentation refined by morphological operations.

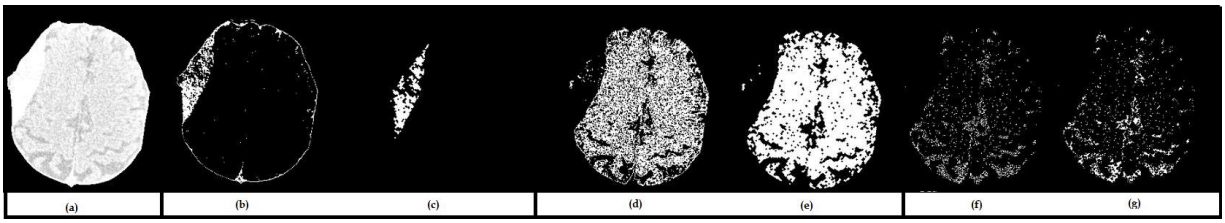

Figure 1. Sample analyzed CT slice (a). Segmentation of brain structures along with morphological refinement: haemorrhage (b, c), brain matter (d, e), and CSF (f, g).

Best results of the above analysis were obtained where segmentation was followed by morphological operations. Histogram analysis and application of the Hounsfield unit scale allowed clear separation of intracranial constituents, therefore it was possible to expose differentiated structures and estimate their volumes. Obtained results demonstrate that computer-assisted volumetric analysis of both normal and pathological brain structures on CT scans is possible. However, an expert evaluation remains extremely significant. Future research will be focused on investigation of more sophisticated segmentation methods as well as extension of analyzed image database.

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Variables in the pattern of the personnel exposure to electromagnetic field in magnetic resonance imaging facilities (0.1-7 T) in the context of workplace legislation

Jolanta Karpowicz, Krzysztof Gryz
Central Institute for Labour Protection – National Research Institute (CIOP-PIB)
Czerniakowska 16, 00-701 Warszawa, Poland
Corresponding Author: Jolanta Karpowicz, jokar@ciop.pl

The magnetic resonance imaging (MRI) medical diagnostic technique involves the use of strong or ultra strong static magnetic field (SMF), intermediate frequency magnetic field (so-called gradient field (IF)) and radiofrequency radiation (RR) sources, delivering patient's exposure. All fields are present also around the MRI scanner in the diagnostic room affecting workers, especially SMF emitted continuously (24 hours per day) by superconducting or permanent magnets. The level of SMF applied to patients is also the key parameter for the diagnostic power of the scanner. Over 25 years a significant development of MRI use in Poland (from several low field MRI scanners – $B \leq 0.5T$ – up to significantly more than 200 MRI scanners of various diagnostic power – (0.1-7) T magnets) was assisted by studies focused on the electromagnetic field (EMF) exposure in the MRI centres, which have been continuously worked out by Laboratory of Electromagnetic Hazards of CIOP-PIB [1-3]. The research methods involved were also developed over the years in parallel with rising understanding of the health and safety hazards linked with EMF exposures caused by MRI scanners, technical progress in the EMF environmental research and progress in the guidelines and legislations on the workers' exposure limitations. Up today a variety of physiological effects were observed during exposure to an inhomogeneous SMF near MRI scanners (such as: phosphenes, vertigo, loss of balance). They may disturb the work performance, or even cause fall down accidents. Health hazards caused by a variety of biochemical effects of SMF influence are still not clear. The acute effects of exposure to IF and RR are well established (electrostimulation in tissues and thermal load). However the effects of combined exposure to various fields are still not clear. The studies on workers' exposure near MRI scanners belong to the current research priorities in EMF, and have significant role in the epidemiological studies and in application of the labour legislation in practice, especially in the field of derogation set out by European directive 2013/35/EU which allows almost unlimited SMF exposure, but under well defined restrictions.

Based on the current understanding of the nature of health and safety hazards, a variety of parameters characterising the static and dynamic influence of SMF, such as B-field level and spatial distribution, spatial gradients (e.g. dB/dx), as well as dynamic changes of exposure caused by body movements (dB/dt) were used to evaluate patterns of workers' exposure to the SMF, as well as electric and magnetic field strength distribution of IF and RR. Statistical analysis were used to find what parameters of exposure scenarios influence the exposure level of various groups of workers (radiographers, nurses, cleaners, engineers, ...). The main variables were analysed, such as: diagnostic power of the scanner, scanner and diagnostic room design, task performed by workers.

We found significant variability in the exposure pattern in tasks performed in the strongest SMF. Analysing exposure in particular tasks we found cases highly dependent on the scanner design. Obtained results suggest the potential to reduce workers' exposure by ergonomic and organisational interventions.

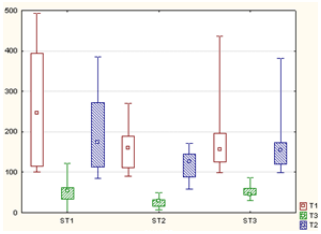

Fig. 1. The example of the variability of the static magnetic field exposure during performance of three different tasks (T1-T3), when the MRI scanners (ST1-ST3) are of equal diagnostic power (1.5T magnets) but of various designs (ergonomic properties).

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Serum metabolomics in Parkinson's disease

Beata Toczyłowska[1,2], Małgorzata Chalimoniuk[3], Małgorzata Michałowska[4], Paweł Senator[1], Urszula Fiszer[4]
1. Nalecz Institute of Biocybernetics and Biomedical Engineering, PAS
2. Institute of Biochemistry and Biophysics, PAS
3. Mossakowski Medical Research Centre, PAS
4. Centre of Postgraduate Medical Education
beata.toczylowska@ibib.waw.pl

Aims
We hypothesized that Parkinson's disease (PD) causes changes in serum metabolite profile of hydrophilic and hydrophobic compound, which would allow us to differentiate control subjects from PD patients.

Method
To test this hypothesis, 5 healthy subjects and 6 PD patients were used to observe metabolite profile in serum and lipid extract using NMR spectroscopy. Lipid extracts were obtained using modified Bligh and Dyer method. Spectra were collected with Inova 400 NMR spectrometer using CPMG pulse sequence (serum) and one pulse sequence (lipid extract). Spectra were analyzed using our own application and the obtained data were analyzed statistically using SIMCA software.

Results
We analyzed 27 NMR signals from the serum. OPLS-DA analysis was performed using Pareto scaling to generate a model. The model consisted of two components one predictive and one orthogonal. This model allowed us to distinguish between the groups of PD patients and control subjects (Fig.1A). The predictive component of the model showed the differences between the groups while the orthogonal component within the groups. The model explained 85% and predicted 75% of the data. The most important metabolite signals differentiating the groups are lipid signals at 1.28 ppm and 0.9 ppm and the signal from the N-acetyl compounds at 2.02 ppm. All patients and healthy subjects were correctly classified to their corresponding groups.

A B

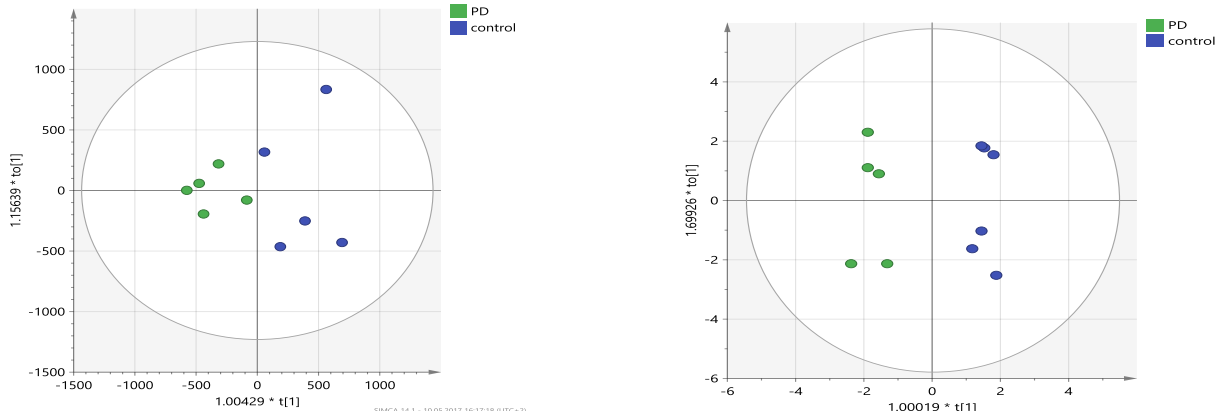

Fig. 1 Serum (A) and lipid extract (B) score plots of the two-component OPLS-DA model; $t_o[1]$ represents within class variation in the first orthogonal component, whereas t[1] represents between class variation in the first predictive component. Ellipse represents Hotelling T^2 with 95% confidence in score plots.

We analyzed 32 compound signals from the serum lipid extract. OPLS-DA was also performed for the statistical analysis (Fig. 1B) to build a model. The resulting model consisted of two components, one predictive and one orthogonal. The most important compound signals involved in the group separation were: unassigned signals at 3.50 ppm and 1.84 ppm, esterified and total cholesterol, phosphatidylcholine and fatty acids. All patients and healthy subjects were classified correctly to their corresponding groups.

Conclusion
Metabolite profile in the serum of PD patients was different then the profile from control subjects. This allowed differentiating PD patients from control subjects.

Influence of the Stochasticity in Threshold Localization on Cell Fate in the PLDE-Model of the p53 Module

Magdalena Ochab, Andrzej Swierniak, Jerzy Klamka, and Krzysztof Puszynski

Silesian University of Technology, Institute of Automatic Control
Akademicka 16, 44-100 Gliwice
Magdalena.Ochab@polsl.pl

Due to the heterogeneity of cells in a population, they react differently to the same stimuli. This diversification results in the population separating into subpopulations with different cell responses such as apoptosis, cell cycle blockade, or proliferation. Here we focus on the regulatory module of the protein p53, which is responsible for cell responses to DNA damage, and analyze a piece-wise linear model with switches discussed in our previous publications. The main goal of this work was to examine the influence of differences occurring between cells on the cellular response for different doses of external stress. We investigate the properties of the whole cell population in the case of three different types of cell diversity: diversity in sensitivity to stress, diversity in gene expression, and diversity in all the processes analyzed. The diversification of the cell population is acquired by stochastic localization of the switching thresholds. The results show that a population with high diversity in sensitivity to stress has a wide range of responses, so that almost all possible trajectories are present and consequently it is impossible, for example, to force all the cells to apoptosis. Differences in gene activation result in differences in the time courses. The apoptotic response can be activated much later and additional possible results appear. In the case of diversity in all processes analyzed, a variety of different responses can be observed even for a narrow range of the changes, and moreover additional stationary points appear. These results show that even minor changes in proper cell functioning can lead to abnormalities, which may lead to cancer.

Full text of this paper can be found at:

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Simulation Analysis of the Homologous Recombination Repair Distribution over the Cell Cycle

Monika Kurpas and Krzysztof Puszynski

Faculty of Automatic Control, Electronics and Computer Science, Silesian University of Technology
Akademicka 16, 44-100 Gliwice
monika.kurpas@polsl.pl

Double-strand breaks (DSBs) are repaired with the use of several distinct mechanisms. The most important of them are non-homologous end joining (NHEJ) and homologous recombination (HR). These mechanisms have different requirements and are characterized by different repair kinetics. Moreover, HR is restricted to S and G2 phases of the cell cycle, however it is still not clear how percentage of DSBs repaired by HR changes over the cell cycle. In this study we are trying to find the most suitable function describing participation of HR among other types of repair. Using our mathematical model, we simulate the response of average cell treated with ionizing radiation (IR) during G1 phase of the cell cycle. Our results show that the exact shape of the function describing percentage of HR is not as important as the fact that this function should be gradually increasing until at least half of the S phase.

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Marked Point Process for Nuclei Detection in Breast Cancer Microscopic Images

Marek Kowal and Józef Korbicz

University of Zielona Góra, Institute of Control & Computation Engineering
ul. Szafrana 2, 65-516 Zielona Góra
{M.Kowal,J.Korbicz}@issi.uz.zgora.pl

The automatic detection of nuclei within cytological sample imagery is crucial for quantitative analysis in medical applications. Unfortunately, the classical segmentation algorithms perform poorly for cytological images if precise seeds of nuclei are not given in advance. To tackle this problem, we propose nuclei detection method based on Bayesian recognition framework. It finds spherical regions with intensity distribution characteristic for nuclei and approximates them by disks. The process of disk generation can be viewed as marked point process (MPP). To penalize disk overlap, we added priori distribution of configuration based on pairwise interaction. The best disk configuration maximizes the probability of configuration given image data and pairwise interactions between disks. Deterministic algorithm based on Steepest Ascent method was used to search the configuration space in order to find the solution. To test the effectiveness of the method, it was applied to recognize nuclei in cytological images of breast cancer tissue.

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Cryopreservation of Cells Encapsulated within Nano-thin Polyelecrolyte Coatings

Magdalena Antosiak-Iwańska[1], Ewa Godlewska[1], Joanna Kinasiewicz[1], Krzysztof Dudek[2], Jerzy Kawiak[1], Ludomira Granicka[1]

[1] Nalecz Institute of Biocybernetics and Biomedical Engineering, Polish Academy of Science, Warsaw, Poland
[2] Department of General, Transplant & Liver Surgery, Medical University of Warsaw, Poland
mantosiak@ibib.waw.pl

Cryopreservation is a method which enables to store the cells for a long time period and allows to obtain the appropriate amount of cells necessary for transplantation. Unfortunately, the cells isolated from organs like e.g. hepatocytes are susceptible to freezing damage. Encapsulation may be considered as a method allowing to protect cells during adverse freezing conditions.
Aim: Assesement of the usability of nano-thin semipermeable membrane coating shell as protective element during cryopreservation of the cells.
Materials and Methods: Liver cells, isolated from living donors (according to Bioethical Community protocol) or hepatoma cell line HepG2 were encapsulated within nano-thin poly-L-lysine/polyethylenoimine with incorporated fullerene (PLL/PEI+f) membrane or within standard alginate microcapsules. As a control group the cells were encapsulated The mitochondrial activity of cells was analyzed after 4 months cryopreservation using 5-diphenyltertrazolium bromide tetrazolium (MTT) test. The viability of cells was assessed utilizing flow cytometry during 8-day culture after thawing.
Results: The cells protected during cryopreservation by nanomembranes or microcapsules were after thawing in better condition than nonencapsulated cells. The mitochondrial activity expressed as absorbance was comparable in both types of encapsulation within nano-thin membranes or microcapsules in MTT test. The percentage share of viable cells in all tested groups was meanly 90%. Conclusions: Applied nanocoating did not delimit the viability of cryopreserved cells as compared to microencapsulation. The cryopreservation within nano-thin semipermeable membranes seems to be promising way to protect cells during long term storage in liquid nitrogen when minimizing the encapsulated transplant volume is necessary.

Full text of this paper can be found at:

Magdalena Antosiak-Iwańska, Ewa Godlewska, Joanna Kinasiewicz, Krzysztof Dudek, Jerzy Kawiak, Ludomira Granicka, Cryopreservation of Cells Encapsulated within Nano-thin Polyelecrolyte Coatings in: Augustyniak P., Maniewski R., Tadeusiewicz R. (eds.) *Recent Developments and Achievements in Biocybernetics and Biomedical Engineering, Proc. of. 20-th Polish Conference on Biocybernetics and Biomedical Engineering,* Springer International Publishing AG, Series: Advances in Intelligent Systems and Computing, 2017, pp. 249-261

Alterations of biomechanics in cancer stem cells induced by cytostatic drugs used in acute myeloid leukemia

Kaja Frączkowska[1], Aleksandra Kaczorowska[1], Weronika Lamperska[2], Jan Masajada[2], Magdalena Przybyło[1], Halina Podbielska[2], Tomasz Wróbel[3], Marta Kopaczyńska[2]

Wroclaw University of Science and Technology, Faculty of Fundamental Problems of Technology, [1] Department of Bioengineering, [2] Department of Physics, Wybrzeze Wyspianskiego 27, 50-370 Wroclaw

[3]Wroclaw Medical University, Dept. of Hematology, Blood Neoplasms and Bone Marrow Transplantation,4 Pasteur St., Wroclaw, Poland, 50-367

kaja.fraczkowska@pwr.edu.pl

Acute myeloid leukaemia (AML) is an aggressive hematopoietic stem cell neoplasm, which is caused by the rapid proliferation of immature malignant blood cells (blasts). Understanding the biomechanics of leukemic cells may be helpful in revealing quantitative information about mechanisms of chemotherapy in AML patients. Anthracycline antibiotics are one of the most effective types of anticancer drugs currently used in the treatment of many types of neoplasms, including AML [1]. Despite the extensive usage in the clinics, the mechanism by which anthracyclines causes its cytotoxicity remains unclear. However, several observations suggest that DNA is a major molecular target of this group of drugs. Anthracyclines insert their tetracyclic regions into the adjacent base pairs of DNA molecule and modifies its structure [2]. This action can lead to changes in mechanical properties of DNA, increase the sensibility to damages and inhibit its biological activity. In addition, another mechanisms of action for anthracyclines have been proposed, such modification of plasma membrane and cytoskeleton [1]. To date, little is known about the effect of anthracyclines on the mechanical properties of cellular structures.

We examined the effects of three anthracyclines – doxorubicin (DOX), daunorubicin (DAU) and epirubicin (EPI) on the mechanical properties of leukemic blast cells obtained from patients with AML. We used holographic optical tweezers as a novel method for determining mechanical properties of cells. We studied the mechanical properties of human AML blast cells and their changes after the interaction with drugs. Observed changes in cellular mechanics were validated on the model phosphatidylcholine membranes by flicker noise spectroscopy, based on the confocal visualization, which allows for direct measurement of membrane bending rigidity coefficient. We also performed confocal laser scanning microscopy imaging of cells with internalized anthracyclines in order to compare the apoptotic stage of cells with their biomechanics.

All of the examined anthracyclines have found to decrease the mechanical strength of blast cells. The strongest action showed doxorubicin which caused the decrease in stiffness of AML blast cells of about two times. The weaker changes in mechanical properties of cells were caused by EPI. DAU affected the mechanical properties of blast cells in the smallest extent. Experiments with model phospholipid membranes confirmed that observed increase in cell elasticity originates, among other things, from the drug incorporation in the lipid membrane itself. DOX was localized preferentially in the nucleus, nuclear membrane and partially in cytoplasm. The fluorescence of the other two drugs was predominantly cytoplasmic, stronger for EPI. In addition, a characteristic feature of DAU was a pronounced staining of the nuclear envelope.

Since most of the neoplastic cells are known to have a higher nucleus-to-cytoplasm ratio than health cells the strongest lowering of blast cells stiffness by DOX may be mainly due to the interaction of this drug with nuclear structures. Moreover, it is known that DOX inhibits the polymerization of actin and thus cytoskeletal modification may also be important in reducing of cell mechanical strength. In addition, DOX was accumulated also in the cell membrane and thus it could reduce its stiffness. In the case of EPI and DAU, the decrease of cell stiffness is rather an effect of interaction with the cytoplasmic structures, such as cytoskeleton, than cell nucleus. The lowering of mechanical strength of leukemic cells may have an significant impact on the effectiveness of chemotherapy. Our observations suggest also that chemotherapy with anthracyclines may decrease the risk of vascular complications in AML, due to increasing the cell elasticity.

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CD133 antibody biofunctionalized intravascular implant surfaces for cardiovascular applications

Maciej Duda[1], Magdalena Wawrzyńska[2], Edyta Wysokińska[3], Wojciech Kałas[3,4], Halina Podbielska[1], Marta Kopaczyńska[1]

[1] *Faculty of Fundamental Problems of Technolgy, Department of Biomedical Engineering, Wroclaw University of Science and Technology, Wybrzeze Wyspianskiego 27, 50-370 Wroclaw, Poland*

[2] *Department of Medical Emergency, Faculty of Health Science, Wroclaw Medical University, Parkowa 34, 51-616 Wroclaw, Poland*

[3] *Department of Experimental Oncology, Ludwik Hirszfeld Institute of Immunology and Experimental Therapy, Polish Academy of Sciences, Rudolfa Weigla 12, 53-114, Wroclaw, Poland*

[4] *Institute of Chemistry, Environmental Protection and Biotechnology, Jan Długosz University, Al. Armii Krajowej 13/15, 42-201 Częstochowa*

Corresponding author: marta.kopaczynska@pwr.edu.pl

Percutaneous coronary intervention (PCI) is currently one of the most important cardiological surgery procedures that uses intravascular implants, called stents. It is a direct answer to cardiovascular disorders, such as atherosclerosis, that cause coronary arteries lumen narrowing. Unfortunately, stent implantation carries serious postoperative risks of which the most dangerous are thrombosis and restenosis. In order to deal with those problems, a number of scientific research trends concerning stent surface modifications emerged. Some of them involve covering the bare metal stents with biodegradable polymer coatings that contain drugs incorporated into its structure, while others focus on immobilization of biomolecules on functionalized stent surfaces. Such molecules, most likely antibodies, are usually specific towards blood circulating endothelilal progenitor cells (EPCs). Once captured, EPCs diffrentiate into fully mature endothelial cells and cover the implants surface, thus reducing the risk of thrombosis and restenosis. Stents with fully biodegradable scaffolds have also been developed, however according to recent literature and clinical trial results, they are significantly inferior to metal-based stents [1].

Our scientific concept is comprised of a multistep 316 L stainless steel surface modification strategy, involving the synthesis of titania-based coating (Ti-BC) followed by mercaptosilanization and an anti-CD133 antibody immobilization. According to current state of the art metal-based stents display the highest degree of biocompatibility and CD133 antibody covered stents are said to have the best endothelialization rate amongst other biofunctionalized surfaces [1, 2]. To evaluate modified samples, we employed spectroscopy (FTIR, Raman), microscopy (confocal, AFM and SEM), flow cytometry (FACS) and *in vitro* studies (hemolysis and cell adhesion assays).

FTIR and Raman spectra showed that chemical and biochemical modification of surfaces was successful. Furthermore, microscopic evaluation revealed that samples were homogenously biofunctionalized with immobilized CD133 antibodies. *In vitro* studies implicated that modified surfaces displayed very low hemolytic properties and at the same time they promoted the adhesion of endothelial progenitor cells.

Through the course of study an innovative approach towards cardiovascular surfaces biofunctionalization has been introduced. Newly obtained coating proves to be effective in EPCs binding and displays highly biocompatibile properties through the reduced risk of thrombosis and restenosis. Obtained results constitute a promising basis for future *in vivo* studies.

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Preliminary study on the effect of zinc oxide nanoparticles (ZnO) on the properties of the endothelial cells

Anna Ciechanowska*, Grazyna Hoser*, Stanislawa Sabalinska*, Jerzy Kawiak*, Artur Kaminski**, Piotr Ladyzynski*
*Nalecz Institute of Biocybernetics and Biomedical Engineering PAS, 4 Trojdena str., 02-109 Warsaw
** National Centre of Tissue and Cell Banking, 5 Chalubinskiego str., 02-004 Warsaw
Email of the Corresponding Author: aciechanowska@ibib.waw.pl

Aims Nanoparticles can selectively reach different types of cells and deeply penetrate specific human tissues. Due to their properties nanoparticles can be widely used in medicine and cosmetology. Zinc oxide nanoparticles (ZnO NPs) are used in sun protecting and face creams [1], in various antimicrobial applications [2], to transfer pharmaceuticals to the target site in the body, to fight cancer cells [3]. A significant problem is the determination of cytotoxicity of nanoparticles. The endothelial cells (ECs), which lines the interior surface of blood vessels, compose dynamic structure readily reacting to stimuli and responding to different activating factors. The aim of our preliminary study is to investigate the effect of ZnO NPs on the properties of the human EC cultured in vitro in a culture plate (static conditions). We plan to use results of this study to select the culture conditions in tests, which will be carried out using capillary bioreactor with ECs seeded inside capillaries. In such a bioreactor we will be able to introduce the flow of the culture medium generating a shear stress similar to this occurring in the blood vessel. Such conditions ensure a response to the activation caused by the ZnO NPs closely reproducing the in vivo cells' reaction.

Methods The human umbilical vein endothelial cells (HUVECs) were isolated from umbilical cords obtained by Caesarean section. Then cells grew in culture flasks in the supplemented medium M199. Cells were passaged one time and cryopreserved in –190^{o}C. Cells were thawed and passaged for the second time before the final use. The HUVECs were labeled with CellTrace Violet Cell Proliferation Kit (CTV) and seeded in 12-well culture plates. The density of cells was 60,000 cells/cm^2. Cultures were kept in an incubator at 37°C in an atmosphere of 5% CO_2 and 95% air. After 24 h of culturing a suspension of ZnO NPs was added to the culture medium in the concentration of 0, 2.5 or 5 μg/ml. After another 48 h, the cells were detached using 0.25% Trypsin and analyzed in a cytometer FACSCanto II for the proliferation capacity, CD31 and CD62e expression. At the end of the culture, cells were fixed in 4% formalin, stained with hematoxylin and eosin, and photographed in a fluorescence microscope to evaluate cells' morphology.

Results The cell viability analysis showed that HUVECs treated with ZnO NPs exhibited higher fluorescence intensity than those cultured without ZnO NPs (by 12% and 13% for 2.5 and 5 μg/ml of ZnO NPs, respectively). There was no difference in the CTV dye fluorescence intensity after incubation with ZnO NPs at concentrations of 2.5 and 5 μg/ml, which suggested that concentration of 2.5 μg/ml was high enough to inhibit cells' division. The dividing cells lose half of the dye associated with the cytoplasmic proteins. With a rise of the nanoparticle concentration, a decrease in fluorescence intensity associated with expression of CD31 was observed (by 2% for 2.5 of ZnO NPs and 10% for 5 μg/ml of ZnO NPs compared to 0 μg/ml of ZnO NPs). The decrease in the expression of CD31 may indicate a change of cells' adhesion properties resulting in the detachment from the substrate. Some cells with CD31 phenotype bind to Annexin V. The increased expression of Annexin V is an evidence of ZnO NPs-induced apoptosis. The highest level of Annexin V binding by CD31 positive cells was observed at 5 μg/ml ZnO NPs concentration (by 26% higher than for 0 μg/ml of ZnO NPs). The CD62e expression is present on the cytokine-activated HUVECs. Under the influence of ZnO NPs, expression of CD62e was reduced, which can be explained by the inhibition of these cells (by 3% for 2.5 and 5 μg/ml of ZnO NPs compared to 0 μg/ml of ZnO NPs). An analysis of the cell morphology, carried out at the end of the culture, demonstrated that the cell damage was increasing with the increase of the concentration of ZnO NPs.

Conclusion It can be hypothesized that in the static cultures the level of 2.5 μg/ml of ZnO NPs is toxic to HUVECs. The presence of nanoparticles at such concentration results in changes in the cell adhesion properties and inhibition of their proliferation.

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Pitting corrosion resistance of NiTi alloy in simulated physiological solutions

Marcin Kaczmarek, Zbigniew Paszenda, Witold Walke, Marcin Basiaga
Department of Biomaterials and Medical Devices Engineering, Faculty of Biomedical Engineering,
Silesian University of Technology, Roosevelta 40, 41-800 Zabrze, Poland
marcin.kaczmarek@polsl.pl

Nowadays, stainless steels, titanium alloys and cobalt alloys are the basic groups of metallic biomaterials. However, in recent years there has been a growing interest in NiTi alloys as biomaterials. Considering NiTi alloys as biomaterials, it should be mentioned that they must have a number of utility properties, both in terms of mechanical, physicochemical and biological properties. The latest NiTi literature focuses on issues related to mechanical and physicochemical properties that ensure the safe use of these alloys in clinical practice [1-3].

In the research, superelastic NiTi alloy was used. The chemical composition of the alloy met the requirements of the ASTM F 2063 standard. To determine the influence of various surface modification methods on the corrosion resistance of the alloy, the following surface treatments were carried out: 1) electrolytic polishing - in the bath developed by the author. The applied current densities ranged from 5 to 50 A/dm^2; 2) passivation in boiling water for 1 hour; 3) deposition of the carbon layer in the RF PCVD process.
The objective of the study was to determine the corrosion resistance of the surface modified NiTi alloy in artificial body fluids, appropriate from the point of view of clinical applications. The tests were performed in the following solutions: 1) Tyrode's physiological fluid; 2) artificial urine, 3) artificial plasma.
Corrosion resistance of the analyzed alloy was performed using the potentiodynamic method based on the recording of the anodic polarization curves. The study of pitting corrosion resistance was divided into two stages. The first stage was conducted in currentless conditions and was focused on determining the corrosion potential (E_{cor}). The second step was the recording of anodic polarization curves at the constant scanning rate equal to 1 mV/s. The study was conducted at 37±1°C. The reference electrode was a saturated calomel electrode (SCE). A platinum electrode was used as the auxiliary electrode.

Results of corrosion resistance studies of NiTi alloys with modified surfaces, performed in the Tyrode's physiological solution, the artificial urine and the artificial plasma were presented in Table 1.

Table 1
Results of corrosion resistance of the studied NiTi alloy

Surface treatment	**Tyrode's solution**		**artificial urine**		**artificial plasma**	
	E_{cor}, mV	E_{tr}, mV	E_{cor}, mV	E_{tr}, mV	E_{cor}, mV	E_{tr}, mV
electropolishing	- 106	1222	- 200	1223	- 33	1327
passivation	- 106	1292	- 188	1245	- 126	1548
carbon coating	- 111	1496	- 136	1316	- 156	1156

The corrosion studies of the NiTi alloy performed in the simulated body fluids have shown that the proposed surface treatment methods provide good resistance to pitting corrosion.
However, it was found that the highest values of transpassivation potential were obtained for the carbon coated samples. The use of electrochemical methods resulted in local, heterogeneous discolourations and etching.

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The influence of the heat treatment on the chemical activity of the glasses and glass-ceramics from the SiO_2-CaO and SiO_2-CaO-P_2O_5 systems

B. Zagrajczuk[1], M. Dziadek[1], K.Jartym[1], K. Cholewa-Kowlalska[1], M. Laczka[1]
[1]Dept. of Glass Technology and Amorphous Coatings, Fac. of Mat. Sci. and Ceramics, AGH University of Science and Technology, Mickiewicza Ave. 30, 30-059 Krakow, Poland;
b.zagrajczuk@gmail.com

Bioactive glasses are known for the ability of creating a strong bond with a living tissue, especially bone tissue, by a layer of biomimetic apatite present on its surface. The ability of apatite layer formation depends on many different materials factors such as chemical composition, surface characteristic, textural and microstructural properties. The aim of this study was to evaluate the bioactive performance of sintered glass ceramics from the SiO_2-CaO and SiO_2-CaO-P_2O_5 systems and estimate how the changes occurring in materials after sintering such as increase of density and crystallization, affects the *in vitro* bioactivity process.

Gel derived glasses from the binary SiO_2-CaO and ternary SiO_2-CaO–P_2O_5 systems were obtained. Materials differed in the CaO/SiO_2 molar ratios. Gels were stabilized in 600°C (binary glasses) and 700 °C (ternary glasses). Next, glass powders were pressed into 15mm disks and then subjected to the heat treatment at 800°C degrees or to the free sintering at 1300°C. Moreover, glass powders were also sintered by the hot pressing at 900°C for A glasses or 1200°C for S glasses.

Structural characteristics of obtained materials have been performed with the XRD diffraction and FTIR spectroscopy. Samples surface morphologies were tested with SEM microscopy. In order to evaluate samples bioactive properties *in vitro* test in simulated body fluid SBF have been performed. All of the samples were immersed in the solution for 14 days. Samples morphologies, before as well as after the incubation have been examined with SEM microscopy and with EDS spectroscopy. Changes in materials structural compositions were investigated with FTIR-ATR spectroscopy and XRD diffraction. Moreover, ionic exchange between samples and SBF solution was tested with the ICP-OES spectrometry after 3, 7 and 14 days of incubation.

SEM analyses revealed differences in materials surface morphologies and, differing as well between particular sintering methods as materials chemical compositions. XRD analyses indicated a crystallization occurring in materials after the free sintering. After incubation in SBF, SEM analysis indicated significant differences in rate of apatite layer formation between sintered and non-sintered materials. Moreover, significant differences in layer morphologies between unsintered, free sintered and hot pressed materials have been observed. FTIR spectroscopy and XRD diffraction and EDS spectroscopy indicated significant differences in the bioactive layer composition and structure, between materials from the binary and the ternary system materials as well as between sintered and non-sintered ones. ICP-OES spectrometry revealed different ions exchange dynamics amongst examined materials.

Our study confirmed that materials sintering conditions have a significant impact on the ability of apatite formation and also strongly affect layers morphology, chemistry and structural properties.

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New Methods for Plating Human Liver Cells

Agnieszka Wencel, Karolina Zakrzewska, Anna Samluk, Dorota Pijanowska, Krzysztof Pluta
Nalecz Institute of Biocybernetics and Biomedical Engineering Polish Academy of Sciences
Ks. Trojdena 4 st., 02-109 Warsaw, POLAND
akowalska@ibib.waw.pl

Aims

Culturing of human primary hepatocytes is highly demanding. These cells rapidly dedifferentiate *in vitro* and lose their liver-specific features over few days in culture. Thus, the use of primary hepatocytes for such applications as bioartificial liver (BAL) or cytotoxicity assays is very challenging. To prevent or slow down the dedifferentiation of primary hepatocytes variety of methods have been applied, including: medium supplementation, use of 3D scaffolds, coating of the growth surfaces with the extracellular matrix, etc.. One of the most promising methods to maintain hepatocytes in the differentiated state is the use of feeder layer cells, for example fibroblasts. The aim of this study is an elaboration of the new fibroblasts-based coatings for the liver cells culture.

Methods

In this study, the human hepatoma cells (C3A), model of the hepatocytes, were seeded on the genetically modified fibroblasts or cultured on the growth surfaces coated with the dried fibroblasts. Fibroblasts isolated from human skin were modified using lentiviral vectors to stably produce additional amounts of epidermal growth factor (EGF). To assess the metabolic activity of the C3A cells albumin synthesis and cell viability were analyzed. Additionally, the effectiveness of apical vacuoles formation was determined.

Results

The use of the dried fibroblasts' coating and the modified fibroblasts, that can produce large amounts of the EGF, as the feeder layer cells decreased the number of dead hepatoma cells in the culture. The albumin levels were higher when compared to the control cultures. Moreover, the apical vacuoles formation, the sign of hepatocytes polarization, was also more efficient in the cultures which utilized novel biocoatings.

Conclusions

The use of the feeder layer cells can positively affect cell adherence, and consequently, the distribution of the cells and the cell-cell communication. This can result in differences in the cell physiology and growth rate. The presented results indicate that genetically modified fibroblasts as well as dried fibroblasts' coating are the promising methods to culture hepatic cells. These novel experimental approaches can find their applications in BAL construction and cytotoxicity tests design.

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In vitro mineralization of pectin/bioactive glass injectable composites

Michal Dziadek[1], Timothy E.L. Douglas[2,3], Josefien Schietse[2], Maria Buchweitz[4], Chris Vervaet[5], Barbara Zagrajczuk[1], Katarzyna Cholewa-Kowalska[1], Andre G. Skirtach[2,6]

[3]Department of Glass Technology and Amorphous Coatings, AGH University of Science and Technology, Krakow, Poland
[2]Department of Molecular Biotechology, Ghent University, Belgium
[3]Engineering Department, Lancaster University, UK
[4]Faculty of Chemistry, University of Stuttgart, Germany
[5]Laboratory of Pharmaceutical Technology, Ghent University, Belgium
[6]Centre for Nano- and Biophotonics, Ghent University, Belgium

Hydrogels are hydrophilic, water-swollen polymer networks formed from a variety of natural and synthetic polymeric building blocks. These building blocks have been engineered to enable crosslinking by chemical reaction or through physical interactions that proceeds rapidly enough for injection and *in situ* hydrogel formation [1]. One great advantage of hydrogels is the ease of incorporation of ceramic particles that impart new biofunctionality. For applications in bone regeneration, the presence of an inorganic component is considered desirable. One such inorganic component are bioactive glasses. They are rich source of calcium ions that can cause hydrogel gelation by polymer crosslinking. One of the calcium-binding hydrogels are pectins.

In the present study, bioactive glass particles obtained in the course of sol-gel synthesis were added into pectin solutions to obtain self-gelling, injectable composites. Two different types of bioactive glass particles A2 (2.5 μm and 45 μm) form the basic system SiO_2-CaO-P_2O_5 were used. Two different amidated pectin preparations derived from apple and lemon (hereafter denoted AA and CA, respectively) were compared. Obtained materials were incubated in simulated body fluid (SBF) to assess the effect of bioactive glass on the *in vitro* mineralization process. Materials after incubation were analyzed in terms of morphological, chemical and structural changes using SEM/EDX, FTIR and XRD methods. Furthermore, the changes of ion concentration (Ca, P, Si) in SBF during sample incubation were monitored using ICP-OES technique.

The results showed that gelation of composites was completed within 20 minutes, regardless of the type of pectin or bioactive glass particle diameter. Such gelation speeds are suitable for injectability. SEM analysis showed that the layers of spherical crystals appeared on the surfaces of the composites after 28 days of incubation in SBF. EDS spectra revealed an increase in Ca and P concentration that indicate calcium phosphate layer formation. Increase in intensity in FTIR spectra of double band in the range of 600-540 cm^{-1} that can be assigned to O–P–O bending mode in crystalline form of calcium phosphate (hydroxyapatite) was observed after incubation in SBF. ICP-OES analysis demonstrated that concentration of Ca in SBF rose, but concentration of P fell. This provided evidence of formation of a phosphate-rich layer on materials.

The result indicate that the addition of bioactive glass particles into pectin allow us to obtain self-gelling, injectable composites, with high potential for mineralization after contact with simulated body fluid.

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Identification of the pathophysiological changes within the peritoneal transport barrier in patients undergoing peritoneal dialysis

Joanna Stachowska-Piętka[1], Jan Poleszczuk[1], Bengt Lindholm[2], Jacek Waniewski[1]

[1]Nalecz Instytut of Biocybernetics and Biomedical Enginnering, Polish Academy of Sciences, Ul. Ks. Trojdena 4, 02-109 Warszawa, Polska
[2]Divisions of Baxter Novum and Renal Medicine, Department of Clinical Science, Intervention and Technology, Karolinska Institutet, Stockholm, Sweden
Email of Corresponding Author: jstachowska@ibib.waw.pl

Ultrafiltration failure (UFF) is a serious complication often appearing over time on dialysis and leading to the fluid overload and treatment failure in patients on peritoneal dialysis. UFF is caused by the local, pathophysiological changes within the peritoneal transport system (PTS), which reduce capacity to remove excess water from patient's body. Commonly used mathematical models allow for the time tracking of the PTM's changes by the estimation of the net parameters for the black-box barrier. However, these models cannot be used for the discrimination between particular local changes of the transport properties of the blood microcirculation and interstitium that are components of the PTS. The aim of the study was to verify whether the distributed approach that takes into account spatial structure of the PTS and its physiological properties, can be applied for the identification of pathophysiological changes that occurs within PTS in individual patients with ultrafiltration failure.

The distributed model of fluid and solute transport through the peritoneal tissue was coupled with the model describing intraperitoneal kinetics of fluid and solutes. Clinical data of 11 patients with UFF undergoing CAPD with hypertonic glucose solution 3.86% and radiolabeled albumin, RISA, used as a volume marker, were analyzed and compared with control group of 20 patients with normal ultrafiltration. The frequent sampling of blood and dialysate during typical, six-hour dwell allowed for the calculation of the creatinine, sodium, urea and glucose concentrations. Physiologically based parameters were evaluated for the capillary wall and the peritoneal tissue separately taking into account changes of the tissue hydration, interstitial hydraulic conductivity, lymphatic absorption, blood capillary diffusive permeability and conductance caused by the treatment. The infusion, dwell, and drainage procedures were modeled separately by taking into account changes in the intraperitoneal volume, pressure and effective surface area of the contact with dialysate.

The model was able to describe clinical data with high accuracy, and the average relative fit error per point was 3.68%. Significant changes within the peritoneal transport system were observed for each patient. In general, the tendency for the facilitation of the small solute transport by the high solute diffusive permeability of the capillary wall and tissue accompanied by restrictions in the fluid transport caused by the low capillary wall hydraulic conductance, tissue hydraulic conductivity and tissue reflection coefficient, and caused by the low fraction of ultrasmall pores in the blood capillary wall. In addition, the peritoneal fluid absorption rates as well as local lymphatic absorption were found higher in some patients, whereas remained unchanged in others. The closer analysis of the individual parameters showed various patters of the changes within patients with UFF, typically with few alterations from the above mentioned, with remaining parameters unchanged.

The present study showed that the distributed model can be applied for the identification of the pathophysiological changes that occurs within the PTS during peritoneal dialysis in patients with UFF. Moreover, the study indicates that various patterns of PTS alteration may result in observed changes of the peritoneal barrier transport properties and ultrafiltration failure. The impact of the local alteration on the global changes of the overall parameters remains in the agreement with the finding in other studies.

Composite Membrane with Silver Nanoparticles for Supporting Fibroblastic Cell Growth

Monika Drabik[1], Beata Kazimierczak[1], Angelika Kwiatkowska[1], Anna Grzeczkowicz[1], Magdalena Antosiak-Iwańska[1], Ludomira Granicka[1*]

[1]Nalecz Institute of Biocybernetics and Biomedical Engineering, PAS, Trojdena 4 st., Warsaw, Poland
*lgranicka@ibib.waw.pl

Continuous rising of antibiotic as well as multidrug resistance in microorganisms has promoted development of an alternative antibacterial agents. One of the most promising materials are nanoparticles of metals such as gold, copper or silver [1], [2]. Especially, silver nanoparticles (AgNPs) have attracted much more attention than other metal nanomaterials, which could be attributed to their proven antimicrobial properties, and high biocompability. Due to their unique properties silver nanoparticles have a potential to become commonly used also in the field of biomedicine and biotechnology. However, cytotoxicity of AgNPs to the living organisms, especially human cells, is still unclear and required more complex studies, especially considering their possible biomedical applications. Such tests should also include an evaluation of the cytotoxicity of AgNPs composites with other materials.

In our study, the performance of designed composite collagen membrane substrate with incorporated silver nanoparticles with chosen eukaryotic cells (mouse fibrosarcoma WEHI 164 cell line) was assessed. Collagen I is commonly used in cell culturing and in regenerative medicine, supporting the growth and differentiation of adherent cells [3]. Thus it seems to be natural to combine this material with AgNPs in further biomedical application. The presence and function of targeted cells was evaluated by flow cytometry and MTT test. The viability of WEHI 164 cells maintained in the presence of collagen films with AgNPs immobilized within in concentrations 6.25 ppm or 12.5 ppm or 25 ppm, was tested during 72 hours culture.

Flow cytometry showed that there was no statistical difference in cell viability between the cells cultured within collagen films without AgNPs and composite collagen membrane containing AgNPs . Nevertheless MTT examination revealed lower mitochondrial activity of cells for all composite collagen membranes comparing with collagen membrane. Furthermore, the AgNPs ability to influence membranes properties was examined. The water contact angle of polyelectrolyte membranes adsorbed on the support: collagen or collagen with nanoparticles or the support alone was analyzed. To estimate the applied membrane transport properties the alginate cores coated with evaluated membrane were applied. Diffusive permeability was evaluated using a thermodynamic description of diffusive mass transport across a homogenous membrane (Fick's law) and a two-compartment model. Dextrans of molecular weight of 70 kDa and 150 kDa were used as the model particles in these studies.

Presented studies demonstrated the performance of designed collagen composite membrane films with silver nanoparticles as a substrate for eukaryotic cells immobilization. The MTT assay used to determine the function of fibroblastic cell line cultured within the designed composite membranes revealed significant decline of mitochondrial activity induced by silver nanoparticle exposure of cells cultured within the composite membrane with 25 ppm AgNPs share comparing with collagen membrane, thus the Ag 6ppm and Ag 12ppm can be considered for further applications. The applied membrane composites with silver NPs can be recommended for supporting bandages in biomedical applications.

Supporting role of silver doped silica nanoparticles in antibacterial photodynamic action

Katarzyna Wysocka-Król, Joanna Bauer, Halina Podbielska
Wroclaw University of Science and Technology, Faculty of Fundamental Problems of Technology, Department of Biomedical Engineering, Wybrzeze Wyspianskiego 27, 50-370 Wroclaw, Poland
Corresponding Author: katarzyna.wysocka@pwr.edu.pl

A fundamental problem in hospitals is growing number of drug-resistant bacteria, such as carbapenem-resistant Pseudomonas aeruginosa, cephalosporin-resistant Escherichia coli, methicillin-resistant Staphylococcus aureus (MRSA), etc. [1]. One of the alternative ways for combating drug-resistant bacteria strains may be the antimicrobial photodynamic therapy (APDT) [2] enhanced by an addition of silver nanoparticles, which exhibit antibacterial activity and may be used for sterilization, as well [3].

In our study the silica nanoparticles were prepared by modified Stöber synthesis. Prepared silica spheres were used as the support for immobilization of silver nanoparticles by modified Tollen's method. The sol-gel derived silica spheres, with surface modified by silver nanoparticles, were used to enhance the efficiency of photosensitizer – Photolon. Surface and size of the synthesized materials were characterized by TEM micrography. Optical and antibacterial properties of Photolon in various concentrations were examined in the presence of silica based materials doped with silver nanoparticles.

In this work, nanoparticles diameter of silica spheres and metallic silver was determined by means of computer analysis of microscopic images. The average size of the silica nanospheres SiO_2 was 180±30 nm, whereas metallic silver nanoparticles had diameters in range from 15 to 31 nm. Next, various concentration of Photolon solution and nanomaterials have been prepared in order to examine the maximum absorption peak at about 650 nm and the effectivity of antibacterial activity against *Pseudomonas aeruginosa*. It was proved that the maximum absorption of Photolon solution is dependent on materials concentration and is enhanced by silver nanoparticles. APDT study showed that antibacterial activity of Photolon solution combined with silver doped silica nanoparticles is more effective.

An important conclusion was drawn: lower photosensitizer concentration gave the same antibacterial effect in the presence of silver nanoparticles as martials in higher concentration not enriched by nanoparticles. This study may lead to creation of a new system to combat drug-resistant bacteria.

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Laser irradiated biopolymers for scaffolds with controlled degradation properties

Magdalena Tomanik, Magdalena Kobielarz, Celina Pezowicz, Jarosław Filipiak
Department of Biomedical Engineering, Mechatronics and Theory of Mechanisms, Wrocław University of Science and Technology, ul. Łukasiewicza 7/9, 50-371 Wrocław, Poland
magdalena.tomanik@pwr.edu.pl

Biodegaradable and bioresorable polymers are widely used for different biomedical applications. Polylactide (PLA), polycaprolactone (PCL) and poly(lactic-co-glycolic) acid (PLGA) are the first FDA approved biopolymers for medical usage. Gradual and non-toxic (for human tissues and cells) degradation followed by adequate mechanical properties for healed tissues makes them the promising materials for bone scaffolds. During the scaffold design process one should take into account not only the biomechanical adjustment of the device but also consider its behavior while implanted. In order to adapt biopolymers' degradation to the specific conditions some surface modifications can be performed. One way to customize biopolymers surface is through laser irradiation with different energy concentration depending on the ablation threshold [1]. Conducted study aimed to investigate the changes in hydrolytic degradation process of 3 polymers: poly(L-lactide) in amorphous ($PLLA_{AMO}$) and crystalline ($PLLA_{CRY}$) forms as well PLGA with surface irradiated with CO_2 laser of different powers in comparison to not modified materials.

The polymer sheets having an average thickness of 350μm were extruded from medical poly(L-lactide) (PLLA Evonik L210S) and poly(L-lactide-co-glycolide) (PLGA, Evonik LG857s) by compression molding of the granules pre-heated up to 200°C. As a result the amorphous poly(L-lactide) sheds having the degree of crystallinity Xc ≈ 2% were obtained. In order to get $PLLA_{CRY}$ amorphous specimens underwent thermal crystallization process for 5h in 100°C. To investigate the influence of the CO_2 laser surface modification on the hydrolytic degradation of the polymer specimens were irritated with laser powers: P_1=24J/cm^2, P_2=48J/cm^2 and P_3=71J/cm^2. All samples were placed in demineralized water and incubated in 37°C up to 24 weeks. The mechanical properties of the specimens were determined in uniaxial tensile test. The stress-strain curves were determined and on the basis of obtained curves the tensile strength R_m and Young's modulus E were calculated.

Conducted studies shown that the laser irradiation will not only affect its mechanical properties [2] but also have significant impact on the film surface topography (Fig.2) what will influence the hydrolytic degradation of materials by the increase water adhesion to the surface. Study reveals the relationship between the degradation rate and the increasing power of the laser. Moreover laser modification has stronger influence on the PLGA than PLLA, regardless the PLLA phase and laser beam energy, what can be noticed by more significant reduction of mechanical properties during hydrolytic degradation.

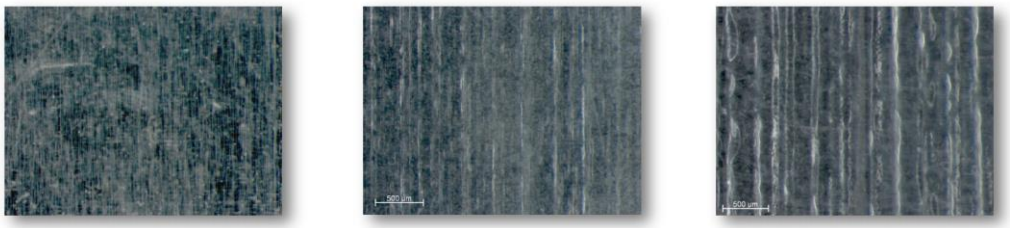

Fig.1. Topography of the polymer film surface after CO_2 laser irradiation with powers: P_1, P_2, P_3 respectively.

Presented work shows great potential of CO_2 laser irradiation as a method of controlled modification of the biopolymers aiming to influence its degradation rate. Regardless the investigated material, the strong relation between the used laser power and degradation speed was observed. Thanks to selective laser modification is possible to reach bone scaffold with the modified external surface in order to degrade quicker resulting in better scaffold integration with the surrounding tissues while the unmodified part can maintain the mechanical support during the bone regeneration process. The authors would like to thank the National Science Centre (Grant no: NCN 2013/09/B/ST8/02423) for providing financial support to this project.

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Sensitivity Analysis of Two-Compartment Model Parameters for Extracorporeal Liver Therapy Purposes

Aleksandra Jung

AGH University of Science and Technology, Cracow
Aleksandra.Jung@fis.agh.edu.pl

Time-stable volume two compartment conjugated bilirubin (cb) kinetics model was applied for sensitivity analysis. Model parameters variation influence on time course of cb concentration was determined. The analysis was performed for central and peripheral compartment during and between extracorporeal treatments. The analyzed model parameters were bilirubin generation G, volume V and intercompartmental clearance Kpc. Sensitivity with respect to G had a maximum at the end of the observed period of 24 hours, while the sensitivities with respect to V and Kpc reached their maxima during the treatment time. Sensitivity with respect to G was negligible at the beginning of the treatment and increased almost linearly after the treatment. It was similar for the central and peripheral output. Parameter V affected cb concentration the most strongly during the treatment, the sensitivity was lower for overhydrated patients. After the treatment sensitivity of V decreased almost linearly. The sensitivity with respect to Kpc was low and even negative. Summarizing, the analysis demonstrated that cb concentration was highly sensitive to G and V whereas it was influenced by Kpc to a much lesser extent. Sensitivity analysis indicates that parameters G and V may be estimated with high accuracy from cb concentration measurements for most patients but identification process must be provided more carefully for overhydrated patients. Kpc is estimated less accurately, similarly to hemodialysis models. The accuracy of the parameter estimation may be improved by selecting the sampling time individually for each patient near the peak values of the sensitivity.

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Anatomy Trains Modelling Based on Photogrammetric Data

Mirosława M. Długosz[1] and Wojciech Kurzydło[2]

[1] AGH University of Science and Technology, The Faculty of Electrical Engineering, Automatics, Computer Science and Biomedical Engineering, Krakow, Poland
[2] Jagiellonian University Medical College, Department of Phsyioteraphy Clinic of Rehabilitation. "Krzeszowice" Rehabilitation Center Krzeszowice
mmd@agh.edu.pl

The research undertakes the issue of objectification of the human body posture (HBP) assessment, for the clinical practice. There are no tools to support physicians in HPB assessment. In our study models of the four major Anatomy Trains (AT) and a method of studying them were developed, to enable an objective assessment of HBP. To this end, the photogrammetric measurement results obtained using a Photogrammetrical Body Explorer system were used. In a healthy person, all AT are balanced, and maintain the correct posture. The occurrence of a specific AT is indicated by shortenings, which result from excessive tension of the AT, or a part thereof. Therefore, standards for the healthy individual parameters chosen to describe the AT were developed. Deviations from the designated standards testify to the occurrence of shortening on the corresponding section of one of the two cooperating AT. Created models of AT became the basis for the development of rules for a decision support system for physiotherapists. The system is based on fuzzy logic. Its main task is to identify which of the considered AT is dominant for a specific patient. The idea and the gathered experience can be the starting point for further research and development in the field of using data mining and artificial intelligence methods in supporting medical diagnosis based on the assessment of the HBP.

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Virtual Tooth Extraction from Cone Beam Computed Tomography Scans

Marta Orlowska[1], Rafal Jozwiak[2] and Piotr Regulski[3]

[1] Institute of Radioelectronic and Multimedia Technology, Faculty of Electronics and Information Technology, Warsaw University of Technology,
Nowowiejska 15/19, 00-665 Warsaw, Poland,
[2] Faculty of Mathematics and Information Science, Warsaw University of Technology,
Koszykowa 75, 00-662 Warsaw, Poland,
[3] Department of Dental and Maxillofacial Radiology, Faculty of Medicine and Dentistry, Medical University of Warsaw,
Nowogrodzka 59, 02-006 Warsaw, Poland
R.Jozwiak@mini.pw.edu.pl

The aim of this paper is to extract a tooth from a Cone Beam Computed Tomography (CBCT) scan. The segmentation combined with the visualization allows for accomplishing the concept of the virtual extraction, which is extremely useful for digital implant treatment planning. We propose a two-step segmentation, which contains a supervised pixel-classification followed by a level set method. The proposed method is implemented as an ImageJ plugin and complemented by a convenient and intuitive user interface. Initial verification and conclusions are also presented.

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Image Analysts' Eye Movement Patterns during Intravascular OCT Interpretation

Elżbieta Pociask[1], Magdalena Ślęzak[2], Kamila Kosińska[2], Klaudia Proniewska[2], Krzystof P. Malinowski[2], and Piotr Augustyniak[1]

[1] AGH University of Science and Technology, Department of Automatics and Biomedical Engineering, Krakow, Poland
[2] KCRI, Krakow, Poland
epociask@agh.edu.pl

The evaluation of eye movement patterns during the analysis of medical images could be especially helpful in assessing the efficiency of this process. It could further influence the improvement and duration of the analysis as well as the learning pathways. In the presented study Eye-Tracker was used to evaluate analysts' eye-paths during assessments of intravascular Optical Coherence Tomography (OCT) images. The various levels of experience of analysts, that took part in the study, led to noticeable differences in the interpretation of vessel's images. As expected, the analysis duration was longer for the analyst in training (107 min) than for the experienced one (69 min).

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Analysis of Various Factors Impact on Safety of Armored Vehicle Crew During an IED Explosion

Marek Gzik[1], Wojciech Wolański[1], Bożena Gzik-Zroska[2], Kamil Joszko[1],
Michał Burkacki[1], Sławomir Suchoń[1]

[1] Silesian University of Technology, Faculty of Biomedical Engineering, Department of Biomechatronics,
[2] Silesian University of Technology, Faculty of Biomedical Engineering, Department of Biomaterials and Medical Devices Engineering
F. D. Roosevelta 40, 41-800 Zabrze
w.wolanski@polsl.pl

Numerical modeling of an IED explosion under an armored vehicle is one of the primary methods of the evaluation of the vehicle crew safety. In the presented paper the authors use numerical models to assess the influence of acceleration pulse on the soldier's body. This work focuses on the ergonomic aspects of the crew compartment. Simulations show the differences in injury levels depending on various factors e.g. the location of an explosion which changes the direction of load. The simulations results include the injury criteria and kinematics of the soldier's body. The outcomes enabled the determination of factors and elements of the compartment which can be dangerous for soldiers.

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Frequency modeling and numerical simulations of uterine contractile activity.

Joanna Gilewska[1] , Marta Borowska[1], Paweł Kuć[2], Piotr Laudański[2]
[1]Faculty of Mechanical Engineering, Bialystok University of Technology, Wiejska 45C, 15-351 Białystok, Poland
[2] Department of Perinatology and Obstetrics, Medical University of Bialystok, Bialystok, Poland
Email of Corresponding Author: j.gilewska@wp.pl

Nowadays, gynecological diseases are frequently occurring health problems. Therefore, monitoring the uterine contractile activity could be useful in controlling the course of pregnancy and labor as well as diagnosing the causes of irregular or painful menstruation, diseases such as infertility, endometriosis, and uterine fibroids.

The aim of this study is to develop a physiological model of uterine contractile activity and to conduct numerical simulations on the obtained model. This model was based on modified primary ion currents described by Hodgkin and Huxley, by introducing different voltage dynamics of individual ion channels. However, the thesis mostly refers to the articles and research conducted by S. Rihana, J. Terrien, C. K. Marque. What may constitute an obstacle is the fact that the research is still in progress. Due to bioethical issues human uterine contractile activity is measured only on animals (rats, rabbits) which may result in obtaining just estimated data. In addition, figures also differ considering various trimesters of pregnancy or a health condition of particular woman. Therefore, such models of signals are being created to gain some knowledge on formation of uterine contractions. What is worth noticing is the possibility of changing the parameters of individual ion channels, their elements concentration and finally observing their influence on amplitude, duration or shape of the signal.

Furthermore, the material of this study includes descriptions of structure, functions of the uterus, possible ways to register its contractile activity and details regarding the steps of creating the model. What is more, I have presented a comparison of the designed model and natural uterine contractions. The material of this study, obtained from Department of Perinatology and Obstetrics Medical University of Bialystok, consists of uterine contractions extracted from EHG signals received from women at risk of preterm pregnancy between 24^{th} and 28^{th} week. The signals analyzed were raw, that is without using any pre-processing. During research the signals were recorded from 8 channels distributed in 8 different muscles on the outside of the abdomen(placed directly above the myometrium). In order to compare natural signals with my model, they were processed using Butterworth filter.

The model successfully recreates the generation of a single spike or train. The shape and duration of a single spike corresponds with the data from the source literature. It also enables analysing the ion channels involved in the formation of uterine contractions. Similarly, makes it possible to analyse a significant effect of ion conductivity on a cell. Observing the electrical activity of the uterus over time while changing parameters, such as ion current, allows creating various examples of the functioning of uterine cell. For example, the model can serve as a platform for predicting the effects of the experimental treatment. Using the model we can study cellular response to uterine ion channel inhibitors or catalysts and the changing rate of the reactions occurring in myocytes.

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Mathematical modelling of relative and absolute blood volume changes during haemodialysis

Leszek Pstraś, Jacek Waniewski
Nalecz Institute of Biocybernetics and Biomedical Engineering, Polish Academy of Sciences
Ks. Trojdena 4, 02-109 Warsaw
leszek.pstras@ibib.waw.pl

During haemodialysis (HD) total blood volume decreases due to imbalance between the ultrafiltration rate in the dialyzer and the rate of plasma refilling from the interstitial space. If the blood volume falls too low or too rapidly, it can lead to intradialytic hypotension, which is highly problematic both for the patients and the medical staff [1]. Monitoring blood volume changes during HD is hence very useful for delivering the prescribed fluid removal while maintaining cardiovascular stability. Since it is not feasible to measure directly the absolute blood volume changes during HD, in clinical practice the relative blood volume (RBV) changes are estimated from online optical measurements of haematocrit or haemoglobin concentration in the blood lines. However, these measurements are subject to certain limitations and their accuracy in describing the absolute blood volume changes is still under debate [2,3]. Therefore, the aim of this study was to compare the commonly used RBV estimates with the absolute blood volume changes during HD through mathematical modelling.

The analysis was performed using a new multi-compartmental model that integrates the model of cardiovascular system and its baroregulation with the models of whole-body water and solute kinetics, including the transcapillary transport of water, small solutes and proteins, and the vascular refilling through the lymphatic system. The model describes a two-phase blood flow (red blood cells suspended in plasma) with water and solute exchange across the red cell membrane, which makes it particularly appropriate for analysing whole-body and central haematocrit variations due to dialysis-induced blood volume and osmolarity changes. We analysed a typical 4-hour HD session in a reference patient – a 70-kg male with 2.3 litres of excess fluid. All model parameters were assigned based on data available in physiological literature.

We showed that RBV reduction during HD calculated from haematocrit variations in the arterial blood line can underestimate the absolute blood volume reduction, mainly due to osmotic water shifts between plasma and red blood cells affecting the total red cell volume. RBV reduction calculated from variations of haemoglobin concentration is a much more reliable estimate of absolute blood volume decrease during HD. According to the model, the ratio between the whole-body haematocrit and central haematocrit increases only slightly during HD (< 0.5%), and hence it does not affect significantly the haematocrit-based RBV estimation.

Tracking haematocrit or haemoglobin variations, as done by different RBV online monitors, is not equivalent for the purpose of assessing blood volume changes during HD. With the relatively stable ratio between the whole-body haematocrit and central haematocrit, variations of the latter can still be used as a basis for estimating blood volume changes during HD, but such an estimation should be ideally corrected for the changes in red cell volume, either by some empirical formula or through optical measurements of mean corpuscular red cell volume.

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Changes in blood gases during therapeutic thoracentesis in real and virtual patients.

Anna M. Stecka[1], Marcin Michnikowski[1], Elżbieta M. Grabczak[2], Krzysztof Zieliński[1], Monika Zielińska-Krawczyk[2], Piotr Korczyński[2], Krzysztof J Pałko[1], Rafał Krenke[2¶], Tomasz Gólczewski[1¶]

[1]Nalecz Institute of Biocybernetics and Biomedica Engineering, PAS. Trojdena 4 st, Warsaw, Poland
[2]Department of Internal Medicine, Pulmonary Diseases and Allergy, Medical University of Warsaw. Banacha 1A st., Warsaw, Poland
[¶]These authors contributed equally to this work.

astecka@ibib.waw.pl

Literature shows contradictory data on changes in the blood oxygen (PaO2) and carbon dioxide (PaCO2) tensions during therapeutic thoracentesis; also the mechanism of those changes are not clear. The aim of this study was to examine the PaO2 and PaCO2 tensions in real patients and in our virtual patient and to analyze when, how and why the tensions can change.

The pleural pressure (Pp), PaO2 and PaCO2 as well as some other factors were measured during thoracentesis in 45 patients with pleural effusion using a measurement system developed by us [1]. Previous analyses of Pp [2,3] was supplemented by analysis of PaO2 and PaCO2; in particular, tensions changes were correlated with changes in Pp and in the amplitude of breathing-induced fluctuations of Pp. Then, our previously modified virtual patient [3] was adjusted to enable simulation also gas transport and exchange.

In both real and virtual patients, PaCO2 did not change or changed insignificantly, whereas PaO2 varied or not, depending on changes in Pp; i.e. when Pp fell significantly during pleural fluid withdrawal, PaO2 also fell at that period (Fig.1).

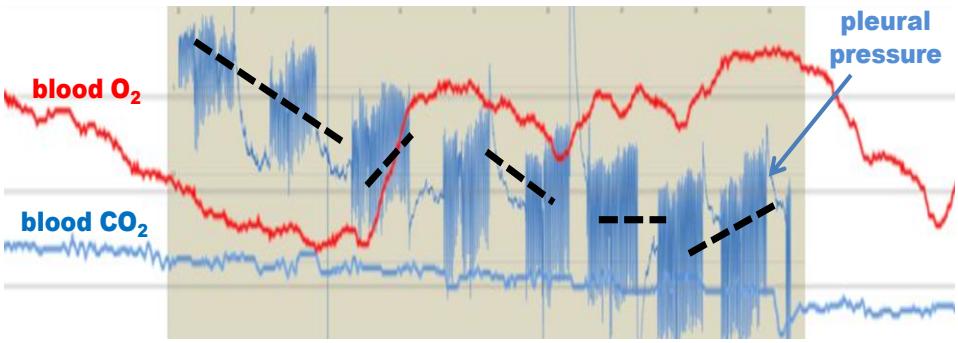

Fig.1. An example of synchronized plots of the pleural pressure (measured by own manometer) and levels of O_2 and CO_2 in peripheral blood (measured by a commercial oximeter) in a real patient

Simulations suggested that despite pleural fluid withdrawal, dependent lung regions might be still collapsed, which led to significant fall of Pp caused by expansion of ventilated regions having nonlinear compliance (the compliance decreases with the expansion). Therefore, PaO2 could fall for the two following main reasons: (a) still collapsed regions were not ventilated while decreased perivascular pressure dependent on low Pp expanded pulmonary vessels increasing blood flow; hence, a considerable shunt appears; (b) lung edema might appear as a consequence of that perivascular pressure decrease, which disturbed O2 diffusion and thus enhanceed the shunt. Since CO2 diffuses much easier and the minute ventilation is controlled mainly by PaCO2, thoracentesis does not impact PaCO2. Concluding, the doubt - whether PaO2 changes or not during thoracentesis - disappears when Pp is considered.

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Numerical modelling of direct biophysical effects of electromagnetic low or intermediate frequency influence in the user of wearable medical devices

Patryk Zradziński, Jolanta Karpowicz, Krzysztof Gryz
Central Institute for Labour Protection – National Research Institute (CIOP-PIB)
Czerniakowska 16, 00-701 Warszawa, Poland
Corresponding Author: Patryk Zradziński, pazra@ciop.pl

The direct biophysical effects in the human body, caused by electromagnetic field (EMF) exposure at low or intermediate frequency (up to 10 MHz), is evaluated by numerical calculations of the electrical potentials (Ein) inside conductive tissues. Results of calculations are comparing with the limits provided by international guidelines on the protection against electrostimulation in nervous system caused by such exposure. In the body of the medical implant user, an induced Ein has different distribution comparing to the people without implant, what may increase EMF hazards for implant user. Legislation and guidelines require that EMF exposure is evaluated with attention to this potential hazard [ICNIRP, Health Physics 2010, 818-836; European Directive 2013/35/UE; Polish Journal of Law 2016, item 950]. Variety of EMF exposure sources and increasing number of medical implants (over 100 000 in Poland) are in use today, but the majority of studies covered the safety of cardiac implants where mobile wireless communication systems (e.g. mobile phones) are in use. The aim of this study was to evaluate the direct biophysical electromagnetic hazards for the users of partly implanted (wearable) medical devices present near to sources emitting low or intermediate frequency EMF of dominating magnetic component (MF). This problem was not studied before, but it is important for the evaluation of electromagnetic hazards in the work and general public environments, as well as medical use of EMF (with respect to patient's exposure).

Numerical models of typical sources of low or intermediate frequency MF were worked out and validated by measurements of MF distribution near the real devices. Wearable medical devices were modelled together with the user's body: hearing implants of bone conduction type (HIs) and insulin pumps (IPs) [1,2]. Values of E_{in} in the tissues of implant user were calculated by finite integration technique in the high resolution, heterogeneous body phantoms of and validated by published referenced data on MF exposure effects in generic models of exposure scenarios. Modelled MF exposures scenarios may be considered as representative for such sources as: electro-thermic gastronomy or industrial appliances, or magneto therapeutic applicators – where local MF may significantly exceed the typical level of public exposure.

It was found that the use of HIs significantly increase the level of induced Ein - up to 4 times, depend on the exposure scenario (the spatial distribution of EMF which affects the head, determined by the dimensions of EMF source, its location against head), as well as the implant user individual properties (thicknesses of tissue adjacent to implant and type of implant). Near the needle of IPs up to 3.2 times (steel needle) and up to 1.4 times (Teflon needle) higher induced Ein was found (depend on the exposure scenario).

The use of HIs or IPs (equipped with steel needle) may be a contraindication for the work activities or receiving therapy involving exposure to low or intermediate frequency MF. Presented studies do not replace the need for studies involving the volunteers and other possible interaction of EMF, such as for example direct influence on the function of electronic circuits in the implant and its malfunction.

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Mathematical model of methylation and demethylation of cytosine forms

Karolina Kurasz[1]*, Dorota Hudy[1], Magdalena Skonieczna[1], Ewelina Zarakowska[2], Krzysztof Fujarewicz[1], Joanna Rzeszowska-Wolny[1]

[1]Silesian University of Technology
ul. Akademicka 16, 44-100 Gliwice, Poland
[2]Department of Clinical Biochemistry, Faculty of Pharmacy,
Collegium Medicum in Bydgoszcz,
Nicolaus Copernicus University in Toruń,
Karlowicza 24, 85-092 Bydgoszcz, Poland
*Karolina Kurasz e-mail: karolina.kurasz@polsl.pl

Aim: The aim of the study is to propose mathematical model of methylation and demethylation of cythosine forms, which is able to predict amount of different cythosine forms based on biological data. Second aim of this work is selection of model structure, to find out which TET protein work on next stages 5-methylcythosine's transformation.

Methods: The model is described by six ordinary differential equations. To calculate parameters of the models we used Nonnegative Linear Least Squares which compute a nonnegative solution to a linear least squares problem, and the predictive ability of the model was based on leave-one-out cross-validation which is a model validation technique for evaluating how the results of a statistical analysis will generalize to an independent data set. The model based on data from biological experiments for five different cell lines (cancer and normal cell Line). The cancer lines were: HCT 116, K562, Me45, Raji, and the normal one was NHDF.

Results: Our research was focused on places where TET proteins work. The best model structures suggests that in the process of transformation 5-mC to 5-hmC TET3 proteins are not involved and between 5-hmC and 5-fC TET2 proteins are not involved.

So far in the reaction of 5-mC conversion in 5-hmC no direct enzymatic activity of TET3 has been demonstrated [1][2]. The fact that the TET3 does not work between 5-mC and 5-hmC has been shown in the model. Comparison of model and experimental data shows differences, forexample levels of uracil and 5-carboxylcytosine are much lower or higher than the experiments show. Those differences may suggest another processes of eliminating those modifications from the genome.

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A hybrid interface to connect an IABP balloon to a circulatory system hybrid simulator to improve its assistance abilities

Maciej Kozarski, Krystyna Górczyńska, Krzysztof Jakub Pałko, Marek Darowski
kpalko@ibib.waw.pl
Nalecz Institute of Biocybernetics and Biomedical Engineering, Polish Academy of Sciences
ul. Ks. Trojdena 4 , 02-109 Warszawa

Intra-aortic balloon pump (IABP) assistance successfully practiced from above 60 years is still the most widely used mechanical support for a failing heart, especially in post-operative conditions to reduce myocardial work and to improve heart muscle perfusion [1]. Recent works on improvement of the balloon properties [2] and the IABP control systems and devices as well are continued. Universal equipment convenient to perform very precise and repeatable research investigations of the IABP is a hybrid circulatory system simulator developed jointly by the Nalecz Institute of Biocybernetics and Biomedical Engineering (IBIB) of the Polish Academy of Sciences (PAN) from Warsaw and the Institute of Clinical Physiology (IFC) of the Italian National Council of Research (CNR) from Pisa.

To put the research values of the simulator to good account it occurred indispensable to elaborate a specific hybrid interface to enable an intra aortic balloon including to the circulatory system which in its original form is a computer program. The hybrid simulator contains four modules playing a role of impedance transformers (TR) which enable to switch on external physical devices in any of four points of the circulatory system mathematical model, to be investigated. From the model of the circulatory system a physical segment was excluded to represent a section of the aorta into which a physical IABP balloon can be inserted. Inlet and outlet of the separated aorta section (placed in a rigid chamber) are hydraulically joint to input chambers of two from among four TRs of the simulator. Whereas, an internal chamber of the interface is connected to a chamber of the third TR of the simulator to enable involving the additional condenser on its numerical side; its role is to change the resultant value of the compliance of the excluded aortic section. The discussed resultant compliance can be linear (with constant value) or nonlinear - modeling variable stiffness of a native aorta.

The presented solution was tested with positive results. Preliminary results of the IABP investigations in a form of PV loops obtained on the circulatory system hybrid simulator equipped with the above discussed hybrid interface presented in the poster give a clear evidence that the elaborated interface allows to enlarge the range of investigations performed on the circulatory system hybrid simulator. It can also be satisfyingly used in education of medical students and technical stuffs working in medical projects.

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Adaptive lung ventilation minimizing the work of breathing

Krzysztof Zieliński, Łukasz Kozarski, Maciej Kozarski, Marek Darowski
Nalecz Institute of Biocybernethics and Biomedical Engineering, Polish Academy of Sciences
Ks. Trojdena 4 Str., 02-109 Warsaw
kzielinski@ibib.waw.pl

Long-term ventilation of the lungs is a complex process and for years has been a subject of model and clinical investigations. Both – clinicians and bioengineers aim at development of ventilation methods that would minimize bad side effects appearing during generating positive pressure in thorax by a respirator. Especially, in cases of lungs pathology alveoli are at risk to be destroyed mechanically (baro- and volumetrauma) if ventilation parameters are not adjusted properly. As it was proved [1, 2, 3] spontaneous breathing is performed by a patient with frequency that minimizes the work of breathing. So, in order to conduct artificial ventilation with a maximal comfort for a patient it is postulated that a ventilation frequency should be set by a anaesthesiologists on a value, that corresponds to a minimal work of breathing for a particular patient. But this chosen, optimal frequency of breathing changes during prolong artificial ventilation as airway resistance and compliance of lungs may change. So, adaptive lung ventilation must be applied to follow these changes and this concept was realized in a modern respirator produced by a Swiss company Hamilton Medical Inc. in 1994. Adaptive ventilation algorithm was based on a lung mechanics model proposed by A.B. Otis at al [2] and modified by F. Tehrani [3]. A drawback of this solution is that an adjusted frequency of ventilation depends on fidelity of on-line calculation of airway resistance and lung compliance. A high fidelity of lungs parameters on-line calculation in clinical environment is practically impossible to achieve, so the question is how far these calculated values of lungs parameters are far from their actual values. Besides, it is also difficult to assess an error connected with the use of a lung mechanics model, that is old, very simple, linear and not adequate for description of lungs mechanics, that according to our knowledge today is very complex in cases of lungs pathology.

Our original concept of adaptive ventilator frequency adjustment (patent pending) is based on automatic seeking of the minimum of the work of breathing that is calculated on-line. Routine in intensive care measurements of pressure and flow of inspiratory gases done by each type of a respirator deliver the current values of these parameters to calculate the work of breathing for each ventilator cycle. The values of work of breathing obtained for two successive cycles are compared and a sign of their difference decides if a regulator increases or decreases ventilator frequency.

Computer simulations of the described above ventilator system connected with lungs mechanics model was conducted. The obtained results of these simulations show how the whole system of adaptive lungs ventilation behaves, especially how it reacts to dynamic changes of airways resistance and lungs compliance.

From the clinical point of view it is very important that the ventilator system generates small oscillations of tidal volume of unpredictable frequency when its working point is close to a minimum of work of breathing. Such oscillations are a characteristic feature of spontaneous breathing. It means that “noisy” ventilation with a variable tidal volume improves respiratory function of a patient, arterial oxygenation and reduces histological damage in comparison to standard, conventional ventilation with constant tidal volume.

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The influence of atherosclerosis on the delamination properties of human thoracic aorta

Marta Kozuń, Celina Pezowicz
Wroclaw University of Science and Technology, Department of Biomedical Engineering, Mechatronics and Theory of Mechanism, Lukasiewicza 7/9, 50-371 Wroclaw, marta.kozun@pwr.edu.pl

Aortic delamination is a result of negative remodeling of aortic wall structure and is associated with development of atherosclerosis. Atherosclerosis changes the mechanical properties of the blood vessel wall and its individual layer (media, adventitia, intima). Despite only three authors [1-3] have attempted to describe the mechanism of the aortic dissection process but the subject of research were healthy arteries or arteries with early stage of atherosclerotic lesions. There is still no answer how development of atherosclerosis affect the resistance to dissection of human artery and the mechanism of the aortic dissection has not been identified and explained yet. The aim of this research was a determination of the mechanical properties of interface between the individual layers of human aortic wall with different stages of atherosclerosis.

The subject of the research was 91 human thoracic aorta collected "post mortem". First of all the histological examination were conducted and the arteries were classified based on the six-stage scale of atherosclerosis proposed by Stary. The group of healthy, pathological unchanged vessels (n=17, 4 woman, 13 men) were classified as stage I on the histological scale of Stary and constituted the control group. 74 thoracic arteries were classified to the group of pathological vessels and they were divided into 5 groups. Each group corresponds to the stage of the disease according to the Stary's scale. Then each artery wall was punched out in two perpendicular directions: longitudinal and circumferential and 124 specimens were obtained.

In the next step the specimens were initially dissected about 5mm and they were mounted in the grips of an MTS Synergie 100 testing machine. We analysed dissection between: (1) the adventitia and the media-intima complex (A-MIC) and (2) the intima and the media-adventitia complex (I-MAC). The mechanical properties of the interfaces were determined based on the peeling test (T-peeling test configuration) with at a constant rate of 2mm/min. During test, propagation of the previously initiated dissection was forced and the changes in the value of force and displacement were recorded. Next the force/specimen width vs. displacement curves were prepared and the mechanical properties: stiffness coefficient (k), energy dissipated during delamination (W), the maximum value of force (F_{MAX}) and average value of force during delamination (F_{AVER}) were calculated.

The results show the mechanical properties undergo significant in parallel with the development of atherosclerosis. In the case of the A-MIC interface the highest values of energy and average force were obtained for healthy tissue: F_{AVER}=47.35mN/mm, W=7.7mJ/cm^2, for circumferential specimens and F_{AVER}=54.92mN/mm, W=9.3mJ/cm^2, for longitudinal specimens. This group is also characterized by the lowest values of stiffness coefficient. The values of energy and mean force decrease from normal vessels until stage IV (F_{MEAN} = 23.00 mN/mm ,W = 4.8 mJ/cm^2, for circumferential specimens and F_{MEAN} =33.45 mN/mm, W = 5.6 mJ/cm2, for longitudinal specimens) in the development of atherosclerosis and then they increase for V and VI group. In the case of stiffness coefficient the trend is an opposite. In the case of both A-MIC interface and I-MAC interface, higher values of the mechanical properties were obtained for longitudinal specimens.

The research conducted in this study indicate that development of atherosclerosis decreases resistance of the thoracic aortic wall to delamination, with the greatest risk of dissection at stage IV. The I-MAC interface is most susceptible to dissection due the fact that lesions develop within the intima. The values of mechanical parameters of A-MIC and I_MAC interfaces are directional, indicating that atherosclerosis does not lead to the disappearance of the anisotropy of the mechanical properties. Lower values of energy and force obtained for the circumferential direction explain why, as demonstrated by clinical practice, delamination of the thoracic aortic wall propagates in this direction.

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Mechanical investigation of the annulus-endplate anchorage failure

Magdalena Wojtków, Celina Pezowicz
Department of Biomedical Engineering, Mechatronics and Theory of Mechanisms, Wroclaw University of Science and Technology, ul. Lukasiewicza 7/9, 50-371 Wroclaw, Poland
magdalena.wojtkow@pwr.edu.pl

The intervertebral disc comprises three regions- the nucleus, annulus fibrosus and endplate, which consists of a cartilage endplate- *CEP*, subchondral bone- *SB* and growth plate layer- *GP*. The endplate fulfills a very demanding mechanical role in the spine biomechanics- the intervertebral disc through collagen fibers transport loads directly to the endplate structure, where stresses are distributed evenly on the vertebra. Therefore, examination of both microstructure and mechanics of the collagen fiber anchorage into endplate is a critical element of the spine biomechanics in-depth understanding. Especially important is an analysis of integration of the annulus-endplate. Despite the fact, that recently knowledge of the architecture of this connection was widerly investigated [1], the mechanical properties of annulus-endplate anchorage are still unknown. The aim of this study was to investigate the mechanical and microstructural properties of the annulus-endplate anchorage failure.

Six lumbar motion segments were extracted from pig spines and trimmed to provide specimens of vertebra-endplate-disc-endplate-vertebra from the anterior and the posterior regions of the disc. Each sample was kept hydrated with physiological saline before test (approx. 5 min). Samples were subjected to cyclic preloading followed by the axial tension. Tension test were carried out with a displacement rate of 0.3 mm/min until the annulus-endplate anchorage failure. Tests were conducted on the MTS Synergie 100 testing machine using specially designed system to prevent separation of the endplate from the vertebral body. For the microstructural studies samples were fixed in 10% glutaraldehyde and decalcified. 30µm thick slices in sagittal plane were obtained by cryosectioning and examined using optical microscope (Zeiss Stereo Discovery V20).

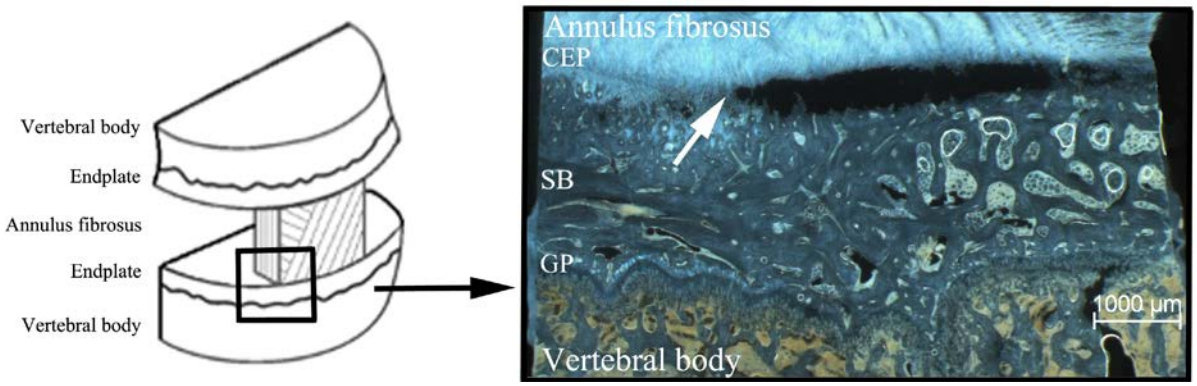

Fig.1. Schematic representation of the sample and zoom into the annulus-endplate anchorage failure occurred at the cement line (indicated by the white arrow).

Conducted studies shows that failure of the endplate-disc-endplate structure occurs respectively with the average force 315.72 ± 109.60N and 349.51 ± 66,51N, in the anterior and posterior region (Fig.1.). Extension of samples were equal 9.34 ± 0.98 mm and 4.74 ± 0.48 mm (statistical significance, p=0.043) in the anterior and posterior part of the disc. It is wort to notice that in the anterior region, pure annulus-endplate anchorage failure was observed. In comparison, for each sample from the posterior region, separation of the endplate from vertebra was observed. This effect occurred always in the upper endplate (according to the motion segment).

Failure of the annulus-endplate anchorage in the anterior region occurred with a force about 300 N. The integration of the annulus-endplate was stronger in the posterior region, where similar forces caused endplates separation from vertebrae. Anchorage failures were more often observed at the tidemark (interference between the annulus fibrosus and *CEP*), rather than at the cement line (interference between *CEP* and *SB*).

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The numerical analysis of the damping properties of soft tissue and bone elements in lumbar-pelvic complex under impact load

Katarzyna Arkusz[1], Tomasz Klekiel[1], Grzegorz Sławiński[2], Romuald Będziński[1]
[1]Division of Biomedical Engineering, Department of Mechanical Engineering, University of Zielona Gora, Licealna Street 9, 65-417 Zielona Gora, Poland
[2]Faculty of Mechanical Engineering, Department of Mechanics and Applied Computer Science, Military University of Technology, Kaliskiego Street 2, 00-908 Warsaw, Poland
k.arkusz@ibem.uz.zgora.pl

The energy dissipating damping mechanism in bone-tissue structures is extremely complicated due to the varying material characteristics of anatomical structures and complex boundary conditions. Damping properties of soft tissue were included in the experimental and numerical analysis using only the damping coefficient calculated for the whole structure and not for single ligaments/muscles/discs. Further analysis was carried out to examine the distribution of mechanical energy in muscles and ligaments and this explained the protective role of ligaments, rapidly absorbing the energy and transfer it gradually into muscle during initial force reaction [1]. Hitherto, performed analysis aiming to define the fracture mechanism of the lumbo-pelvic complex (LPC) under a side impact load was limited to calculation of stress distribution and critical occurring in the LPC with the main focus was being to determine the location of bone fracture and the value of acting forces.

The aim of this research was to determine the influence of ligaments and muscle force on stiffness and protection of lumbar-pelvic complex. The activation order of further ligaments, both pelvic and lumbar vertebral, under impact load was indicated and the influence of disc stiffness on vertebral column stabilization was also determined. The susceptibility of spinal buckling increases with increase to the elastic modulus of vertebra, especially in the L4-L5 spine segment. In contrast to the literature models, the elaborate LPC FE model consists of lumbar spine and pelvis which allows us to determine the damping coefficient of single structures and the energy transfer between pelvic plates and sacrum bone [2]. The obtained results are a significant complement to the pelvis fracture mechanism under impact load, as described in the literature.

Firstly, we determined the stress distribution in osteoarticular structures and the role of ligaments in LPC under impact load. Initial impact load results indicated rapid growth of stress and a maximum stress concentration value of 82.1 Mpa localized in the left ischium for 0.012s, then distributed to right-side sacroiliac cartilage. The maximum stress in the sacrum bone was recorded in the first 0.017s (5.67 MPa) and localized at the height of the second sacral foramen. The energy transmission up to the lumbar spine was seen predominantly during 0.014-0.0165s.

Further analysis focused on strain distribution and energy transfer in lumbar spine structures. The maximum force reaction was observed on the S1/L5 facet joint, value 140 N. The energy decreased on each segment of lumbar spine over time, which may indicate the energy dissipation on each side's appendages.

The performed analysis using the elaborated LPC model indicated a significant role of the sacrotuberous ligament in stress/strain distributions and energy dissipation under impact load. According to ligament force, the main role in stress/strain/energy distribution is played by: sacrotuberous ligaments, snterior sacro-iliac ligaments and superior pubic ligaments, which complies with Hammer's analysis [3].

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A prophylactic program in degenerative changes in the hip joint - suggested exercise and equipment

Piotr Borkowski[1], Jolanta Zuzda[2], Robert Latosiewicz[3], Katarzyna Stepaniuk[1]
1 Bialystok University of Technology, Faculty of Mechanical Engineering, Department Biocybernetics and Biomedical Engineering, Wiejska 45 c,15-351 Bialystok
2 Bialystok University of Technology, Faculty of Management, Department of Tourist Economy, Ojca Tarasiuka 2, 16-001 Kleosin
3 Medical University of Lublin, Faculty of Health Sciences, Department of Rehabilitation and Physiotherapy, Magnoliowa 2, 20-143 Lublin
p.borkowski@pb.edu.pl

1. Aims

Pelvic asymmetry - bad pelvis and hip position- can cause functional disorders of the entire motion and degenerative changes of hip joint. The consequences are difficulties with movement or sleeping on the side of the painful hip which significantly reduces the quality of life. Hip problems develop gradually over weeks, months and even years. Many difficulties caused by motion disorders, especially the pelvis and spine, are reversible. Early intervention and a well-programmed physical training program can help reduce symptoms and pain, increase the range of motion, and reduce the negative impact of joint damage and prevent further damage [1]. For some hip disorders, it is enough to improve the elasticity of shortened and tight muscles around the joint, which can be done with the help of a physiotherapist, either alone or with a suitable device.

2. Methods

We have developed a new program for rotational training and supporting device which enables to perform such program correctly. Basically, this program consist of simple movements low/medium intensity. In this kind of movement the recruitment of muscle groups occurs that are practically not stimulated in the linear movements. Moreover, rotational movements can improve the structure and functions of the ligaments, tendons and joints, increasing flexibility [2, 3].

The aiding device has been designed using parametric CAD software. The main structural assumptions are: hip joint rehabilitation and co-operating muscles, active one-legged exercises without resistance or dosed resistance, two configurations (flexion–extension and internal–external rotation) with adjustable angular range, simplicity of construction, small dimensions, mobility and packaging.

3. Results

As the result of research and design work a workout program and specially designed device was developed. Movement is performed in two planes (sagittal and transverse) with the help of auxiliary device.

4. Conclusion

Based on the anatomy and biomechanics of the lower limb and the review of the existing rehabilitation equipment, a new rehabilitation program for the hip joint has been developed with supporting device. The device was reported in the Polish Patent Office (P.420968)

Acknowledgments

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Low-frequency fluctuations of postural sway velocity in Parkinson's disease

Klaudia Kozlowska[1], Miroslaw Latka[1], Slawomir Budrewicz[2], Magdalena Koszewicz[2], Bruce J. West[3]

[1] Department of Biomedical Engineering, Wroclaw University of Science and Technology, Wybrzeze Wyspianskiego 27, 50-370 Wroclaw, Poland
[2] Department of Neurology, Wroclaw Medical University, Borowska 213, 50-556 Wroclaw, Poland
[3]Army Research Office, Information Sciences Directorate, Research Triangle Park, 27709, USA
Email of Corresponding Author: klaudia.kozlowska@pwr.edu.pl

Aims. Postural instability is one of the cardinal symptoms of Parkinson's disease (PD) - the second most common neurodegenerative disorder, after Alzheimer's disease, with an overall prevalence of 300 cases per 100,000. The mean age of onset of PD is around 60 years and the prevalence of disease increases with age. Thus, the impairment of balance control in PD patients may result not only from the pathophysiology of the disease but also from aging. |There is an ongoing search for unambiguous signatures of Parkinson's disease in temporal evolution of center of pressure (COP) time series of static posturographic tests.
Methods. Most measures of balance control are derived from displacement of the center of pressure. However, there is an evidence that balance control is more likely to be velocity-based than position-based. We performed Romberg test (eyes open and eyes closed) during quiet, narrow based stance of $n = 30$ PD patients (PDP) in ON state on a static posturographic platform and compared the results with those of $n = 30$ age-matched senior controls (HSC) and $n = 60$ young controls (HYC). We applied low-pass wavelet differentiator filter to COP time series to calculate sway velocity in mediolateral and anterior-posterior directions. The level crossing statistics was determined for sway velocity time series.
Results. In closed eyes condition, the mediolateral zero-level crossing rate for HSC 0.86 ± 0.10 s was significantly higher than that of PDP 0.67 ± 0.13 s ($p = 1.5\times 10^{-7}$). This quantity effectively differentiated between HSC and PDP (90% sensitivity and 82% specificity).
Conclusion. We identified a property of low-frequency fluctuations of mediolateral postural sway velocity unique for Parkinson's disease. Further research is needed to determine the onset of observed pathological changes and verify whether they can become a foundation for low-cost, early diagnosis of PD.

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Keywords:
static posturography, Parkinson's disease, wavelet differentiator filter, level crossing statistics

The mechanical properties of the denticulate ligament in different levels of the spine

Sylwia Szotek[1], Katarzyna Polak-Kraśna[2], Diana Petryczuk[1], Celina Pezowicz[1]
[1]Department of Biomedical Engineering, Mechatronics and Theory of Mechanisms, Wrocław University of Science and Technology, Łukasiewicza 7/9, 50-371 Wrocław, Poland
[2]Department of Mechanical Engineering, University of Bath, BA2 7AY, United Kingdom
sylwia.szotek@pwr.edu.pl

The denticulate ligament (DL) (Fig. 1A) is a structure allowing to maintain a correct anatomical position of the spinal cord within the vertebral canal [1]. It plays significant role in protecting him from overloading during trauma. Unfortunately, so far very few studies concerning mechanical properties of denticulate ligaments are available and precise and detailed analysis of their biomechanical characteristics has not been conducted. The aim of this study was to perform an experimental determination of stress-strain characteristics of the denticulate ligament through a tensile test and to verify if their properties change at cervical and thoracic levels of the spine. Obtained results are preliminary and are considered by authors as a starting point to future research.

Experimental specimens were denticulate ligaments dissected from different vertebral levels of porcine spinal cords. The mechanical characteristics of all the samples were determined under the uniaxial tensile test in an MTS® Synergie 100 testing machine (MTS Systems, Inc., USA). The specimens were preconditioned by three loading-unloading cycles to obtain reproducible identical curves. The test was conducted at a constant speed of 2mm/min until rupture [2]. During each testing, the values of the tensile force, the displacement of upper jaw and the time were recorded. Stress-strain curves were obtained on the basis of initial ligament lengths and cross-sectional areas. The Young's modulus was calculated from the linear part of the stress-strain curve.

Nonlinear stress-strain curves were obtained from each tested specimen (Fig.1B). Samples dissected from the cervical spine, in most cases, were characterized by higher values of mechanical properties. The ultimate tensile strength of specimens from cervical spine was about 30% high then the specimens from thoracic level and it was about 0,5 MPa. The highest elastic modulus was obtained for ligaments from the upper cervical vertebras level and it was 2 MPa.

A) B)

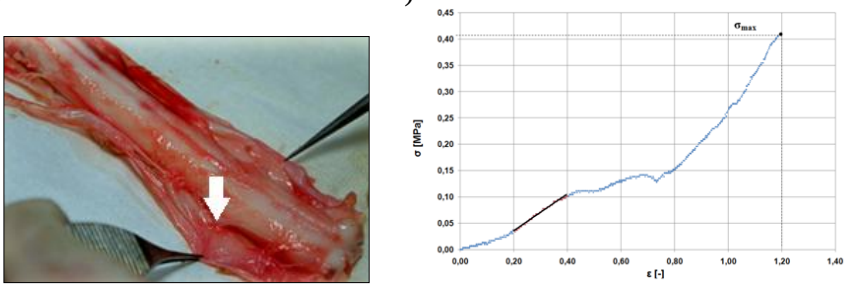

Fig.1. A) The denticulate ligament (white arrow); B) the stress-strain characteristic obtained for the denticulate ligament samples from thoracic spine level

The obtained data is relevant for modeling and better understanding of mechanical behavior and stabilization of nervous structures within spinal canal. Our results can be extrapolated to human medicine, however, further analysis with human specimens is recommended to confirm compatibility of porcine and denticulate ligaments samples.

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Biologically Inspired Linguistic Habit Graph Networks Used for Text Correction

Marcin Gadamer, Adrian Horzyk

AGH University of Science and Technology, Department of Automatics and Biomedical Engineering
30059 Krakow, Mickiewicza Av. 30
gadamer@agh.edu.pl

This paper describes a biologically inspired Linguistic Habit Graphs (LHG) which could be used as a new way of storing, compressing, and processing sentences. The common letter and word orders from sentences are used to construct a special neural graph that is able to associate and memorize the natural human linguistic habits. The used algorithms can learn from texts written by people and transform the information of orders, frequencies, and contexts into a graph structure, labeled vertices with word properties, and weighted connections. Vertices of this graph are reactive to input data as well as neurons in biological brains. The way in which the human brain works is an inspiration for many known algorithms from contemporary computer science. In the brain, there is no time and no place for nested loops and other time consuming classic algorithms and computational techniques. Based on this approach, we developed new algorithms. They use a graph structure to perform a semi-automatic spell checking and text correction. The above mentioned functionalities of this model are always available in constant time.

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Computer-aided Detection of 3D Region of Interest for Image-guided Needle Biopsy

Agata Wijata, Marta Galińska, Bartłomiej Pyciński, Jan Juszczyk,
Joanna Czajkowska, Dominik Spinczyk, Ewa Piętka
Department of Computer Science and Medical Equipment, Faculty of Biomedical Engineering,
Silesian University of Technology, ul. Roosevelta 40, 41-800 Zabrze, Poland
agata.wijata@polsl.pl

Purpose

The biopsy procedure is an everyday clinical procedure in patients with breast cancer. Samples of the tissue are subjected to a histopathological analysis. Simultaneous tracking of the lesion and the needle using two-dimensional ultrasound image during the biopsy is not a trivial case. The application supports biopsy spot location when the needle is not visible in the ultrasound image.

Methods

The aim of the study is to indicate in real time a region of interest (ROI) which is located inside the lesion and the needle placement in relation to the ROI, based on the US image. During the biopsy procedure, supported by the tracking system, a two-dimensional ultrasound image and its position in the three-dimensional space are recorded. Based on this information, the estimated area of the lesion can be obtained. The tracking system records the position of the markers placed on the biopsy gun and the ultrasound transducer. The mask of the lesion has been automatically determined on the 2D US image to define the ROI. In the algorithm histogram analysis, thresholding, morphological operations have been employed. Once a 2D lesion mask is obtained the centroid and lengths of the major and minor axes are found. Centroid and radius of the inscribed circle determine a sphere which has been the 3D region of interest.

Results

Visualization including the gun, the needle, the transducer, 2D US image and designated ROI was implemented in a 3DSlicer environment. The application enables collaboration with optical and electromagnetic tracking systems, which are approved for medical use. Two evaluations procedures have been performed. In the first stage, a phantom of animal tissues with a hydrogel sphere of known dimensions placed inside has been prepared. The ultrasound image of the hydrogel sphere yielding low echogenicity signal simulates the cyst. The phantom was scanned 30 times. When only the hydrogel sphere appeared in the image, it was found, marked and traced correctly. The second evaluation procedure was used 98 clinical images with a lesion. In 71% of cases, the region of interest detection indicated the lesion was performed correctly.

Conclusion

The application supports the radiologist's work during the biopsy. Visualization of the needle position related to the ROI is possible by tracking the biopsy gun and the transducer. The radiologist has the ability to evaluate the state of the tissue objectively based on the visualization of the point of collection of biopsy material. The correctness of the system is determined by the calibration procedure and type of the tracking device.

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Application of Kohonen and MLP networks for prediction of 1st-year response to growth hormone treatment in children

Urszula Smyczyńska
AGH University of Science and Technology, Department of Automatics and Biomedical Engineering,
Av. A. Mickiewicza 30, 30-059 Krakow, Poland
usmycz@agh.edu.pl

Aims

Prediction of response to growth hormone (GH) treatment in children is complex, multivariate problem. Its solution is needed in order to correctly decide who should be treated or to identify patients responding poorly to therapy after it was started. Another important issue is determination of factors that significantly affect GH treatment effectiveness. Currently, the most popular method of answering those questions is development of multiple regression models [1].

Methods

In present work multilayer perceptrons (MLP) and Kohonen self-organizing maps (SOM) were applied to predict 1st-year response to GH treatment. To enable solving regression task, SOM were implemented as hidden layer in radial basis (RBF) networks. MLP were trained with the use of genetic algorithm. Input cancellation algorithm was applied to both types of models to eliminate redundant variables. Experimental data set contained 272 cases with 17 inputs, describing auxological and hormonal parameters and 1 output, namely change in height standard deviation score (SDS). It was provided by Department of Endocrinology and Metabolic Diseases of Polish Mother's Memorial Hospital – Research Institute in Lodz.

Results

Among 4000 tested networks – 1000 MLP, 3000 Kohonen networks (KN) – with different architectures and training parameters, the most accurate ones were chosen and subjected to input reduction algorithm. Finally, one model of each type was selected such that number of inputs was reduced significantly (in MLP to 9 and in KN to 5) while accuracy only slightly or not at all. Results in terms of errors (RMSE) and coefficients of determination (R^2) of model are listed in Table 1. Both reduced models included some of patients' auxological parameters, while none of them contained results of GH secretion tests.

Table 1: Characteristic of derived models

Network architecture	RMSE [SD/y]		R^2 [%]	
	TR	TS	TR	TS
MLP 17:17-2-1:1	0,258	0,267	42,8	48,7
MLP 9:9-2-1:1	0,254	0,277	44,5	45,0
KN 17:17-5x7-1:1	0,255	0,277	44,5	42,5
KN 5:5-5x7-1:1	0,225	0,275	56,6	43,4

TR – training set, TS – testing set, MLP number(n#) of inputs: n# of input neurons – n# of hidden neurons – n# of output neurons: n# of outputs, KN number(n#) of inputs: n# of input neurons – dimensions of SOM layer – n# of output neurons: n# of outputs

Conclusions

Accuracy of derived models is comparable to results of other authors [2], however they included only prepubertal children while we also pubertal ones. Input cancellation algorithm significantly reduced number of inputs, what makes model easier to interpret and indicates what factors actually influence height gain during 1st year of GH treatment.

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Construction of brain atlases based on dataset of Polish adults

Krzysztof Psiuk-Maksymowicz[1], Damian Borys[1], Marek Kijonka[2]
[1]Institute of Automatic Control, Silesian University of Technology,
ul. Akademicka 16, 44-100 Gliwice, Poland
[2]Department of Medical Physics, Maria Skłodowska-Curie Memorial Cancer Center and
Institute of Oncology, Gliwice Branch, ul. Armii Krajowej 15, 44-101 Gliwice, Poland
krzysztof.psiuk-maksymowicz@polsl.pl

The main aim of this work was to develop a statistical brain atlas and brain tissue probability maps for the Polish population. Application of brain atlases is of great importance for brain and cognitive sciences. Brain templates are very useful in diagnosis of developmental abnormalities of children brains [1], and diagnosis of neurodegenerative diseases (such us Alzheimer's disease, or Parkinson's disease) [2]. Recently, constructing population-specific templates is gaining more attention [3].

We used a dataset of T1-weighted magnetic resonance images (MRI) obtained from 99 healthy adults (age range: 20-66 years). Another dataset consisted of adults without anatomical variants and counted 74 cases. Division of the complete set was also made due to sex and age. Filtration of all images was performed by means of the FMRIB Software Library (FSL). Further processing, including: coregistration, segmentation, normalization and generation of tissue probability maps, was performed by means of the Statistical Parametric Mapping (SPM) Matlab toolbox. Post-processing of the data was conducted using the Matlab environment.

We constructed 6 different sets of tissue probability maps and 6 brain atlases from MRI datasets mentioned above. The most important segmented tissues were: gray matter, white matter and cerebrospinal fluid. Tissue probability maps were compared with each other by means of global and local similarity measures. Our tissue probability maps were also compared with other: International Consortium for Brain Mapping (ICBM), Korean, and Chinese maps.

Due to application of described methodology we were able to obtain complete set of segmented brain tissues for 99 adults, as well as, 6 sets of brain tissue probability maps, and 6 different brain atlases for Polish population. Comparison of global similarity measures indicates that the biggest differences between tissue probability maps are between: sex-specific maps (considering only our data), and our and ICBM maps (considering publicly available maps). While local measures are suitable for visualization of differences between tissue probability maps.

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Combined use of time-resolved near infrared spectroscopy and diffuse correlation spectroscopy in monitoring of brain perfusion and oxygenation

Saeed Samaei, Piotr Sawosz, Anna Gerega, Aleh Sudakou, Adam Liebert
Nalecz Institute of Biocybernetics and Biomedical Engineering, Polish Academy of Sciences
Ks. Trojdena 4 st. 02-109, Warsaw, Poland
ssamaei@ibib.waw.pl

Nowadays clinicians are looking for non-invasive methods for monitoring of cerebral blood flow, as well as tissue oxygen saturation which can be easily applied in clinical conditions. The aim of our project is to develop an optical portable instrument based on combination of time-resolved near infrared spectroscopy (TR-NIRS) and diffuse correlation spectroscopy (DCS) techniques which will show usefulness for assessment of brain tissue oxygenation and blood flow changes in adult humans. Combination of TR-NIRS and DCS might not only allow to monitor optical properties and blood flow of tissue simultaneously, but will also help to distinguish information from extra- and intra- cerebral tissues. Applying combination of time-resolved strategies based on time-correlated single photon counting (TCSPC) and the DCS-resolved autocorrelation functions makes the potential to determine the blood flow index for different depths.

With the aim of using TR-NIRS-DCS as a new technique in non-invasive tissue monitoring, we combined long coherence length CW NIR laser beams which typically are employed to DCS studies [1], and ultra-fast illumination pulses of durations as short as picoseconds from TR-NIRS technique [2]. We applied a diode laser module (PicoQuant, Germany) which generates pulses of 80 to 100 picoseconds width and 80MHz in repetition rates. This light reveals an effective coherence length which is sufficient for the photons to remain correlated at the detector.

In order to validate feasibility of the TR-NIRS-DCS technique we began our investigation with phantom studies. During the first experiment a phantom has been made to mimic grey matter optical properties. The TCPCS technique provides information about time of flight and absolute arrival time of each single photon. The distributions of times of flight of photons (DTOF) and based on them autocorrelation functions were calculated in a sequence of several experiments while the temperature of the phantom was constant. In the next stage, we compared the autocorrelation curves at two different temperatures.

The results show that when the phantom temperature is constant most of the autocorrelation curves are in the same range, while by increasing temperature the autocorrelation curve is shifted to the left. Because the particles velocity in the medium is directly related to the temperature, a shift in the autocorrelation curve occurs. This result suggest that the method is able to detect changes in particles movement in the medium. In next step, our measurements will be done on layered phantoms to study sensitivity of the technique to particle movements appearing at different depths in the medium.

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Smooth pursuit eye movements in patients with Huntington's disease

Maciej Perdziak[1], Dagmara Witkowska[1], Wojciech Gryncewicz[1], Paweł Czarnecki[1], Daniel Zielonka[2], Jarosław Łopatka[1], Jan Ober[1]
[1]Nalecz Institute of Biocybernetics and Biomedical Engineering, Polish Academy of Sciences**,** Ks. Trojdena 4 st., 02-109 Warsaw, Poland
[2]Department of Social Medicine, Poznan University of Medical Sciences, 6 Rokietnicka Str, 60–806 Poznan, Poland
mperdziak@ibib.waw.pl

The aim of this study was quantitative evaluation of the smooth pursuit (SP) in Huntington's disease (HD) patients. SP is an eye movement that allows to track moving object. HD is a rare genetic illness caused by a CAG trinucleotide repeat expansion (in the first exon of the HD gene) [1]. One of its many symptoms can be symmetric impairment of SP (it can observe the saccadic intrusions and low SP gain [2]). The progression of HD is usually assessed using Unified Huntington's Disease Rating Scale (UHDRS) [3]. Examination of smooth pursuit is usually performed by slowly moving of finger or pencil by the physician and asking a patient to follow it. UHDRS rates SP by using a four-point scale [3] meanwhile subjective observation (without the eye movement instrumentation) does not give possibility to notice small saccadic intrusions, and detect the gain impairments.

To measure eye movement and project the stimuli we used the device designed in our lab. Eye movement sensor was placed on the subject's head. Laser projector, mounted on forehead plate, projected moving target on the wall (observed by subject sitting in front of the wall). We examined six subjects with HD including three symptomatic and three presymptomatic (with genetic diagnosis) patients. Subject was asked to keep his/her gaze on the moving target. The target was displayed on the central position and performed 3 cycles of displacements. Each cycle included 3 smooth displacement of the target from the left external to right external positions and back. Calibration was performed at the end of the experiment.

We found significant correlations between the number of CAG repeats (abnormal allele) and following parameters:

- number of inconsistent saccades
- the number of inconsistent saccades per cycle
- the cumulative amplitude of the inconsistent saccades per cycle

The results can suggest that the device allowing for quantitative evaluation of the smooth pursuit can be potentially a useful tool supporting the assessment by UHDRS scale.

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Photoactive matrix for intravascular photodynamic therapy applications

Aleksandra Kaczorowska[a], Iwona Hołowacz[a], Agnieszka Ulatowska-Jarża[a], Maciej Duda[a], Wojciech Kałas[b,c], Edyta Wysokińska[b], Halina Podbielska[a], Marta Kopaczyńska[a]

[a] Department of Biomedical Engineering, Faculty of Fundamental Problems of Technology, Wroclaw University of Science and Technology, Wybrzeze Wyspianskiego 27, 50-370 Wroclaw, Poland
[b] Department of Experimental Oncology, Ludwik Hirszfeld Institute of Immunology and Experimental Therapy, Polish Academy of Sciences, ul. Rudolfa Weigla 12, 53-114 Wroclaw, Poland
[c] Institute of Chemistry, Environmental Protection and Biotechnology, Jan Długosz University, Al. Armii Krajowej 13/15 , 42-201 Czestochowa, Poland

aleksandra.kaczorowska@pwr.edu.pl

Rupture of unstable atherosclerotic plaque is the cause of most cardiovascular events, including myocardial infarction and stroke. Intravascular photodynamic therapy (PDT) is a promising therapy for treatment of vulnerable atherosclerotic plaque. Photosensitizers (PS) can accumulate in plaque inflammatory cells. Production of reactive oxygen species (ROS) in targeted tissues inhibits plaque progression and leads to plaque damage [1].

The innovative procedure of unstable atherosclerotic plaque treatment is to apply intravascular PDT. Our studies focused on PS delivery straight to the targeted cells from photoactive stent coating. Intravascular PDT of vulnerable plaque requires optical irradiation system.

Silica based coatings were prepared as a matrix for PS doping. As a PS Photolon and Protoporphyrin IX (PPIX) were used. Physicochemical properties of coatings were evaluated by mercury porosimetry, Fourier transform infrared spectroscopy (FTIR) and atomic force microscopy (AFM). Optical properties of PS-doped matrices were characterized using spectrophotometric measurements. Biocompatibility, phototoxicity and hemolysis studies of photoactive materials were performed. Vascular smooth muscle cells (VSMC) adhesion to the coatings was investigated to exclude in-stent restenosis promotion. Colocalization of PS was determined using confocal laser microscopy. The efficiency of *in vitro* PDT was evaluated by reactive oxygen species (ROS) production in human umbilical vein endothelial cells (HUVEC) and VSMC.

We prepared photoactive matrices with specific roughness and mechanical properties for use as coating for cardiovascular stent. Photoactive coating is biocompatible, non-hemolytic, athrombogenic and promotes endothelialization. Confocal microscopy images demonstrated colocalization of Photolon mostly in cell nucleus, whereas PPIX accumulated mainly in cytoplasm. The biological experiment results demonstrated higher ROS production in VSMC incubated on Photolon-loaded matrix. High ROS production is the cause of endoplasmic reticulum stress and leads to cell apoptosis. Our studies indicated that obtained photoactive matrix may be successfully applied in intravascular PDT of unstable atherosclerotic plaque.

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Antibacterial agents characterization by means of light diffraction phenomenon

Mariusz Linard, Igor Buzalewicz, Agnieszka Ulatowska-Jarża

Department of Biomedical Engineering, Faculty of Fundamental Problems of Technology,
Wroclaw University of Science and Technology , 50-370 Wrocław, Wybrzeże Wyspiańskiego 27
E-mail: igor.buzalewicz@pwr.edu.pl

Bacterial infections caused by very difficult to identify multidrug resistant bacteria, are one of the main reasons of the hospital patients' mortality increase. The bacteria resistance to commonly used antibacterial agents (antibiotics, sterilization agents, chemicals etc.) is worldwide observed. In consequence, the therapeutic treatment and affords have limited ability to fight infectious diseases and infectious complications common for patients undergoing chemotherapy, dialysis and surgery for which the ability to treat secondary infections is crucial. Therefore, some efforts are made towards the development of new methods and physicochemical factors exhibiting the antibacterial properties. There is also a need, to develop novel technique, which can be used for these antibacterial agents efficiency characterization.

In presented studies, novel measurement methodology for antibacterial agents characterization by light diffraction phenomenon. It was proved, that the diffraction signatures of bacterial colonies are affected by their optical and morphological properties. Therefore, it is possible to characterize their influence on bacteria by means of the correlation between the spatial changes of Fresnel diffraction patterns and bacterial colonies properties variations induced by the application of selected physicochemical agents as: UV radiation, ethyl alcohol, chemical disinfectant Desprej® and photosensitizer Photolon used in antibacterial photodynamic therapy. The examination was performed on two different bacteria species: *Escherichia coli* (ATCC 4157) and *Yersinia enterocolitica* (ATCC 23715). The bacterial colonies Fresnel patterns were registered in optical scatterometer with converging spherical wave illumination developed in Bio-Optics Group from Wrocław University of Science and Technology. The examination of the morphology of colonies were performed by means of the optical microscopy in transmission and phase contrast mode. The influence of the physicochemical agents on the diffraction patterns was characterized by the qualitative and quantitative analysis. The qualitative analysis was performed by characterization of the recoded microscopic images of bacterial colonies and their diffraction patterns. The quantitative analysis was performed by means of the analysis of variance (ANOVA) based on changes of features extracted from the Fresnel patterns by the proposed computer algorithms from the Fresnela patterns.

Obtained results have shown that the Fresnel diffraction patterns of the bacterial colonies treated by different analyzed agents are changing their intensity spatial distribution (see Fig. 1) and the significant variance of the values of fractures extracted from these optical signatures (see Fig. 2).

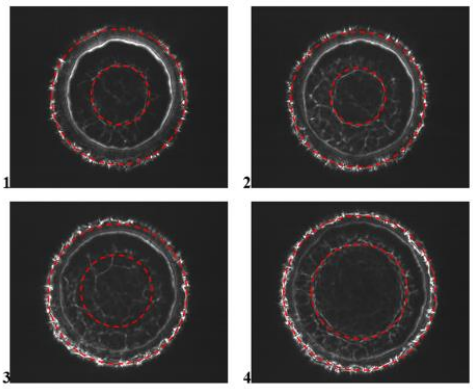


Fig. 1 The exemplary *E. coli* colonies diffraction patterns after application of several physicochemical factors (1-control sample, 2-Desprej®, 3-ethanol, 4-UV radiation)

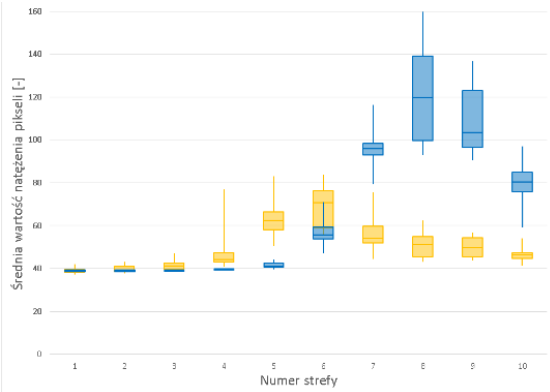


Fig. 2 The exemplary box-plot representing the variation of mean values each limiting zone of *Y. enterocolitica* colonies diffraction patterns (control sample – blue, ethanol – yellow)

Performed examination confirms, that applied physicochemical agents affect the optical and morphological properties of bacterial colonies and their growth dynamics. The colonies induced changes lead to the differences in optical wave transformation on these colonies and spatial distribution changes of the their diffraction patterns intensity. Obtained results confirms, that the analysis of the diffraction patterns can be used for characterization of antibacterial agents efficiency. Therefore, it is possible to extend the functionality of the develop method for complex microbiological examination for bacteria identification and characterization of the antibacterial agents by means of light diffraction.

Optical tweezers as a powerful tool to study changes in mechanical properties of cancer cells

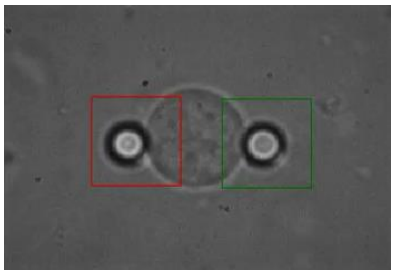
Weronika Lamperska[1)], Kaja Frączkowska[2)], Aleksandra Kaczorowska[2)], Jan Masajada[1)], Halina Podbielska[2)], Tomasz Wróbel[3)], Marta Kopaczyńska[2)]

[1)]Department of Optics and Photonics, [2)] Department of Biomedical Engineering, Faculty of Fundamental Problems of Technology, Wrocław University of Science and Technology, Wybrzeże Wyspiańskiego 27, PL50370 Wrocław, Poland
[3)]Dept. of Hematology, Blood Neoplasms and Bone Marrow Transplantation, Wroclaw Medical University, Wybrzeże L. Pasteura 1, PL50367 Wrocław, Poland

marta.kopaczynska@gmail.com

Optical tweezers (OT) are a powerful device for optical trapping to precisely manipulate and examine micro- and nano-sized objects. Once the object is trapped in the tightly focused laser beam, it can be displaced or rotated by the use of optical forces. Optical tweezers have become particularly useful in biotechnology and chemistry as they allow to study piconewton forces acting on a specimen. So far, a number of biomedical experiments involving various structures were performed with the use of optical trapping [1], such as stretching DNA, DNA-protein complexes, cell structures and erythrocytes, studying cytoskeletal transport, estimating the force produced by molecular motors.
We propose a novel method of studying biomechanical properties of cells with the holographic optical tweezers setup. It is believed that cell stiffness is an indicator of cancerous tissue [2]. The aim of our research was to develop a technique which allows to measure cell stiffness and then determine how it is affected by pharmaceutical agents currently used in therapy. In particular, the AML (Acute myeloid leukemia) blast cells were examined with and without the presence of three cytotoxic drugs. All of them belong to a group of anthracycline antibiotics and so far little is known about their influence on mechanical properties of cells.

Holographic optical tweezers consist of a laser, an SLM (spatial light modulator) and a high numerical aperture microscope objective. By the term ‘optical trap’ one means a laser beam tightly focused in the sample plane. The trapped objects were dielectric microbeads acting as handles. The preparation of samples was a complex, multi-stage process which was aimed at modifying the cell membrane. A special method relying on stretching the cell was invented (figure below). Then, the force exerted on the cell as well as the stiffness of the cell were calculated with a self-made software.



Two polystyrene beads attached to the opposite sides of an AML blast cell.

Optical tweezers technique can be effective in detecting the changes in the mechanics of cell membrane and studying the cell dynamics. The experiments were performed with the use of AML blast cells and erythrocytes. This shows that proposed method is applicable to determine mechanical changes of both nucleated and non-nucleated cells. The results obtained with OT technique prove that the changes in cell stiffness indicate whether the cell is in the stage of apoptosis. For example, it has been noticed that the presence of certain cytotoxic drugs leads to a significant decrease in stiffness of AML blast cells. Thus, cell stiffness may become a biomarker of metastatic potential of cancer.

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Porous silica materials as photosensitizers carriers

Iwona Hołowacz[a], Agnieszka Suchwałko[b], Igor Buzalewicz[a], Katarzyna Kowal[c], Halina Podbielska[a], Agnieszka Ulatowska-Jarża[a]
[a] Department of Biomedical Engineering, Faculty of Fundamental Problems of Technology, Wrocław University of Science and Technology, Wybrzeże Wyspiańskiego 27, 50-370 Wrocław, Poland
[b] QuantUp, Litewska Street 30/9, 51-354 Wrocław, Poland
[c] Nonwovens Innovation and Research Institute, NIRI Ltd., University of Leeds, LS2 9JT Leeds, United Kindgom
E-mail: Iwona.Holowacz@pwr.edu.pl

Porous silica matrices may found plenty of applications, e.g. as carriers for various substances, which can be exploited for sensing purposes or as drug releasing carriers. Our studies focused on the influence of the porosity of silica matrices produced by sol-gel process on the spectral properties of the photosensitizers (PS) protoporphyrin IX (PP IX) and Photolon immobilized in the interconnected pores. Those matrices could be deposited onto the metal parts of the medical devices to create antimicrobial coatings.

First, we determined structural parameters for pores characterization in the applied matrix. Than the absorption and luminescence intensity changes and shifts were stated for PS doped matrices in form of bulks/blocks and single- or multilayer coatings deposited onto stainless steel. The photobleaching effect – as a unwanted process - was analyzed as well.

Covering the metal parts of the medical device with developed coatings could bring some benefits. On the one hand one can check if the fotoactive layer is still present on the medical device external surface by luminescence excitation at about 400 nm (damage detection). On the other hand the matrix is loaded with PS microbially active after the red light irradiation (microbial contamination removal). Microscopic studies proved that we found stable porous silica materials with the very high absorption and luminescence intensity of immobilized PS. The spectroscopic properties of both PS's proved to be strongly dependent on the structural properties of the silica matrices, especially material porosity. Taking into account the mechanical properties of the porous silica matrices as well as spectroscopic properties of PS (absorption, luminescence, and photobleaching) we established that the optimum number of layers deposited onto the stainless steel is 4.

The performed experiments demonstrated that physical parameters of the porous silica matrices strongly influenced on spectral properties of PS immobilized within them. The photobleaching process plays an important role in PS biomedical application. It is possible to perform the suitable carrier for PS by luminescence intensity comparison. The porous silica matrices with controlled particle size and porosity has made sol-gel materials highly attractive as the structural basis for a wide variety of technological applications in biomedical engineering.

Laser cladding of bioactive glass coating on metallic substrates with refined grain structure - computer modelling

Szymon Bajda[1], Martin Palmer[2] and Michal Krzyzanowski[1, 2]
[1] AGH University of Science and Technology, Mickiewicza 30, Krakow 30-059, Poland
[2] Birmingham City University, Faculty Computing, Engineering & the Built Environment, Millennium Point, Curzon Street, Birmingham B4 7XG, UK
Corresponding email address: sbajda@agh.edu.pl

Laser cladding can be applied to produce medical implants composed of bioactive glass-coated metallic substrates [1]. Titanium alloys are currently used as substrates due to their superior mechanical properties and biocompatibility [2, 3]. However, the applied Ti alloys containing aluminium and vanadium, may be potentially toxic if they are released in the human body. The problem can be overcome by replacing titanium alloys with commercially pure titanium (cpTi) having ultrafine-grained structure. The yield and ultimate strength of such metallic materials can both exceed 1000 MPa.

It is the objective of this paper to analyse the thermal and stress-strain distributions during laser cladding of bioactive glass on the refined grain cpTi structure using the finite element (FE) based numerical modelling.

The sequential FE model of the laser cladding process using element birth and death technique was developed. The Gaussian distribution heat source model was applied using DFLUX subroutine. The multiple layers representing bioactive glass have been imposed on the metallic basement during the modelling in order to evaluate the relationship to each other. The obtained transient temperature distributions were used in the stress analysis. Effects of laser cladding processing parameters on the stress-strain distributions within the composite material were subject to numerical analysis.

The results obtained during the computer simulation show that the level of stresses in case of using the conventional cpTi substrates may cause cracking, whereas application of cpTi with refined grain structures significantly decreases the cracking susceptibility. The level of stresses obtained for such strengthened ultrafine-grained structure material can be well below its tensile strength limit.

The application of cpTi substrate with refined grain structure is very beneficial because it allows for exclusion of potential toxic elements from the human body. At the same time, the developed FE based numerical model can be used for determination of the optimal laser cladding processing parameters in order to support the manufacture of the novel and durable medical implants.

Acknowledgments:
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NIRS in analysis of physical activity influence on the way of muscular circulation response to breath-holding at the breakpoint - a pilot study

Anna M. Stecka, Karolina Bejm, Tomasz Gólczewski
Nalecz Institute of Biocybernetics and Biomedical Engineering, PAS. Trojdena 4 st, Warsaw, Poland
astecka@ibib.waw.pl

Vasoconstriction in muscular, cutaneous, and splanchnic circulations is one of responses to diving protecting brain and heart from hypoxia [1]. Gólczewski's previous studies (with Doppler flowmeter) related to Folkow's hypothesis [2] on the genesis of the primary arterial hypertension showed similar muscular circulation response (MCR) to breath-holding. In particular, the vasoconstriction started and intensified after the moment when a subject wanted to restart breathing, and it was significant at the breakpoint, i.e. at the moment when a subject could no longer hold breathing and had to restart it. However, such a MCR was not observed in all subjects. Since blood flow measurement by means of Doppler equipment cannot be a long-term procedure, we have tried to test usefulness of the near infrared spectroscopy (NIRS) in a more advanced analysis of the MCR to breath-holding and its dependence on various factors. Here, the level of physical activity is considered as such a factor.

13 subjects (5 males, 8 females; age 28±7) examined until now were grouped into the following 3 sets: present advanced physical activity, previous such activity stopped no earlier than 3 yrs ago, and the others (see the Table 1 for numbers). A high resolution diffusive optical tomography (HD-DOT) [3] was used to measure changes in oxygenated and reduced hemoglobin concentrations in cerebral and muscular circulation (in a leg) during intentional breath-holding. Subjects indicated moments when they stopped breathing, wanted to restart breathing and when they had to breathe again, i.e. the breakpoint. Fisher's exact test for the 2x3 contingency table was used to estimate the statistical significance.

MCR significantly depended on whether a subject was physically trained or not (Table.1; $p<0.0014$): close to the breakpoint, the total hemoglobin decreased in not trained subjects (Fig.1) suggesting vasoconstriction, while in both trained groups muscular hemoglobin concentration changed similarly to the cerebral one or did not change.

Table 1.Response in the leg at the breakpoint

	dec	no	Σ
Active now	0	6	**6**
past activity	0	3	**3**
others	4	0	**4**
Σ	**4**	**9**	**13**

dec/no – the total hemoglobin was/was not decreased at the breakpoint (the point 3 in Fig.1)

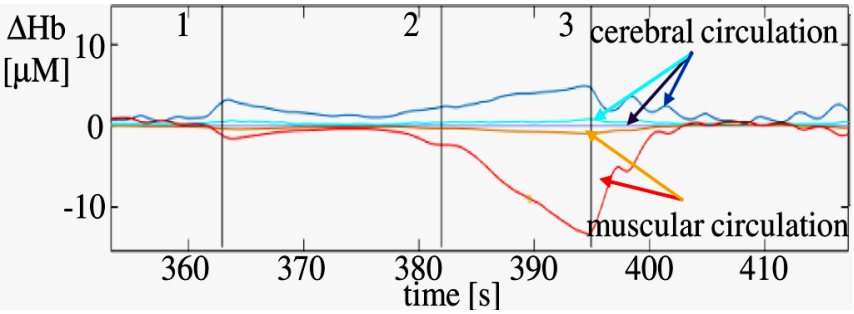

Fig. 1. An example of total hemoglobin changes during breath-holding in a not physically active subject. The subject started breath-hold (1), wanted to breathe (2) and had to breathe – the breakpoint (3)

One could expect MCR to breath-holding similar to MCR to diving, i.e. some vasoconstriction in the muscular circulation to protect the brain and heart; however this theoretical response was not observed in physically trained subject. Those findings suggesting impact of physical exercise on the vasomotor control, if confirmed by more numerous measurements, may appear extremely important in consideration why physical activity protects against arterial hypertension.

The work was supported by the Nalecz Institute of Biocybernetics and Biomedical Engineering (the internal grant for young scientists No 1PW6).

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Near infrared light propagation profiles in an optically turbid medium – experimental studies and its comparison with Monte Carlo simulations

Magdalena Morawiec, Piotr Sawosz*, Aleh Sudakou, Adam Liebert
Nalecz Institute of Biocybernetics and Biomedical Engineering PAS, 4 Ks. Trojdena Street, 02-109 Warsaw
*psawosz@ibib.waw.pl

Introduction

The Near-Infrared-Spectroscopy (NIRS) is a non-invasive technique which allows for estimation of changes in oxy- and deoxy- hemoglobin concentration and thus cerebral blood oxygenation. The main weakness of this method is its inability to precisely assess the depth of light penetration. As a result, it is difficult to distinguish properly between intra- and extracerebral changes in tissue oxygenation. In order to illustrate a propagation of light in an optically turbid medium, we used an experimental set-up [1] with a time-gated intensified CCD (ICDD) camera. For validation of proposed system, we refer to theoretical profiles of the photons fluence within considered medium, obtained with the use of the Monte Carlo code.

Method & Data analysis

All experiments were carried out on two kinds of homogenous liquid phantoms, built of plexiglass aquarium and filled with a solution of milk and water (type 1) or the solution of Intralipid and water (type 2). In both cases a small amount of India Ink was added. Changing the ink concentration resulted in obtaining different absorption coefficients, similar to those of living tissue.

The ICCD camera was mounted in the plane perpendicular to the optical table, so that the phantom's top surface was imaged. The near infrared light from pico-second diode laser (λ=780nm) was coupled into an optical fiber and delivered to the lateral wall of the aquarium (5mm below the upper edge). During the experiments the fiber position on the phantom was moved to seven different locations, separated by 1cm.

The time gated camera allowed to collect photons within a 200ps long time window at defined delays with respect to the laser pulse. The delay of the collection window was changed by a delay line. It allowed to obtain a histogram of times of flight of photons for an individual pixel of the image. For the considered pixel, further signal processing includes: selection of 2 source positions and convolution of corresponding histograms. Described procedure of data analysis enables estimating a distribution of visiting probability of photons travelling from source to detector at the specified delay.

Monte Carlo simulations

For comparison to experimental results we refer to the Monte Carlo simulations, which are often used in modeling of light transport in turbid medium [2]. The method is based on the fact that photons entering the object are traced until they are absorbed or exit from the medium. When all simulated photons have been propagated and their paths are known, the distribution of times of flight of photons is obtained. The calculations were carried out for a semi-infinite, homogeneous, diffusely scattering medium. The optical properties of the model, such as reduced scattering coefficient μ_s, absorption coefficient μ_a, refractive index n, the distance r between the source and detector and the wavelength λ of the incident light were assumed. The variable parameters were μ_a, r, λ and their values were selected in such a way that they mach experimental conditions.

Conclusions

Time-gated imaging is a useful tool for the approximation of the photons penetration probability in an optically turbid medium. The experimental results will be compared with the theoretical ones, obtained from the MC simulations. It will be shown that the shape of the visiting probability profiles depends on several aspects, which are interoptode distance, the delay between the laser pulse and the collection window and the optical properties of the object.

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Optimal selection of wavelengths for estimation of oxy-, deoxy- hemoglobin and cytochrome-c-oxidase from time-resolved NIRS measurements

Aleh Sudakou, Piotr Sawosz, Anna Gerega, Adam Liebert
Nalecz Institute of Biocybernetics and Biomedical Engineering, Polish Academy of Sciences
Ks. Trojdena 4 st. 02-109 Warsaw Poland
asudakou@ibib.waw.pl

The uncertainty of the results of estimation of changes in chromophores concentrations using Near-Infrared Spectroscopy (NIRS) depends on the choice and the number of wavelengths utilized. The two aims of this study are (1) to determine the dependence of the uncertainty of the estimation of the changes in chromophores concentrations on the number of wavelengths used and (2) to identify the optimal 16 wavelengths for a time-resolved, multiwavelength NIRS system. Our system will use time-resolved method [1] to resolve changes in concentrations of oxyhemoglobin (ΔC_{HbO2}), deoxyhemoglobin (ΔC_{Hb}) and cytochrome-c-oxidase (ΔC_{CCO}) separately in intracerebral and extracerebral compartments. The topic of optimal wavelengths for continuous-wave systems has been extensively studied and the benefit of adding more wavelengths has been addressed [2, 3]. However, to our knowledge there are no studies that perform similar analysis for the time-resolved NIRS method.

The time-resolved NIRS method relies on changes in moments of the distributions of times of flight of photons (DTOFs) [1] and the Beer-Lambert law. The matrix that converts statistical moments of the DTOFs into depth-dependent changes in the chromophores concentrations for a two-layered model of the medium was analyzed. The propagation of uncertainty proposed by Liebert [1] was extended to take into account the choice of wavelengths. Monte Carlo simulations were performed for 25 wavelengths (650 to 950 nm in steps of 12.5 nm) by setting wavelength dependent optical properties of the medium as described by Correia [2] in order to obtain DTOFs and sensitivity factors for each wavelength.

The uncertainty of the changes in chromophores concentrations in the deeper layer of the model (mimicking brain tissue compartment) for different numbers of wavelengths ($k=4,8,12,16,20,25,32$) were calculated using wavelength-independent sensitivity factors. Furthermore, uncertainties of the changes in chromophores in the deeper layer of the model were obtained for different choices of 16 consecutive wavelengths that are separated by 12.5 nm and in the range of 650 to 950 nm. The following assumptions which influence the results will be also studied: the use of wavelength-dependent sensitivity factors, the model of the background medium, the thickness of the top layer and the number of chromophores analyzed.

We found that an increase of the number of wavelengths utilized in the process of estimation of changes in chromophores concentrations leads, as expected, to a reduction of the uncertainty. The optimal set of 16 wavelengths should cover the range between 770 and 950 nm to reduce the uncertainty of ΔC_{CCO} in the deeper layer of the model.

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High-resolution optical imaging of cerebral cortex activity during visual stimulation

Karolina Bejm[1], Stanisław Wojtkiewicz[2], Piotr Sawosz[1], Anna M. Stecka[1], Nikodem Hryniewicz[3], Roman Maniewski[1] and Adam Liebert[1]

[1]Nalecz Institute of Biocybernetics and Biomedical Engineering PAS, 4 Trojdena Street, 02-109 Warsaw

[2]School of Computer Science, University of Birmingham, Birmingham, United Kingdom

[3]CNS Lab, Nalecz Institute of Biocybernetics and Biomedical Engineering PAS, 4 Trojdena Street, 02-109 Warsaw

kbejm@ibib.waw.pl

Aims: Functional magnetic resonance (fMRI) has become a gold standard for imaging a human brain, but in practice this method has disadvantages and limitations. Near-infrared spectroscopy (NIRS) presents several advantages relative to standard functional neuroimaging. It provides non–invasive measurement of concentration changes in both oxygenated and deoxygenated hemoglobin. It enables to carry out an examination in the ICU and during surgery in the operation room, which cannot be performed by other available functional imaging methods. Furthermore, NIRS permits to perform studies in humans with implanted electronic devices (cardiac pacemakers, cardioverter defibrillators, deep brain stimulators) or patients who cannot be transported to the MRI facility. The classical NIRS technique can provide a low- resolution topography images of the brain cortex activity rather than high spatial resolution images like the fMRI. Now, an advanced high-density diffuse optical tomography systems overcome previous challenges providing improved resolution and brain sensitivity [1, 2]. A device in which large source-detector separation optodes, was developed by the Nalecz Institute of Biocybernetics and Biomedical Engineering Polish Academy of Sciences [3]. The high resolution diffuse optical tomography (HD-DOT) measurement setup, based on principles shown in [1,2], is capable of imaging an adult brain cortex activity with high spatial resolution. This non-invasive method allows collecting optical signals at two wavelengths within a dense mesh of sources and detectors located on a head surface. The system records signals for all combinations of source-detector pairs within the mesh. This creates multiple pairs and allows imaging of the cortex activity with a high-resolution [2]. In following work we demonstrate functional imaging of the human visual cortex activity by a high-resolution diffuse optical tomography.

Methods: We have carried out series of visual stimulations on healthy volunteers. The cortical activity was recorded with HD-DOT measurement setup. The optical fibers fixing system including 12 detectors and 16 sources was positioned on the surface of the head above occipital. The stimulation of visual cortex was induced by blinking quarter of checkerboard image, which rotated 10 degrees per second making a complete sweep. Moreover, participants were showed gray screens which were presented 30 seconds before and after each stimulation. This cycle of stimulation was repeated 5 times. Measurements were performed in a sitting position. Head of the subject was located at the distance of 90 cm from a 24inch screen.

Results: The experiments showed that we can successfully image the hemodynamic changes within the brain cortex with the use of HD-DOT. We were able to visualize changes in oxyhemoglobin and deoxyhemoglobin concentration at the source- detector distance greater than 3.35 cm (4.5 cm, 5.4 cm, 6.1 cm). Moreover, we did not observe significant changes at 1.5cm distances correlated with the stimulation. Measurement sensitivity to changes in absorption occurring in the grey matter region at the short source-detector distance is too low to register changes related to the activation.

Conclusion: The results obtained during visual cortex stimulation are in accordance with results obtained during the visual stimulation reported in [1]. These outcomes illustrate that high-resolution diffuse optical tomography can be a functional and powerful tool for high resolution imaging of human cerebral cortex activity.The possibility of measuring changes in both forms of hemoglobin gives more complete picture of brain function. A large number of sources and detectors may allow for imaging of cortical regions on the whole head.

Acknowledgements

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Biomedical engineering in Gdansk University of Technology – the follow up

Nowakowski Antoni
Gdansk University of Technology – Department of Biomedical Engineering; ul. Narutowicza 11/12; Gdansk
antowak@biomed.eti.pg.gda.pl

This abstract relates to educational issues of the studies of biomedical engineering performed at the Gdansk University of Technology (GUT) since seventies XX Century, but concentrates on the results of the EFS POKL.04.01.01-00-236/08 project, funded in 2009, devoted to organization of interfaculty courses in GUT and it's follow up after 2015. This project was developed in formal cooperation of the Faculty of Electronics, Telecommunication and Informatics GUT (ETI) as the coordinator, with faculties of FTMS and Chemistry GUT and with the Warsaw University of Technology, the faculties Mechatronics and ETI as well as with the AGH University of Technology, Cracow, with all faculties running the School of Biomedical Engineering. The results of this project (since 2010) counted only as graduate diplomas are ranging around 500 BSc, >200 MSc and 20 PhD in biomedical engineering, plus 2 habilitation dissertations in 2017.

In historical perspective the first important publications devoted to biomedical engineering, in GUT at the Faculty of Electronics, were the monograph [1] by Prof. Zimmermann and the PhD dissertation of S. Raczynski, in 1972 [2]. In 1973 regular MSc courses of medical electronics started, with the first MSc diploma given in 1976. Formal situation importantly changed in 1992, when the Department of Medical and Ecological Electronics was funded, renamed in 2002 to the Department of Biomedical Engineering. In 2008 formally interfaculty study of Biomedical Engineering started. The Faculty of ETI TUG received the right to perform procedures of PhD in biocybernetics and biomedical engineering in 2013 and habilitation in this field of research in 2016.

How to measure a success in science and education?! This question is always open for discussion. Presently bibliometric factors are of the highest recognition in evaluation of scientific staff. On the other hand different rankings including staff position and quality, research and education infrastructure, availability of digital and distance learning facilities, textbooks, student labs and some other factors, as e.g. market recognition, are published each year. TUG is placed in comparable, leading positions with Warsaw, Cracow, Wroclaw and Silesia universities.

The situation of the "educational market" has been strongly changed as biomedical engineering and medical physics are offered in many Polish institutions, what makes strong competition among existing entities. Especially important seems to be the future development and even existence at all, of this direction of research and education in terms of "the university system reform" to be introduced within next two or three years in Poland. One of possible solutions may be individual object oriented study with broad scientific background and well defined scientific objective already at the second degree MSc level. Unfortunately such approach is expensive and this might be a real barrier in practical implementation.

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The theory, practice and needs of the medical engineering in Poland.

K. Peczalski, T. Palko,
Institute of Metrology and Biomedical Engineering WUT, Warsaw 8 Boboli st.
K.Peczalski@mchtr.pw.edu.pl

The three steps model (B. Sc., M. Sc., Ph. D.) of academic education in biomedical engineering is good developed and realized on sixteen technical high schools in Poland. Rough estimation gives us the total number of about eight thousands absolvent's on the labor market. For comparison in US every year about three thousands students complied the biomedical engineer education. Following the biomedical engineering absolvent's survey of AGH University of Science and Technology the rate of getting job during first year is pretty high but the rate working in biomedical engineering is rather low.

There are couple of reasons for not satisfactory number biomedical and medical engineers in medical area. The first one is still not enough good developed biomedical industry. This issue should be solved in the quick future. The health care units are the next big areas of professional activity for medical and biomedical engineers.

During last year's two very extensive processes were observed: significantly higher rate of high specialized equipment in the health care system and pretty high rate of not satisfactory or sometimes even fatal decisions referred to parameters versus real needs estimation. The reason for mentioned above and other events of not optimal purchasing and handling of very expensive and sophisticated medical equipment is the lack of biomedical engineering professionals in health care structure. The people responsible for medical equipment in the health care units are usually without professional and very often even without any technical education. The only source of information on the medical equipment are representatives of biomedical companies very often also without biomedical engineering background but very good trained in order to proof that their products are the best.

As it was reported on previous our meetings the position of the biomedical engineering professionals is still not established in the model of the polish health care. The transformation of the polish health care system gives us an unique opportunity to introduce biomedical engineers to the structure of health care professionals of the new system.

In our opinion it should be obligatory positions of biomedical and/or medical engineering professionals for multiprofile hospitals, specialized departments and also for some specific procedures. According to current regulations for providing specific medical services certain certified staff, equipment and facilities are obligatory. There is the must to introduce biomedical and/or medical engineering professionals for such standards. For a start it should established three obligatory positions for biomedical and medical engineers:

- net hospitals - biomedical engineer supervising of purchasing & handling processes of medical equipment,
- specialized departments such as cardiology, neurology, surgery etc. - medical engineer supervising of application of highly specialized equipment,
- specialized procedures such as open heart surgery, neurosurgery, interventional cardiology etc. - medical engineer supervising or executing of application of highly specialized equipment.

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The innovative model of education of medical engineers

K. Peczalski, T. Palko, N. Golnik, E. Slubowska, K. Lewenstein

Institute of Metrology and Biomedical Engineering WUT, Warsaw 8 Boboli st.
K.Peczalski@mchtr.pw.edu.pl

The specialization of medical engineer has been established by Ministry of Health of Poland in order to train medical/clinical engineers for clinical divisions of polish health care system but so far there are only nine such specialists within Poland. The novel model of education was designed in order to provide more convenient option for professionally active trainees.

The postgraduate program of the Medical Engineer is designed for Masters in mechanical engineering, electrotechnical engineering (ET), and biomedical engineering (BME), physics and informatics with at least one year of clinical practice and also for some other medical professionals with longer clinical practice. The program consists of 11 thematic modules and it is tailored for two years completed by the State Exam. The course, prepared for already working trainees, consists of 700 hours of theory classes, labs, seminars and 23 weeks of clinical trainings.

In order to provide the less time absorbing (less travel and less stationary classes) offer for candidates for the medical engineer specialization, the Mechatronics Faculty of Warsaw University of Technology has prepared the novel program consisting of distance learning elements. The program is executed by the Academic Distance Learning Centre "OKNO" of Warsaw University of Technology. The current format of education SPRINT (in Polish: Studia PRzez INTernet) was modified in order to fulfill the requirements of Ministry of Health and the regulations for the postgraduate study of Warsaw University of Technology. The two academic years are divided into four semesters. Each semester lasts 16 weeks, consists of 8 working meetings and is completed by two weeks examination session consisting of two meetings. The working meetings are organized on Saturday and Sunday. The laboratories and practices are offered during working sessions. The lectures, seminars and some practices are performed on eLerning platform.

However the direct contacts between students and teachers are diminished in the proposed model due to the importance of the personal education in the teaching process the following types of face to face contacts are introduced:

1. consultations between trainees and tutors during working meetings,
2. work with tutors during laboratories and practices,
3. the final examination at the university,
4. consultations of each trainee with the personal director of his specialty.

The multimedia lectures, consultations etc. on-line are so far not taken under consideration, however they are assumed as very suitable tool for the future.

Conclusions

1. The proposed model of distance learning of postgraduate course of Medical Engineer should encourage the interest of clinical engineers in further professional education,
2. The decrease of sessions in the university facilities makes the education offer more practical, especially for working students,
3. The wider application of multimedia tools should broaden the opportunities of the face to face contacts between trainees and teachers in the future.

Information Systems in Medicine - new specialization in English on Bachelor level, at Faculty of Biomedical Engineering of the Silesian University of Technology.

Marek Gzik, Pawel Kostka, Zbigniew Paszenda, Marcin Kaczmarek.
Faculty of Biomedical Engineering, Silesian University of Technology (40 Roosevelt St. Zabrze)
marek.gzik@polsl.pl

The broad scope of sciences, creating the background of Biomedical Engineering (BE) is a big challenge while designing educational programs of this multidisciplinary field of study, which must prepare students for a successful professional performance in the fields of modern engineering applied to support life sciences and medicine [1, 2]. One of the crucial issues requiring careful approach are types of narrowed specializations created within BE field of study, adapted to dynamic chainging work environment.

Taking into consideration how much currently information technologies enter into medicine in many aspects, Faculty of Biomedical Engineering of the Silesian University of Technology have just prepared, in June 2017, a study program completely in English for a new specialization on Bachelor level: *Information Systems in Medicine*, with the additional elements of management of health care units and Bio-IT projects.

Base on common fundamental subjects, the main track of modules in the program is focused on developing students' skills in the area of hospital information system designing and programming as well as maintain, starting from such modules like e.g. algorithms and data structures, computer programming, through biomedical signals acquisition and processing, embedded systems programming to more advances topics connected with big data analysis, hospital information systems, web and mobile application development. The program is completed by issues connected with design of medical equipment, especially modern mechatronic rehabilitation systems including automatic control algorithms and virtual reality modeling as well as telemedicine solutions within available IT infrastructure.

The new specialization *Information Systems in Medicine* is the response to wide and still growing impact of information technologies on medicine and health care units systems. The study program was created in the close cooperation with biomedical industry companies, and assumes their important role also during education process in students' internships, trainings and common project realization. This specialization conducted entirely in English is focused on international cooperation in the range of students and academic staff exchange, study visits and webinars. The block of subjects connected with the management of health care units, completing skills biomedical engineer with new important elements e.g. academic skills, organizational development, finance, marketing and strategy, is planned to be carried out at the Nyenrode Business University in Netherlands during students' exchange.

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Specialization and certification in medical engineering

Ewa Zalewska[1], Tadeusz Pałko[2]

[1] Nalecz Institute of Biocybernetics and Biomedical Engineering PAS, Ksiecia Trojdena 4 str., Warsaw, Poland, ewa.zalewska@ibib.waw.pl
[2]Institute of Metrology and Biomedical Engineering of Warsaw University of Technology, A. Boboli 8 str., Warsaw, Poland

Medical engineering is a professional specialization within biomedical engineering and is a profession applicable in the health care. Medical engineering deals with all aspects of the medical equipment, systems and technology and the technical means used in hospitals and medical care. Medical engineers are specialist responsible for management and maintenance of medical equipment in hospitals.

The role of medical engineers include training and supervising the work of the technicians and operators of the medical equipment, conducting controls and audits, consultations for doctors, administrators and the IT department. Medical engineers should also follow the development of the market for medical equipment and know the current producers both in terms of equipment and accessories, to serve as experts in the development and implementation of the concept of comprehensive equipment in the hospital.

Education in the field of biomedical engineering (for direction or specialty) at the technical universities does not give permission to perform engineering profession in health care. Biomedical engineering is a field of academic knowledge whereas medical engineering means the professional competence for work in the health care. In the field of medical engineering in most countries, as in Poland, the postgraduate education is required to obtain the title of specialist, to be prepared to work in the medical environment.

Medical engineering environment is represented in the International Federation for Medical and Biomedical Engineering (IFMBE), through the activities of the Clinical Engineering Division (CED). The section carries out several projects aimed at comparing programs of specialization in different countries, determine the standards and certification requirements and the preparation of training materials, including e-learning courses in clinical engineering. Current arrangements are the criteria required for the international registration of clinical engineers. CED is an international forum for developing and promoting of the clinical engineering profession resulting in improvement of global healthcare delivery through the advancement of safe and effective innovation, management and deployment of healthcare technology. CED activity is also to to promote global communication, networking, and understanding of challenges related to healthcare technology management, to define and promote quality standards in clinical engineering practices and to internationally represent and advocate the interests of the profession of clinical engineers and their global exchange.

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