First Symposium

"Toward translational research in brain and heart studies: Achievements and challenges in knowledge and technology transfer"

ABSTRACT BOOKLET

February 18, 2008, Zagreb, Croatia

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"Toward translational research in brain and heart studies: Achievements and challenges in knowledge and technology transfer"

February 18, 2008, Zagreb, Croatia

Organizers: Selma Supek, University of Zagreb, Faculty of Science
Ratko Magjarević, University of Zagreb, Faculty of Electrical Engineering and Computing

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PROGRAM SCHEDULE

10: 00 – 10:15 **Welcome and introductory remarks**
Selma Supek, Univesity of Zagreb, Faculty of Science, for the Organizers
Vedran Mornar, University of Zagreb, Faculty of Electrical Engineering and Computing, dean
Ivica Kostović, Croatian Society for Neuroscience, President
Stanko Tonković, Croatian Medical and Biological Engineering Society, President

10: 15 – 10:30 Jens Haueisen:
"The influence of forward model conductivities on EEG/MEG source reconstruction"

10:30 – 10:45 Selma Supek:
"Neurodynamic imaging in the assessment of sensory and cognitive functions in health and disease"

10:45 – 11: 00 Ivica Kostović
"Neuroimaging in developmental cortical disorders"

11: 00 – 11:30 Coffee Break

11:30 – 11:45 Hrvoje Hećimović:
"Clinical model of neural networks"

11:45 – 12:00 Dražen Domijan:
"How computational modeling might contribute to neuropsychology"

12:00 – 12:30 **Discussion**

12:30 – 14:00 Lunch

14: 00 – 14:15 Ratko Magjarević:
"Can we predict cardiac events? - Our experience on atrial fibrillation prediction after CABG"

14:15 – 14: 30 Jens Haueisen:
"Optimization of magnetic sensor systems for magnetocardiography"

14:30 – 14:45 Sven Lončarić
"An approach to aortic outflow velocity analysis"

14: 45 – 15:00 Coffee Break

15: 00 – 17:00 **Round table discussion**
Intellectual property system
Transfer of knowledge
Transfer of technology
Spin-off companies
Academia-industry/hospitals cooperation
Conflict of interest challenges

Jens Haueisen
TU Ilmenau

Sven Lončarić: ***Technology Transfer Office of the University of Zagreb: An Overview of Activities***
University of Zagreb

Bojan Benko: ***Simple strategy for facilitated protection and utilization of research results***
State Intellectual Property Office of the Republic of Croatia,

Nataša Maršić: ***CARDS 2003 "Intellectual Property Rights Infrastructure for the Research and Development Sector in Croatia"***
Croatian Institute of Technology

Ivo Orlić: ***Science and Technology Park of the University of Rijeka, STeP Ri***
University of Rijeka

The influence of forward model conductivities on EEG/MEG source reconstruction

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***Abstract* – In order to reconstruct the neuronal activity underlying measured EEG and MEG data both the forward problem (computing the electromagnetic field due to given sources) and the inverse problem (finding the best fitting sources to explain given data) have to be solved. The forward problem involves a model with the conductivities of the head, which can be as simple as a homogeneously conducting sphere or as complex as a finite element model consisting of millions of elements, each with a different anisotropic conductivity tensor. The question is addressed how complex the employed forward model should be, and, more specifically, the influence of anisotropic volume conduction is evaluated. For this purpose high resolution finite element models of the rabbit and the human head are employed in combination with individual conductivity tensors to quantify the influence of white matter anisotropy on the solution of the forward and inverse problem in EEG and MEG. Although the current state of the art in the analysis of this influence of brain tissue anisotropy on source reconstruction does not yet allow a final conclusion, the results available indicate that the expected average source localization error due to anisotropic white matter conductivity might be within the principal accuracy limits of current inverse procedures. However, in some percent of the cases a considerably larger localization error might occur. In contrast, dipole orientation and dipole strength estimation are influenced significantly by anisotropy. In conclusion, models taking into account tissue anisotropy information are expected to improve source estimation procedures.**

I. INTRODUCTION

Source localizations based on magnetoencephalography (MEG) and electroencephalography (EEG) data require a mathematical model of the human head (volume conductor model) in order to compute the electric potential and magnetic field distribution produced by electrical sources in the brain. This model includes an approximation of the in vivo conductivity distribution present in the head of the subject under investigation. Volume conductor models range from simple homogeneously conducting spheres to complex numerical models which can consist of millions of elements, each with a different conductivity value (e.g. [1-4]). While in clinical practice simple volume conductor models are still often applied, recent advances in modeling techniques and information technology make the use of individual high resolution volume conductor models nowadays feasible. One of the numerical methods which is often employed is the Finite Element Method (FEM). Since the FEM allows for a detailed 3D modeling of the head, conductivity information for various tissue types and also anisotropy information as obtained through diffusion tensor imaging [5] can be included. The question arises in how far the inclusion of anisotropic tissue conductivity might affect EEG/MEG source reconstruction.

II. METHODS

Two FEM software packages were used: the SimBio / NeuroFEM package [6] and Galerwin [7]. With both packages models of the human head and the rabbit head were constructed out of T1 weighted MRI data sets (human resolution: 1x1x1 mm^3; rabbit resolution: 0.5x0.3125x0.3125 mm^3). Segmentation was performed semi-automatically. Standard conductivity data were taken from the literature. Diffusion tensor data were obtained both for the rabbit and the human head and included into the FEM model. Please see [8,9] for further details on the modeling.

Validation of the FEM modeling was performed in 3 steps: simulations, phantom measurements and animal measurements. While the simulations provided a comparison with analytical models, the phantom measurements and animal measurements used artificial dipoles and physiological stimulus modalities in order to determine procedural limits of the source localization accuracy under real world conditions. In the physiological stimulus modality, the median nerve was stimulated for the cortical representation of the forepaw and the tibeal nerve for the cortical representation of the hindpaw. A 16 channel micro SQUID-MEG system was used for recording the magnetic field. The electrocorticogram was recorded by a grid of 4 x 4 electrodes simultaneously over the contralateral hemisphere of the stimulated nerves. The cortical areas of both nerves have a distance of about 2 mm. This we used to evaluate the results of the source localization procedures.

III. RESULTS

Validation results showed that for the rabbit brain a principal accuracy of the source localization procedure of below 1 mm is achieved. This holds for the artificial dipoles in a spherical phantom and in the rabbit brain. For the physiological stimulus modality, the localized sources were within an accuracy of 1 mm in the expected cortical areas. The difference between the cortical representations of the two nerves was found to be 2.1 mm. We found also a very good agreement between isotropic BEM and FEM model based source reconstructions. Thus, the FEM models were successfully validated.

Sensitivity analysis in the rabbit showed that for both measured tensor distributions and simple artificial anisotropic structures the closer the dipole to the anisotropy, the larger the influence of anisotropy. Whereas dipole location and strength estimation error depend on the dipole-white matter orientation configuration, dipole orientation seems not. Source estimation errors might be largest when the dipole is central over white matter or over an edge of white matter, depending on the dipole-white matter orientation configuration.

For the human studies several brain regions showed a high sensitivity to anisotropic conductivity of white matter tissue, regardless of the anisotropic ratio which was varied from 1:2 to 1:100. In particular, medial regions such as the cingulate, the parietooccipital and the calcarine sulcus were more affected than lateral regions. These results are in good qualitative agreement with [10].

Overall, the influence of anisotropy on source estimation was found to be complex. It seems to depend on the geometry of the anisotropic structure, the geometry relation between the anisotropy and the sources, and the orientation of the sources and the anisotropy with respect to each other.

IV. CONCLUSIONS

Anisotropic volume conduction influences source strength and source orientation estimation more than source location estimation. Local conductivity properties in the vicinity of the source crucially influence source estimation. Thus, the inclusion of tissue anisotropy information will improve source estimation procedures.

ACKNOWLEDGMENT

I would like to thank all my PhD students and collaborators who contributed to the material behind this talk. Special thanks to Daniel Güllmar and Carsten Wolters. Part of the work was supported by the European Union, the German Ministry of Science, and the German Research Council (DFG).

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Neurodynamic imaging in the assessment of sensory and cognitive functions in health and disease

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Four decades ago the use of ultra-sensitive *Superconducting Quantum Interference Device* (SQUID) has allowed extracranial measurements of extremely weak (on the order of 100 fT) magnetic fields of neuronal origin and a direct, real-time measuring of spontaneous and evoked responses of the human brain. Magnetoencephalography (MEG) today represents one of the major functional brain imaging techniques capable to provide unique insight into the sensory and cognitive processing. Our earlier visual studies identified multiple visual areas in the human brain, demonstrated retinotopical organization not only of the striate visual cortex but extrastriate cortex as well. Millisecond temporal resolution of MEG allowed us to provide first empirical evidence of the earliest selective visual attention effect in the striate cortex as a consequence of a feedback mechanism. Spatio-temporal source localization and statistical analysis allowed us to identify earliest face-selective processing in the occipital cortex occurring already at 100 ms post stimulus (Susac et al., HBM 2008, in print). The experimental paradigms and modeling approaches developed for examining sensory and cognitive processing of a normal human brain are used currently in the NIH funded longitudinal study *Functional Neuroimaging of Normal Aging and Alzheimer's Disease* in which our group is focussing on the analysis of a simple auditory oddball task responses from normal aging subjects and AD patients to test medial temporal lobe functions.

Neuroimaging in developmental cortical disorders

Ivica Kostović

Croatian Institute for Brain Research, School of Medicine, University of Zagreb

Major advances in the study of neurodevelopmental, cognitive and mental disorders are related to the application of neuroimaging in the field of clinical neuroscience. In order to evaluate the contribution of neuroimaging in translational neuroscience of neurodevelopmental disorders, it is necessary to have critical evaluation of current methods and their application in diagnostic, as well as treatment procedures.
The early diagnosis is essential for perinatal lesions caused both by genetic and external factors. The following methods are widely used in pediatric neuroimaging: structural MR of high resolution (3Tesla), 3D and volumetric studies, MR spectroscopy, BOLD technique and functional magnetic resonance, MR perfusion, MR diffusion and diffusion tensor imaging (DTi) with tractography.
MR spectroscopy is indicated in monogenetic metabolic disorders within the first days after birth. Migratory disorders, in combination with genomic analysis, require fine structural high-resolution MR (3T) in combination with volumetric studies.
Intractable focal epilepsy requires high-resolution 3Tesla imaging. White matter damage, which is the most frequent cause of neurological deficit in perinatal neurology, is accompanied with hypoxic-ischemic mechanisms and results in reorganization of the white matter, which can be demonstrated by diffusion tensor imaging, tractography and 3D analysis.

A new role of neuroimaging is currently accepted for study of autism spectrum disorders, schizophrenia (also developmental disorder) and adolescent depression where combination of functional MR and 3D gray matter-white matter analysis reveal some surprising results (i.e. enlarged volume of cerebral cortex in autism).
In adolescents suffering of mental disorders, combination of pharmacogenomics and neuroimaging is a new approach, which can direct to a better psycho-pharmacotherapy of individual patients.
In conclusion, neuroimaging has a crucial role in revealing causes of neurodevelopmental disorders, early detection and better planning of treatment. This application of modern neuroimaging methods in study of major neurodevelopmental and cognitive disorders will bridge the gap between basic neuroscience and clinical medicine in the sense of translational neuroscience.

CLINICAL MODEL OF NEURAL NETWORK

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Epilepsy is a neurological illness that adversely affects social, vocational, and psychological functioning. Recent studies show that depression is the most common comorbidity in patients with epilepsy, especially in people with temporal lobe seizures.

The brain regions commonly involved in various types of epilepsies, such as the hippocampus and amygdala in temporal lobe epilepsy and subcortical nuclei in idiopathic generalized epilepsies, are also important components of current models of depression. Increased understanding of mechanisms of depression in epilepsy can improve patients care, and may also yield useful insight of principal mechanisms underlying both depression and epileptogenicity. Recent neuroimaging studies associated depression with specific cerebral structural and functional disturbances, suggesting that a dysfunction in neural networks underlie mood changes.
Current evidence suggests that smaller hippocampal volume in humans is not only a hallmark of mesial temporal lobe epilepsy, but is also associated with depression, and functional imaging studies point to dysfunction in the fronto-limbic network in patients with major depressive disorder. This is also in accord with reports from animal, lesional, and human postmortem studies. Understanding neuroanatomy and interconnectivity of the structures, neurotransmitter pathways and molecular mechanisms implicated in this dysfunction creates a basis to understand clinical expression of the disease. The fronto-limbic pathway presents a model to study a network dysfunction associated with epileptogenicity and mood changes. Currently this lab is involved in assessment of serotonergic and noradrenergic modulation of clinical symptoms of limbic system dysfunction.

How computational modeling might contribute to neuropsychology

Dražen Domijan
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Computational models of the hippocampal region link psychological theories of associative learning with their underlying physiological and anatomical substrates. Gluck and Myers (1993; 2001) proposed a model where the hippocampal region was treated as an information-processing system that transformed stimulus representations. Representations of inputs that co-occur or that are redundant are compressed. On the other hand, the model differentiates input representations that predict different future events. The model makes specific predictions regarding the behavior of humans with brain damages. Based on the theoretical arguments derived from the model, authors developed a neuropsychological test that was able to differentiate healthy elderly individuals from older people with hippocampal atrophy. Due to the fact that mild hippocampal atrophy is a risk factor for subsequent development of Alzheimer's disease, the test might be useful indicator of early signs of degenerative processes in individuals who are not yet showing behavioral impairments. This is an interesting example how theoretical and computational work in psychology and neuroscience might contribute to clinical practice, especially in developing new diagnostic tools.

Can we predict cardiac events? – Our experience on atrial fibrillation prediction after CABG

Ratko Magjarević
University of Zagreb, Faculty of Electrical Engineering and Computing

As a result of the new advances in medicine, health care technology and increased medical knowledge enabling accurate diagnosis and effective treatment of a large number of diseases, average human life span is significantly increasing. In highly developed and industrialized countries, it is expected that the elderly (65+) and very old (80+) population will increase twice by 2050. Through a large number of research projects, many problems regarding elderly population have been opened; and solutions have been found for some of them. Large communities such as EU, USA and Japan have defined research and development goals for future support systems aimed to help the elderly, patients with chronic diseases and the disabled. In order to further enable the increase of the life quality and well-being of the population, future solutions are focused on prevention rather than curing. Some of the solutions that have been already offered deal not only with curing the existing health problems and monitoring of targeted persons, but also with disease prevention and prediction. Considerable efforts have been dedicated to disease prevention through learning and (self)education of population, preferably by means of ICT. Some recently launched projects for future health care include continuous monitoring of physiological parameters from a mobile person, on site information extraction and processing as well as making decision for further actions, when necessary. The number of possible symptomatologies to address is practically uncountable. Our presentation aims to present our research of potential predictors of atrial fibrillation after CABG from continuously recorded ECG after the surgery. We also address problems which rise from switching from laboratory/ward conditions to mobile devices (mHealth) with the same or similar function as well as present some of our thoughts on bringing the device to medical practice and to the market.

Tabu Search Optimization of Magnetic Sensor Systems for Magnetocardiography

Stephan Lau, Roland Eichardt, Luca Di Rienzo, *Member, IEEE*, and Jens Haueisen, *Member, IEEE*

Abstract—**This paper addresses the question of optimal sensor placement for magnetocardiographic field imaging. New magnetic sensor technologies allow less restrictive sensor positioning in this application. We develop a constraint framework for sensor positioning and use tabu search (TS) and particle swarm optimization (PSO) for finding an optimal set of sensors, whereby a new PSO algorithm is designed to fit the needs of our constraint framework. Numerical simulations are carried out with a three compartment boundary element torso model and a multi-dipole heart model. We find an optimal value of about 20 to 30 vectorial sensors and both TS and PSO yield similar sensor distributions. The comparison to sensors on regular grids shows that optimization of vectorial magnetic sensor setups may significantly improve reconstruction quality and that the number of sensors can be reduced.**

Index Terms—**Boundary element methods, optimization methods, inverse problems, magnetostatics, multisensor systems.**

I. Introduction

MAGNETOCARDIOGRAPHIC FIELD IMAGING (MFI) is a technique to record contact free the magnetic field distribution and estimate the underlying source distribution in the heart [1]. Typically, the cardiomagnetic fields are recorded with superconducting quantum interference devices (SQUIDs) [2]. SQUIDs are restricted in their positioning to cryostats, since they require liquid helium (low temperature superconductors) or nitrogen (high temperature superconductors) cooling.

Recently, however, new technologies of magnetic sensor systems for magnetocardiography (MCG) (e.g. optically pumped magnetic sensors [3]) make less restrictive sensor positioning feasible. Therefore the general question arises how to optimally place the sensors obeying a technical minimum distance between them. To this end, a typical goal function used in sensor array optimization is the condition number (CN) of the kernel (leadfield) matrix [4].

Since the generation of the kernel matrix for a given position of magnetic sensors is computationally expensive, a pre-computation for a dense enough grid of sensor positions and orientations is needed. Consequently, the search space of the optimization scheme is discretized.

Tabu Search (TS) [5] is a discrete optimization technique that creates in each step new candidate solutions (sets of sensors) in the neighborhood of the current solution that are not classified as tabu (previously examined). Neighbor solutions are created from the current solution by exchanging elements (sensors) with unused elements with the advantage that local minima in the goal function can be overcome.

In order to validate TS optimization results, a new quasi-continuous particle swarm optimizer (PSO) [6] with minimum sensor distance constraint is proposed in the present paper. Swarm intelligence makes use of the gradient. Not one candidate solution is optimized but a swarm of solutions (the particles) is optimized. PSO, like TS, is robust against local minima. At the same time it is a continuous technique, moving the sensors through the search volume smoothly.

II. Computational Methods

A. Simulation Setup

As described in [7] and [8], we construct a three compartment Boundary Element Method (BEM) (Fig. 1) model out of a three-dimensional magnetic resonance image of a healthy volunteer. We assign homogeneous conductivities of 0.2 S/m and 0.04 S/m for the torso and the lungs, respectively. The ventricular depolarization phase of a heart beat is modeled with the help of 13 electric current dipoles, which are placed around the left ventricle. For all sources we compute the magnetic field distribution considering the sensor arrays discussed below by means of the freely available SimBio toolbox [9].

By fixing the dipole locations, the inverse problem is linearized and a kernel matrix is set up. The kernel matrix contains information on the geometry of the source space, on the forward BEM model and on the geometry of the sensor array. Each row $L_s(i)$ of the kernel matrix L_s contains the linear coefficients that are required to map a set of dipole amplitudes $\mathbf{p}$ to a signal amplitude $\mathbf{b}(i)$ at a sensor with index i, corresponding to $\mathbf{b}=L_s\cdot\mathbf{p}$ with $\mathbf{b}\in\Re^{s\times 1}$ and $\mathbf{p}\in\Re^{1\times t}$.

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To find an optimal setup with r out of altogether s sensors, we first create the kernel matrix $L_s \in \Re^{s \times t}$ for all s sensors and t sources. The kernel matrix of a subset of r sensors $L_r \in \Re^{r \times t}$ can then be obtained simply by taking the respective rows of L_S.

The objective of the optimization is to find the kernel matrix $L_r^* \in \Re^{r \times t}$ by choosing the rows of L_S with minimal CN. The kernel matrix with smallest CN has the highest information content. Thus, also the array of the respective sensors is the optimal selection.

B. *Tabu Search (TS)*

The optimization for the selection of r rows from L_s (and r of s sensors, respectively) is performed by tabu search (TS) [7] with an infinite memory (tabu list).

The sensor search space is discretized in positions by a regular 11x11 grid (distance 2 cm) in front of the torso (similar to [7]). The full directional space is discretized regularly (distance 45°). Our minimum distance of 2 cm is implicitly satisfied by the grid.

To find an optimal configuration with r (between 13 and 100) out of s sensors, we first create the kernel matrix $L_s \in \mathrm{R}^{s \times t}$ for s=7502 sensors (11x11 positions, each with 26 discrete directions) and t=13 sources. The TS optimization is constrained not to select two sensors with same positions.

In our TS algorithm, neighbor solutions L_r are created from the current solution $L_r^{\#}$ by exchanging e rows of $L_r^{\#}$ with unused rows of L_S, which means to use e different sensors in the setup. To make a transition from global to local search, we reduce the number e of exchanged sensors linearly from $s/2$ to 1 over the first 2/3 of the iterations. To prevent reevaluations of any L_r, the tabu list contains information on all previously created matrices (indices of used sensors). The applied TS approach works as follows:

1. create neighbors L_r from the current solution $L_r^{\#}$;
2. compute CN for all L_r that are not in the tabu list;
3. insert newly evaluated L_r into the tabu list;
4. update current solution $L_r^{\#}$, if a new best solution L_r is found in this iteration;
5. continue with 1. or stop, if the maximum number of iterations is reached.

The best out of 10 repetitions is used. The number of iterations and neighbors is chosen to require 1 million CN computations over all.

C. *Particle Swarm Optimization (PSO)*

In this study the standard PSO algorithm 2006 [10] (w=1/3, c=2) is implemented and adapted in the object-oriented (C++) framework SimBio [9]. A swarm of particles is randomly initialized with positions and orientations for a fixed number of sensors. The number of particles is $\#_{particles} = 2\sqrt{5s}$ with 5 being the number of position and orientation parameters (X, Y, Z, Φ, Θ) and s being the number of used sensors. The number of informants per particle is set to exactly 95% of all particles (almost fully informed swarm).

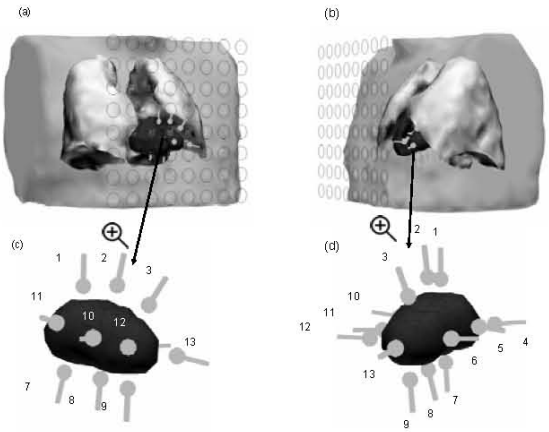

Fig. 1. Sensor plane in front of the boundary element model of torso, lungs and ventricular blood mass. The source model consists of 13 dipoles. Figure after [8].

In each iteration, the velocity vector is updated using the current vector to the individual best solution **f** so far and the informants' best solution **g** so far:

$$\mathbf{v}' = w\,\mathbf{v} + R(c) \cdot (\mathbf{f} - \mathbf{x}) + R(c) \cdot (\mathbf{g} - \mathbf{x}), \qquad (1)$$

where the function R returns a random number in $[0, c]$. Second, particles are moved by their velocity vector:

$$\mathbf{x}' = \mathbf{x} + \mathbf{v}'. \qquad (2)$$

Initially, in order to match the available resources of TS, the optimization is repeated up to 1 million goal function evaluations. Since the first runs show a convergence well below 1500 iterations ($1500 \cdot \#_{particles}$ goal function evaluations) for all simulations this limit is used. To eliminate initialization effects repeated runs are performed up to 1 million goal function evaluations.

PSO is run in a quasi-continuous fashion. The search space is discretized because the repeated computation of kernel matrices is too time consuming. An 85x85 grid (distance 2.5 mm) in the same plane and location is used. Directions are discretized regularly using 30°.

D. *Constraint Framework for Continuous PSO*

The PSO algorithm is equipped with a constraint restoration strategy. After each PSO iteration, the sensor positions are snapped back into the grid, so that a goal function evaluation is possible. Additionally, the minimum distance is restored by iteratively resolving clashes between sensors with the following algorithm (Fig. 2):

1. pick a sensor with maximum number of clashes;
2. move all clashing sensors away radially;
3. snap into grid without re-violating restored distances;
4. if mean(mininum distance violation) > tolerance, continue with 1, otherwise stop.

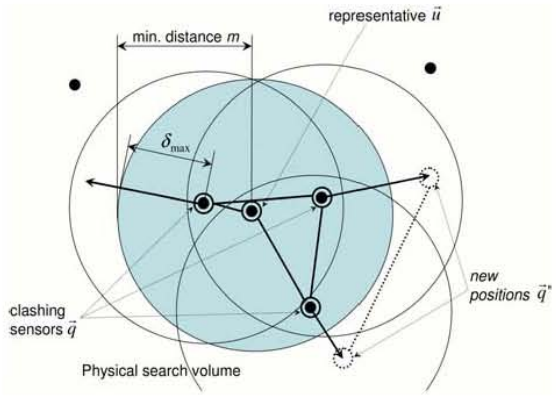

Fig. 2. Restoring the minimum distance in the constraint of PSO. Black dots indicate sensor positions in the search volume and black dots with small circles clashing sensors. Large circles indicate the minimum distance of each sensor, the gray shaded large circle for the representative of the cloud. Exemplary two new sensor positions are indicated by small dotted circles (right).

For this algorithm, a maximum number of iterations of 50 is defined. However, this number of iterations is only reached if the number of sensors approaches the maximum number of sensors that the search space can hold. The sensor with maximum number of clashes is the representative (at position $\vec{u}$ in the search volume) of the sensor cloud (Fig. 2) and is not moved, because its position can be expected to be valuable. Each clashing sensor (at position $\vec{q}$ in the search volume) is moved radially by a length l:

$$\vec{q}' = \vec{q} + l \cdot \frac{(\vec{q} - \vec{u})}{|\vec{q} - \vec{u}|}, \tag{3}$$

where l is actually a weighted sum according to:

$$l = \xi \cdot \delta_{max} + (1 - \xi) \cdot (m - |\vec{q} - \vec{u}|). \tag{4}$$

The minimum sensor distance m is in this paper 2 cm. The maximum violation δ_{max} is defined as the maximum depth of intrusion of any clashing sensor into the space of the representative sensor. The parameter $\xi \in [0,1]$ regulates the influence of δ_{max}. If $\xi = 0$ the clashing sensors are moved to the edge of the space of the representative sensor, which will result in too close positions of the moved sensors in case they have close to parallel movement vectors. If $\xi = 1$ this is prevented but sensor are moved over relatively large distances and the optimization results are potentially disturbed. We heuristically set ξ to 0.05. The advantage of moving the clashing sensors radially away from the representative sensor is that the clashing sensors themselves are moved as little as possible from the cloud center. At the same time, the distance between two clashing sensors is increased.

The radial movement of sensors could potentially result in a new cloud of clashing sensors. A subsequent radial shift would possibly move the clashing sensors back to the first cloud. This would result in oscillations when applied in an iterative procedure as outlined above. This problem may theoretically yield infinite oscillations in the collinear case. Thus, we implemented a small additional random angle to the radial shift (here set to 7°).

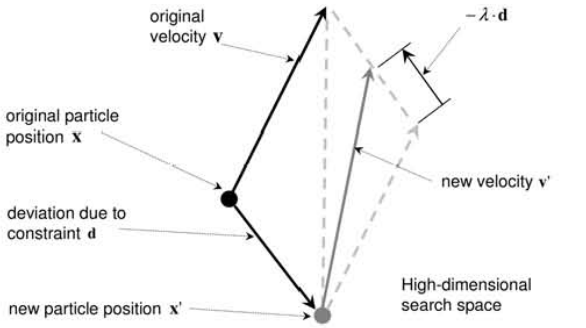

Fig. 3. Correction of the velocity of particles in the PSO algorithm. The black dot indicates the old particle position and the gray dot indicates the new, shifted particle position. The new velocity (gray) is adjusted with the help of λ. Note that particles encode multiple sensor positions and directions and are thus defined in high dimensional search space.

The *snap into the grid without re-violating restored distances* (3. in algorithm above) is realized by selecting the closest grid node to the desired new position, which is at the same time outside the volume occupied by the representative sensor.

E. Modifications to PSO due to Constraints

From the perspective of the optimizer the fulfillment of the constraints in each iteration results in a deviation $\mathbf{d}$ from the current position $\mathbf{x}$ ($\mathbf{x}' = \mathbf{x} + \mathbf{d}$) in high-dimensional space. The current velocity vector $\mathbf{v}$, describing the individual direction in which the global optimum is expected, should then be adjusted (Fig. 3). The new velocity $\mathbf{v}'$ is set using the scaled deviation vector:

$$\mathbf{v}' = \mathbf{v} - \lambda \cdot \mathbf{d}, \tag{5}$$

where $\lambda \in [0,1]$. The parameter λ is set heuristically to 0.5. Keeping the old velocity ($\lambda = 0$) would distract the optimization process, while the case $\lambda = 1$ would overcompensate the shift.

III. Numerical Results

Both optimization techniques reduce the CN significantly when compared to a regular grid with the same number of aligned sensors (Fig. 4). In these noise-free simulations, the optimal number of sensors s is around 20 - 30 for both TS and PSO. The optimal number of sensors for the regular grids is between 36 (6x6) and 49 (7x7). The strongest gain (largest difference between regular grids and optimized sensor setups) is achieved for setups with low number of sensors. This is expected because the lower the number of sensors available the higher the information gain when optimal sensor positions are used.

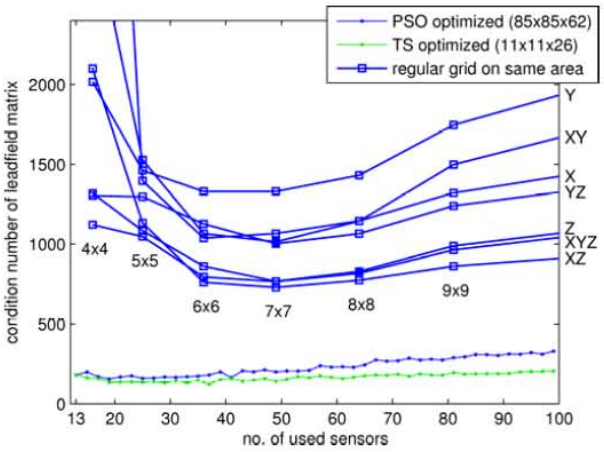

Fig. 4. CNs of optimized and regular grid setups (X = all sensors aligned with positive X-axis, etc.) for a range of numbers of sensors.

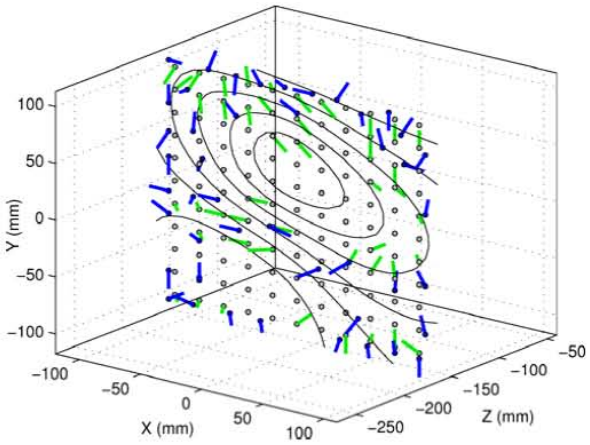

Fig. 5. TS (gray/green bars) and PSO (black/blue bars) optimized setups of 45 sensors on top of 11x11 grid (circles) and a magnetic field map of the X component (thin solid lines). The sensor grid is positioned centrally in front of the torso.

TS and PSO produce very similar CNs for about $s < 45$ (Fig. 4). For denser sensor setups ($s > 45$), TS performs a bit better. The higher CNs for PSO at higher numbers of sensors can be explained by the difficulties PSO encounters in moving sensors in a densely populated search volume. Moreover, slight differences between the two optimization approaches can be explained by the fact that the direction discretization was different for PSO (30°) and TS (45°). Thus, the in reality continuous optimal sensor directions could be better explained by one or the other discretization.

On regular grids, the CNs for the sensor directions show significant differences. As expected for single component sensors the Z-direction sensors exhibit best CNs, while X and Y perform worse. When Z-direction sensors are combined with X or X and Y sensors, yet lower CNs are obtained, which is in line with our previous findings [7].

TS and PSO optimized setups show similar positions and orientations of sensors (Fig. 5). The main difference to regular grids is that sensors tend to be placed in areas of strong magnetic field gradient. Many of the optimal sensor positions are close to the boundary of the search volume (see edges of the square in Fig. 5). This indicates that the search volume might not have been large enough.

Similar results of PSO and TS and repeated runs (results not shown) indicate the existence of few strong minima in the goal function. Thus, there is a potential to develop application specific setups.

IV. Conclusion

Both TS and PSO optimization of vector sensor setups may improve reconstruction robustness and reduce the number of sensors while retaining information in terms of CN.

A strength of TS is its ability to handle dense sensor setups, because sensors are not gradually moved but exchanged. A limitation of TS is that it can only handle a combinatorial optimization on a pre-selected set of sensor positions.

The new quasi-continuous PSO optimization incorporates the gradient and spatial closeness information into the optimization while being robust against local minima of the goal function.

For future work, projection method [11, 12] based and lower error bound [13] based sensor setup optimizations and more extensive search volumes are planed.

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An Approach to Aortic Outflow Velocity Analysis

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In this presentation, we present an overview of ongoing research on signal and image analysis of cardiac Doppler outflow profiles. Morphological changes of aortic outflow profile are used in clinical practice for diagnosis of cardiovascular diseases. A hypothesis is that cardiac aortic outflow profiles are correlated to myocardial function. To test this hypothesis, a new method for analysis of Doppler aortic outflow profiles has been developed. The image obtained by Doppler ultrasound has been processed to extract aortic outflow profile and profile features have been extracted to characterize the profile shape. Statistical analysis of 112 individuals showed that normal cases and diseased cases have different statistical distributions, showing that profile shape is indeed correlated to myocardial function. Furthermore, in order to classify a patient into a normal or diseased group, it is necessary to compare the patient aortic outflow profile to a statistical atlas representing normal cases. To create the atlas, a method for aortic outflow velocity image registration has been developed. The proposed image registration method can be used to construct an atlas for population comparison. The method for aortic outflow velocity image registration is based on mutual information as similarity measure and genetic algorithm as optimization algorithm. Current experimental results will be presented.

Round Table Discussion

Technology Transfer Office of the University of Zagreb: An Overview of Activities

Sven Lončarić, FER, University of Zagreb

Technology transfer from universities and research institutes to business sector is an important step towards the knowledge-based economy. The University of Zagreb makes significant part of Croatian academic community with long tradition in science and engineering with strong potential for technology transfer. The establishment of the Technology Transfer Office at University of Zagreb is the first necessary step to make the technology transfer process more efficient. In this presentation, a short overview of the goals and current activities of this new office will be presented.

Simple strategy for facilitated protection and utilization of research results.

Bojan Benko, Ph.D.
State Intellectual Property Office
of the Republic of Croatia

Summary

This short presentation consists of two parts:

- patentability and patent protection in the field of biomedicine and
- timeline of actions that would be performed to increase chances for obtaining protection of an invention and to gain business result out of this.

Due to the moral reasons and broad public interest, patentability of an invention in biomedicine is particularly sensitive issue that belongs to the edge-limiting area of intellectual property rights, burden with considerable restrictions. On the other hand the market for biomedical products is most propulsive one, giving chance for capitalizing high-tech invention. To cope efficiently with such dichotomy researcher should be well informed about legal side of biomedical invention protection in advance.

Considering existent researcher habits and views about intellectual property protection in Croatia, it could be useful to propose simple model of managing research project and its results with several goals:

- to observe potential invention as soon as possible;
- to make necessary improvement of the invention in the research phase of the project;
- to avoid problems with simultaneous publication of the research results and patent application;
- to increase the chances for favourable licensing of the invention;
- to gain direct financial effect from the research activities;
- to build the status of preferential research group for further projects;
- to improve the image of their own research institution in scientific community as well as in business sector.

CARDS 2003 "Intellectual Property Rights Infrastructure for the Research and Development Sector in Croatia"

Nataša Maršić
Croatian Institute of Technology

Component 1 - **Institutional and legal framework**
The CARDS International and Local Team have worked with the specialised Intellectual property Unit of the Ministry of Science Education and Sports to develop generic procedures for IP protection, valuation of commercial potential prior to publication and technology transfer options.
Material for Component 1 has been supplied in the form of an Innovation Manual that was distributed to the wider innovation network in Croatia.

Component 2 - **Targeted Training and Public Awareness**
Critical mass of key actors improved their knowledge, skills and attitudes to effectively enforce and foster innovative capacities in the filed of IP protection and commercialisation.
Non-specialist workshops
Train the trainers workshops

Component 3 - **Implementation in the R&D institutions- Pilot Project**
Component 3 of this CARDS project focuses on implementing procedures for identifying, protecting and transferring IP at selected pilot partner locations. These 9 pilot partners form part of the IP Network that is being built across Croatia and linked to networks abroad.

Pilot project institutions:
1. Ruder Boakovic Institute/ Rudjer Innovations (www.irb.hr)
2. Faculty for Food Technology and Biotechnology (www.pbf.hr)
3. Faculty of Electrical Engineering and Computing, University Zagreb, FER, (www.fer.hr)
4. Faculty of Mechanical Engineering and Naval Architecture CTT (www.ctt.hr)
5. Brodarski Institute (www.hrbi.hr)
6. University Split + TEMPUS CREATE (www.create-project.info)
7. University Rijeka + STeP (www.uniri.hr/step-ri)
8. Technology Development Centre University of Osijek TERA (www.tera.hr)
9. The University of Zagreb (www.unizg.hr)

Science and Technology Park of the University of Rijeka, STeP Ri

Ivo Orlić

University of Rijeka, Department of Physics

Science and Technology Park in Rijeka (STeP Ri) is being established within a new University Campus (a former military complex) in Trsat, one of the most attractive suburbs of Rijeka. The originator of the initiative is the University of Rijeka, which will be the majority owner. City of Rijeka and County Primorsko Goranska will enter in equity as minority co-owners. The STeP Ri will be established under Croatian Company Law as a limited liability company (d.o.o.).

The principal rationale standing behind the STeP establishment is an intention to commercialize existing knowledge and intellectual property generated at the university faculties and R&D departments and to direct the future R&D toward the projects with the high level of commercial viability. The main goals of the STeP are IP protection and technology transfer from university to business sector through: formation and incubation of new companies; technology licensing to established regional, national and international businesses: networking with similar institutions nationally and internationally and ensuring access to existing small and medium size companies to university research and high technology laboratories.

The range of products and services offered by the STeP will evolve around three programs: IP transfer and protection, licensing and incubation. Beside, a range of professional services and training programs will be offered to the STeP tenants and outside associates at a schedule bases or on demand. Incubate companies will receive individual and shared services. Various pre-incubating services will be offered to the researchers, university and high school students.

The STeP up-stream target markets are faculties, researchers and students as potential technology providers and spin-off candidates and small and medium size regional companies dawn-stream. Technology licensing program, in particularly in the field of biomedicine, is aiming at big national and international companies. Different arrangement can be envisaged in this area: licensing, joint venture, collaborations, joint R&D project etc.

STeP Ri will be centrally located within the University Campus in a three story building with the net area of 3500 m2. This is an old building that will be renovated into a modern, attractive and stimulating space that will inspire researchers.