

B2 Inverse Problems and Biosignal Processing 1

Time: Wednesday, 15.09.2010

Location: Humboldt-Building, Lecture Room 211

Chairman: J. Haueisen (DE-Ilmenau)

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| 9:00 a.m. | T. Elsarnagawy, E. Alhilah, M. Farrag (Saudi-Arabia, Riyadh) |
| A Comprehensive Benchmark To meet Standards of National and International Academic Accreditation (AA) and Quality Assurance (QA) for the Biomedical Instrumentation Specialization | |
| <p>This study presents the experience of the Department of Applied Medical Sciences (AMS) - Riyadh Community College - King Saud University in its way to achieve the international accreditation standards to ensure quality. The study is based on a three years experience (2008-2010). The following questions had to be clarified:</p> <ul style="list-style-type: none">• The list of criteria adopted by AMS to ensure quality?• What procedures are adopted by AMS to apply accreditation standards to ensure quality of outputs? <p>The study followed the iterative descriptive approach in answering the questions. The results show the procedures how the standards were applied to ensure the quality of outputs by meeting the requirements in all aspects, national and international, especially of the internationally recognized organization <i>Council on Occupational Education</i>* COE, by which the AMS was then accredited in June 2010. A four year development strategic plan is set for the department to ensure consistent quality and improvement standards.</p> <p>By reviewing the literature, the former experiences of Arab, foreign and international bodies for accreditation and quality assurance, the study concluded a list of accreditation criteria and indicators of quality assurance, as well as indicators to ensure the quality of the university environment. The achieved number of accreditation and quality assurance standards from all the mentioned nationally and internationally organizations were found to be:</p> <ul style="list-style-type: none">• 25 accreditation standards leading to• 245 indicators, and• 41 indicators for QA, and• 29 indicators for the QA of the university environment. <p>The study recommended</p> <ul style="list-style-type: none">• the need to activate the academic accreditation and assessment of academic programs periodically internally and externally, and• to adopt sections of Applied Medical Sciences Section of similar experience in the application of the principles of accreditation and quality assurance, and• to make each section to itself a strategy that meets the needs and aspirations. | |

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| 9:20 a.m. | R. Eichardt, J. Hauseisen (DE-Ilmenau) |
| <p>Evaluation of the Effect of Sensor Variations on the Condition of the Magnetostatic Linear Inverse Problem</p> <p>We evaluate in this study the influence of random variations of sensor orientations on the condition of the linear inverse problem in magnetostatics. Sensor arrays with one and two layers of perfectly in parallel aligned mono- and three-axial sensors are compared to similar arrays but with randomly varied sensor directions. The variations of the sensor directions are obtained by normally distributed random rotations about X, Y and Z-axis with standard deviations for the rotation angles between 0.05 and 25 degree. The source space is modelled by four different regular grids of dipoles that carry between 100 and 1350 source positions in one, three, or six layers. As evaluation criterion, the condition numbers of the related lead field matrices are used. Our results reveal that even small variations of the sensor orientations by 0.05 degree lead for mono-axial sensor arrays to a considerable improvement of the condition of the linear inverse problem. Larger variations improve the condition further. Furthermore, our findings indicate that also small variations of the sensor Z-positions of planar mono-axial arrays, in our case between 2 mm and 2 cm, can lead to a better condition of the magnetostatic linear inverse problem.</p> | |
| 9:40 a.m. | D. Baumgarten, J. Hauseisen (DE-Ilmenau), F. Wiekhorst, U. Steinhoff, L. Trahms (DE-Berlin) |
| <p>Characterization and optimization of the cylindric 18 channel SQUID scanner in terms of source reconstruction performance</p> <p>Recently, PTB completed a stand-alone multichannel SQUID scanner. In this device, 18 SQUIDs measuring the radial field component are equally distributed on a circumference around the measurement object. Additionally, a superconducting Nyobium cylinder shields outer magnetic field disturbances. The device is designed to obtain data for quantification, localization and imaging of magnetic sources in biological systems. Possible applications are the detection of magnetic nanoparticle accumulations or magnetocardiography in small animals. In this paper, we investigate the performance of linear and non-linear source reconstruction algorithms on data simulated using the described sensor system. Additionally, synthetic sensor setups with the given positions and their sensors tilted out of the radial direction were analyzed. The target functions for magnetic dipole fit methods were estimated by computing the difference between a given source field and the field of a dipole moved through the source space and analyzed for different tilting angles. For a more general evaluation, the condition number of the leadfield matrix was studied. This matrix describes the geometric relation of possible source points and the sensor position; its condition number serves as a measure for the ill-posedness of the inverse problem. For comparison of our simulation results to measurement data, we also took into account the effect of the superconducting shield. Our investigations show more convenient target functions and a decreasing condition number when tilting the sensors out of the radial direction. This indicates a less ill-posed inverse problem compared to the given sensor setup.</p> | |

10:00 a.m. | S. Biller, D. Baumgarten, J. Haueisen (DE-Ilmenau)

New magnetic marker design for Magnetic Marker Monitoring with magnetoresistive sensors

The physiologic behavior of the gastrointestinal tract (GI-Tract) is of high relevance for the diagnosis of functional disorders as well as for pharmaceutical research. The technique of Magnetic Marker Monitoring (MMM) has high potential to determine the motility of the GI-Tract and to observe the dissolution of pharmaceuticals. After ingestion of a magnetically marked tablet the magnetic field outside the patient is measured using sensitive sensors and the behavior of the marker is analyzed continuously. Current markers mostly contain magnetized Magnetite as a magnetic label which produces very weak fields. Due to this fact, measurements are performed using Superconducting Quantum Interference Devices in shielded environment. For a wider class of applications, stronger magnetic labels and more flexible recording conditions are required. We designed a new magnetic marker which allows for recordings of the disintegration with magnetoresistive sensors. The novel marker is composed of one permanent magnet and a compartment of iron powder. The iron powder is positioned only at one side of the magnet to form a magnetically instable configuration. During dissolution the iron powder reallocates and encloses the magnet, thus altering the external magnetic field. The feasibility of the novel design was tested by attaching iron powder fully surrounding a magnet and measuring the magnetic induction. Additional, pharmaceutical capsules were prepared with the magnetic components and the magnetic field was measured before and after dissolution. The external magnetic field was quantified at different distances and orientations using a fluxgate sensor in both experimental setups. The proof of principle showed a significantly reduced magnetic field after attaching the iron powder to the magnet. The field decreases by 20% to 30% in all investigated distances and orientations. The prepared pharmaceutical capsules produce a magnetic induction in the range of some μT . During dissolution the iron powder reallocated around the magnet and the magnetic induction was decreased between 13% and 21%. The results indicate that the novel marker design is well suited for MMM using less sensitive sensor technologies. This study was partly funded by the German Research Council (GRK 1567/1).

10:40 a.m. | A. Halbleib, D. Strohmeier, M. Gratkowski, J. Haueisen (DE-Ilmenau)

Source Localization Algorithm based on Topographic Matching Pursuit

Spatio-temporal decomposition methods in combination with source localization algorithms can contribute to an improved description and allocation of neural activity from electrical and magnetic multichannel measurements to underlying generators. We introduce a new algorithm, which combines Topographic Matching Pursuit (TMP) as spatio-temporal decomposition method and dipole-source localization, thus we extend the equivalent current dipole model with new parameters. The single channel Matching Pursuit (MP) iteratively creates an approximation of signals with a sum of weighted time-frequency representations called atoms, TMP is a multi-channel extension to the standard MP. In comparison to a hitherto published Multichannel Matching Pursuit (MMP) source localization the new algorithm shows, for a mirrored-dipole configuration, higher Goodness-of-Fit values, if temporal asynchrony exists in the EEG-channels. The new algorithm is applied to EEG-data obtained from a photic driving experiment with eleven volunteers. We show that the temporal asyn-

chrony in the various EEG-channels is captured by the new algorithm and transformed into the phase parameters of the extended mirrored-dipole model. The thus won information of the phase relations is interpreted as the phase parameter of the underlying neural generator. We show in particular that not only the response frequencies but also the phases of the neural sources depend on the stimulation frequency. We conclude that the suggested algorithm is more appropriate for source reconstruction in case of temporal asynchrony than MMP-based procedures used so far.

10:20 – 10:40 Coffee break

11:00 a.m. | U. Graichen, R. Eichardt, J. Haueisen (DE-Ilmenau)

Spatial frequency analysis of cortical surfaces

The human brain exhibits a highly structured surface which is characterized by gyri and sulci. A quantitative examination of the cortical surface can be performed by means of Fourier analysis. In the approach presented in this paper, Fourier descriptors are employed to investigate the spatial spectrum of cortical contours on cross-sections of the human brain. The contour of the brain is defined by the bounding curve in the complex plane and sampled at equidistant points. Fourier descriptors are obtained by a Fourier transformation of the sequence of complex values. This approach provides global frequency information on the whole contour. The proposed methods were validated using artificial data. The layer representing the cortical surface was modeled by a concentric sphere with a modulated circumferential oscillation. It was generated using two scaled basis functions of real spherical harmonics, the monopole and a second function that represents the spatial oscillation. For a given amplitude of the oscillation, the radius of the sphere was chosen such that the greatest extent of the inner layer was 63 mm, which corresponds to the radius of the cortical sphere of the commonly used four-layer conductivity model of the human head. Using the artificial data we showed, that the proposed approach is applicative for spatial frequency analysis of contours of the human brain. Furthermore, we investigated 10 MRI data sets of probands using this approach. The MR imaging was performed on an 1.5-T scanner (Magnetom Vision plus, Siemens AG). The cortical surfaces were segmented using the FreeSurfer software. For both hemispheres of the human brain, cortical contours of cross-sections in sagittal, coronal and transversal directions were analyzed. The estimated power spectral densities show for the sampled contours in all directions two distinct peaks. The first peak is located at wavelengths between 16 and 20 mm, the second peak between 8 to 12 mm. These values correspond to the sulcal depth and intersulcal distances that dominate in the human brain.

11:20 a.m. | M. Gratkowski (DE-Ilmenau), D. Lelic (DK-Aalborg)

Clustering of High-Dimensional EEG Data

Introduction: Source analysis of individual or grand mean evoked brain potentials (EPs) has difficulties studying group differences as few outliers can blur the outcome to a major degree, and the precise time or frequency of the waveforms is not taken into consideration. Recently, we have shown that the accuracy of inverse solutions can be significantly im-

proved by decomposing the EP data into components (usually termed atoms) well defined in time/frequency/space with Multichannel Matching Pursuit (MMP) prior to inverse modelling. We hypothesized that clustering on MMP atoms according to their time-frequency and dipole location would provide a much more reliable tool for studying differences and similarities between groups. Methods: The EPs were decomposed into a number of components well defined in time and frequency using MMP. Inverse modelling was applied to the components and sources were clustered. First, the procedure was tested on simulated EPs in ten phantom subjects, having seven different brain sources. The method was further validated on median nerve somatosensory EP data in ten healthy volunteers, where clusters representing the region around primary somatosensory cortex (SI) were studied. The method was compared to traditional grand mean peak-by-peak source localization and source localization on MMP decomposed grand mean of the same data. Results: For the simulated data, the clustering algorithm gave seven clusters with ten sources each and these sources were localized in correct brain areas. For the empirical data, the three main clusters represented the N20 SI component, background SI activity, and activity peaking frontally to SI around 30ms. For both datasets, the clustering method gave more reliable results than source localization on grand mean and MMP decomposed grand mean. Conclusion: This method proved to be an efficient way to group similar brain activity and thus study brain activation sequence to sensory stimulations.

11:40 a.m. | D. Strohmeier, A. Halbleib, M. Gratkowski, J. Haueisen (DE-Ilmenau)

The Epsilon-Skew-Normal dictionary: A new dictionary for Matching Pursuit based signal decomposition

In the last decade, different extensions to the well-established Matching Pursuit (MP) algorithm have been presented. These techniques, e.g. Multichannel Matching Pursuit (MMP) or Topographic Matching Pursuit (TMP), have been used for the analysis of biomedical recordings such as electroencephalography (EEG) and magnetoencephalography (MEG). Typical analysis schemes involve denoising, artifact reduction as well as component and topographic analysis in the time or time-frequency domain. Moreover, new applications in the field of biosignal source localization have been published. MP techniques are used to decompose single- and multichannel signals into spatio-temporal components (atoms). These atoms are taken iteratively from a highly redundant set (dictionary). Due to the optimal time-frequency characteristics, Gabor dictionaries are commonly applied. However, symmetric Gabor atoms fail at approximating asymmetric oscillatory components. Thus, we present the Epsilon-Skew-Normal (ESN) dictionary built from of symmetric as well as asymmetric oscillatory components. The ESN dictionary can be considered as an extension of the Gabor dictionary and is applicable to both, single- and multichannel recordings. Due to the similarity to the standard Gabor dictionary, existing MP algorithms can be easily adapted. We compare both dictionaries based on the decomposition of simulated as well as real EEG data and conclude that the Epsilon-Skew-Normal dictionary causes smaller decomposition errors.

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| 12:00 noon | P. Fiedler, J. Haueisen (DE-Ilmenau) |
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Novel dry biosignal electrodes based on TiN: Influence of electrode number and arrangement on contact impedance and signal quality in EEG measurements

In order to use conventional biosignal electrodes for Electroencephalography (EEG) it is necessary to fulfill a set of requirements, including time consuming and complex preparation of the skin of a subject. This limits applicability in clinical routine, medical research and possible future applications. For this reason a new class of electrodes is being investigated, eliminating the need for electrolyte gels or pastes and thus being called "dry" electrodes. The concept of these novel electrodes results in the need for a stable and reliable contact with the subject's skin. In order to develop an electrode shape with large contact surface for low electrode-skin impedance while also ensuring a sufficient hair layer penetration, several studies were performed by the authors. In this paper a distinct titanium electrode substrate shape for titanium nitride (TiN) coated electrodes was analyzed regarding influences of the number of interconnected electrodes (called "pins") on electrode-skin impedance and the quality of the acquired EEG biosignal. As a result, 10 interconnected TiN pins had the lowest impedance values of 14 to 55 k Ω (depending on signal frequency) in comparison to 2 to 44 k Ω using conventional Silver/Silver-Chloride (Ag/AgCl) electrodes. Also the mean average deviation (MAD) of two parallel EEG recordings was calculated. The lowest MADs of 2.0 to 2.3 μ V were determined using three interconnected TiN pins. The MADs of 2.1 to 2.5 μ V using a second set of Ag/AgCl electrodes leads to the conclusion that most of the error was related to the measurement method, especially spatial distance of the compared electrodes. This first step in optimization of electrode arrangement showed very promising results and therefore demonstrates the potential of TiN-based electrodes for EEG acquisition.

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| 12:20 noon | S. Klee, D. Link, P. Bessler, J. Haueisen (DE-Ilmenau) |
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Characterization and application of an optoelectrophysiological color stimulator

Introduction: Electrophysiological tests and appropriate stimulators are necessary for objective examination of the visual pathways. Therefore diverse stimuli were imaged on the retina and responses of the visual system were measured using electroencephalography and visual evoked potentials. The silent substitution technique is suitable for a selective chromatic stimulation of the short-, medium-, and long-wavelength-sensitive cones (S-, M-, and L-cones). We present the characterization and application of a combined optical imaging and functional stimulating technique for fundus-controlled optoelectrophysiological silent substitution investigations. **Methods:** We connected a digital color liquid crystal on silicon projector and an electron-multiplying charge-coupled imager to a fundus camera and used a light emitting diode for illumination. Characterizations of the optical and electro-optical components of the stimulator were performed using temporal and spatial modulation transfer functions. Two silent substitution flash sequences were presented to modulate selective activity in the S-cone and the LM-cone pathway. Simultaneously, the visual evoked potentials of six healthy males were recorded and analyzed. **Results:** The temporal and spatial characterization revealed a maximal contrast loss of 7% for the highest stimulation frequency (30 Hz) and maximum cut-off spatial frequencies of about 120 cycles/degree. For

both silent substitution stimulations, we obtained a typical N1-P1 complex in the curve shapes of the S-cone response and the LM-cone response. The latencies after LM-cone stimulation were markedly smaller than that after S-cone stimulation. All volunteers in the study showed higher peak-to-peak amplitudes in the LM-cone responses than in the S-cone responses. Based on the characteristics of all parameters, the ability to produce stimuli to access both the S-cone and the LM-cone pathway could be confirmed. Conclusion: We demonstrated a fundus-controlled optoelectrophysiological stimulation of the human retina using silent substitution technique. The new setup simultaneously provides retinal imaging and electrophysiological investigation of the patient's fundus. The functional integrity of different retinal areas can be examined under direct fundus control.

12:40 p.m. | P. Bessler, S. Klee, J. Haueisen (DE-Ilmenau)

Selective color channel stimulation for objective detection of glaucoma

Introduction: Glaucoma is one of the most common causes of blindness. The aim of the study was the objective examination of glaucoma patients, using selective color channel stimulation based on the silent substitution technique and the classification of the recorded visual evoked potentials of glaucoma patients and healthy subjects. Methods: Visual evoked potentials were recorded for 29 glaucoma patients, 6 severe glaucoma patients and 31 age-matched healthy subjects. On the basis of silent substitution stimulation, cone-specific responses were obtained for short-(S), medium-(M), and long-(L) wavelength-sensitive cones. Stimulation was presented using a 30" liquid crystal display. The cone isolation was tested by an adaption and bleaching experiment. The electroencephalogram was recorded (sample rate 512 Hz) with two electrodes (Oz vs. Fz) simultaneously to the stimulation, using an electrode cap and Ag/AgCl ring electrodes. Results: We found variations in the curve shapes of the stimulated color channels. Statistical analysis revealed significant ($p < 0.05$) differences between the selective stimulated color channels. Furthermore significant differences were observed in some parameters between moderate glaucoma patients and healthy subjects. Distinct changes in the S-cone response profiles were observed in patients with severe glaucoma damage compared with that of a healthy subject following selective S-cone stimulation. Severe glaucoma damage is manifested in the S-cone response for 9 of the 10 eyes. A change in the S-cone response with disease severity can be shown in the analysis of the grand averages. Conclusion: The applied stimulation methods offered advantages in terms of objectivity and flexibility of selective color channel stimulation. We were able to objectively detect glaucoma and its severity using the silent substitution technique. Differences between the color channels of the visual pathways are visible. Therefore, the disease can be assessed by objective electrophysiological testing.

12:40 p.m. – 1:30 p.m. Lunch break