A novel extreme learning machine for dimensionality reduction on finger movement classification using sEMG

Khairul Anam, Student Member, IEEE and Adel Al-Jumaily, Senior Member, IEEE

Abstract— Projecting a high dimensional feature into a low-dimensional feature without compromising the feature characteristic is a challenging task. This paper proposes a novel dimensionality reduction constituted from the integration of extreme learning machine (ELM) and spectral regression (SR). The ELM in the proposed method is built on the structure of the unsupervised ELM. The hidden layer weights are determined randomly while the output weight is calculated using the spectral regression. The flexibility of the SR that can take labels into consideration leads a new supervised dimensionality reduction called SRELM. Generally speaking, SRELM is an unsupervised system in term of ELM yet it is a supervised system in term of dimensionality reduction. In this paper, SRELM is implemented in the finger movement classification based on electromyography signals from two channels. The experimental results show that the SRELM can enhance the performance of its predecessor, spectral regression linear discriminant analysis (SRDA) because it has better class separability than SRDA. In addition, its performance is better than principal component analysis (PCA) and comparable to uncorrelated linear discriminant analysis (ULDA).

I. INTRODUCTION

Extreme learning machine (ELM) is a single hidden layer feedforward networks (SLFNs) that applies a random projection in the hidden layer. Meanwhile, the output weight of ELM is calculated analytically using a least square method. It means no iterative training in ELM. As a result, ELM training is very fast compared to traditional SLFNs that uses gradient descent algorithm. Interestingly, despite employing random projection, ELM performance outperforms backpropagation neural network in most cases, either classification or regression problems [1][2].

The ELM has succeeded to be applied in many applications. As a classifier, it has been implemented in various applications such as myoelectric pattern recognition [3][4], and character recognition [5][6]. In addition, it played an importance role in face recognition [7], cancer detection [8], and protein structure prediction [10]. As for a regressor, ELM has proved its benefits in the physical parameter estimation [9] and electrical power system [10].

In addition to the classifier and regressor, ELM can be implemented in dimensionality reduction. G Huang et al. [11] have developed an unsupervised extreme learning for unsupervised dimensionality reduction. Its characteristic is similar to principal component analysis (PCA) that reduces the feature dimension with an unknown label. In fact, if the label is available, the dimensionality reduction method can be improved much. For this reason, linear discriminant analysis (LDA) has been proposed to take the labels into account. In many cases, LDA performs better than PCA except in a small number of data [12].

Up to the best author’s knowledge, ELM has not been developed as a supervised dimensionality reduction. This paper proposes a new ELM for supervised dimensionality reduction applied to myoelectric pattern recognition. This paper employs spectral regression [13] to calculate the output weight of ELM instead of least square method as in the original ELM. Spectral regression is a spectral analysis of the Laplacian graph solved by least square regression. Its produces eigenvector to project the input space to the output space. This new ELM is called as spectral regression extreme learning machine (SRELM). The SRELM is similar to unsupervised ELM (US-ELM) proposed by G. Huang et al. [11] in the way it utilizes the obtained eigenvector to project the hidden layer output to the output layer. The different is on the calculation of the eigenvector and the label involvement.

The paper provides three main contributions. Firstly, it proposes a new and first ELM for supervised dimensionality reduction, i.e. SRELM. Secondly, it presents a new model of linear discriminant analysis (LDA) for myoelectric pattern recognition system. And the last, it proves experimentally that SRELM enhances the class separability of spectral regression discriminant analysis (SRDA) [14], another model of LDA that uses the spectral regression.

II. METHOD

A. Extreme Learning Machine (ELM)

Extreme learning machine (ELM) is essentially a learning mechanism intended for SLFNs. Instead of adjusting the hidden weight like in a standard SLFN, ELM sets the hidden layer weights randomly and calculates the output weights analytically.

For N arbitrary distinct samples \( \{(x_i, t_i)\}_{i=1}^{N} \) where \( x_i \in \mathbb{R}^n \) and \( t_i \in \mathbb{R}^m \), the output of SLFNs with \( K \) hidden nodes is

\[
 f(x) = \sum_{j=1}^{K} \beta_j G(a_j, b_j, x_i) = h(x_i)\beta = t_i, \quad i = 1, \ldots, N \tag{1}
\]

where \( f \) is an output of ELM, \( G \) is a hidden layer output, \( h(x_i) \in \mathbb{R}^{KxK} \) is a matrix of hidden layer output and \( \beta \in \mathbb{R}^{Kx} \) is a matrix of output weight. To solve the output weights, ELM minimize the sum of squared losses of prediction error as follows:

\[
 \text{Minimize} \quad L_{ELM} = \frac{1}{2} \| \beta \|^2 + C \sum_{j=1}^{K} \| a_j \|_2
\]

Subject to: \( h(x_i)\beta = t_i - e_i^t \quad i = 1, \ldots, N \)

If we substitute the constraint into the objective function, we will obtain:
Minimize \[ L_{ELM} = \frac{1}{2} \| \beta \|^2 + C \frac{1}{2} \sum_{j=1}^N \| T - H \beta \|^2 \] (3)

where \( H = [h(x_1), ..., h(x_N)]^T \in \mathbb{R}^{N \times K} \) and \( T \in \mathbb{R}^{N \times m} \).

Gradient of (3) with respect to \( \beta \) to zero gives:

\[ \nabla L_{ELM} = \beta + CH^T (T - H \beta) = 0 \] (4)

Equation (4) gives two solutions of \( \beta \) subject to the \( H \). If \( H \) has more rows than columns then:

\[ \beta = \left( H^T H + \frac{I_K}{C} \right)^{-1} H^T T \] (5)

where \( I \) is an identity matrix of dimension \( K \). In the contrary, if \( H \) has more columns than rows, then

\[ \beta = H^T \left( H H^T + \frac{I_N}{C} \right)^{-1} T \] (6)

where \( I \) is an identity matrix of dimension \( N \).

B. Spectral Regression Extreme Learning Machine (SRELM)

To modify ELM for dimensionality reduction, we consider unknown labels for ELM. In another word, we employ unsupervised extreme machine learning as explained in [11]. Therefore, the objective function in (2) is modified as:

Minimize \( L_{SRELM} = \frac{1}{2} \| \beta \|^2 + \lambda \frac{1}{2} \text{Tr}(F^T LF) \)

Subject to \( f_i = h(x_i) \beta \quad i = 1, ..., N \) (7)

where \( L_{SRELM} \) is the objective function, \( F \) is a matrix of the output, \( f_i \) is the output of ELM and \( L \) is a graph Laplacian. By substituting the constraint to the objective function, we have

Minimize \( L_{SRELM} = \frac{1}{2} \| \beta \|^2 + \lambda \frac{1}{2} \text{Tr}(\beta^T H^T L \beta H) \) (8)

Subject to \( \beta^T H^T L \beta H = I_m \)

As proved in [11], the optimal solution of (8) is the solution of the generalized eigenvalue problem:

\[ (I_c + \lambda H^T L H) \beta = \gamma H^T L H \beta \] (9)

The spectral graph analysis assumes that the map of a graph to real line \( y \) as a linear function

\[ y = H \beta \] (10)

As a result, Eq. (9) can be formulated as

\[ (I_c + \lambda H^T L H) \beta = \gamma H^T L y \] (11)

According to the spectral regression theory [13] [14], the optimal \( y \) can be obtained by minimizing

\[ \sum_{i,j} (y_i - y_j)^2 W_{ij} = 2y^T Ly \] (12)

where \( L = D - W \) is a graph Laplacian, \( D \) is a diagonal matrix whose elements are \( D_{ii} = \sum_j W_{ji} \), and \( W \) is a symmetric \( N \times N \) matrix which is a pairwise similarity between two data points. \( N \) is the number of samples. Equation (11) can be also optimized by solving the maximum eigenvalue eigenproblem [13]:

\[ Wy = \lambda y \] (13)

In addition, in the spectral regression algorithm, we can include label consisting \( c \) classes. The solution for \( u \) will contain \( c \)-1 solutions as described in [13].

In summary, the solution to (11) is done in two steps. Firstly solves the eigenvalue problem in (13). Secondly finds \( u \) with satisfies \( H u = y \) using:

\[ u = \arg \min_u \left( \sum_{i=1}^N (u^T h(x_i) - y_i)^2 + \alpha \sum_{j=1}^K u_j^2 \right) \] (14)

where \( \alpha \) is a regression parameter and \( u_j \) is the component of \( u \). Finally

\[ \beta = [u, u_2, ..., u_c] \in \mathbb{R}^L \] (15)

Theoretically, the integration of ELM and SR, called SRELM, results in another variation of LDA. The ELM projects the input feature to a random feature. Then, the spectral regression projects the random feature to the reduced and meaningful feature for the classifier. In the structure of ELM, the SR provides values for the output weights. Interesting characteristic of SRELM is, it is an unsupervised method on the side of ELM structure, but it is a supervised one on the side of dimensionality reduction.

C. Finger movement classification

We tested the performance of SRELM in myoelectric pattern recognition system for classifying ten finger movements. EMG signals were recorded at 2000 kHz sampling frequency as in [15]. The signals were collected from flexor pollicis longus and flexor digitorium superficialis muscles (fig.1). Eight subjects, two females and six males aged 24-60 years old, participated in the experiment. All subjects were normally limbed with no muscle disorder. In addition, the subject’s arm fixed at a specific position to avoid the effect of position changing on EMG signals.

This work extracted features from two EMG channel plus one channel formed from summation of the two channels. Signals were extracted every 100 ms in length of 100 ms using time domain (TD) and autoregressive (AR) features. It involved mean absolute value (3 features), zero waveform lengths (3 features), slope sign changes (3 features), number of zero crossings (3 features), and sample skewness (3 features). In addition, some parameters from Hjorth-time domain parameters (9 features) and 6th order autoregressive model parameters (18 features) were included. The total

![Fig. 1. The placement of the electrodes](image-url)
number of features extracted is 42.

SRELM, as LDA, reduces the dimension of features from 42 to c-1 features in which c is the number of classes. Then, the performance of SRELM was compared with other dimensionality reduction methods such as uncorrelated linear discriminant analysis (ULDA) [16]. Another comparison was also conducted with spectral regression dimensionality reduction (SRDA) and orthogonal fuzzy discriminant analysis (OFNDA) [17]. In addition, principal component analysis (PCA) and unsupervised extreme learning machine (USELM) got involved. The trial without dimensionality reduction (baseline) was also considered in the comparison.

In addition, various classifiers will utilize projected features of SRELM to identify individual and combined finger movements. Those classifiers are AW-ELM [18] (adaptive wavelet ELM), RBF-ELM (radial basis function ELM), SVM (support vector machine), kNN (k-nearest neighbourhood) and LDA. Different classes will be tested starting from five up to ten classes. The ten classes consist of five individual finger movements, i.e. thumb (T), index (I), middle (M), ring (R), little (L). The other movements are combined finger movements consisted of thumb-index (T–I), thumb-middle (T–M), thumb-ring (T–R), thumb-little (T–L) and the hand close (HC).

III. RESULT AND DISCUSSION

A. Parameter optimization

The parameter optimization of SRELM influences the performance of the system. It contains two main parameters, i.e. the number of hidden nodes (a part of the ELM parameter) and alpha α (a part of the regression coefficient of the spectral regression). As in many feedforward neural networks, the number of hidden nodes is a trivial parameter that is not easy to determine. Therefore, we varied the number of hidden nodes and selected the optimal one by considering the accuracy and the reduction time.

The fig. 2a presents the experimental result. As shown by the intersection of two red lines in the fig. 2a, 1000-nodes in the hidden layer is the optimum number. As for alpha (α), fig. 2b shows that the accuracy is guaranteed good if the alpha is more than 4. In this paper, we simply select alpha = 10.

B. Class number experiments

In this experiment, we tested the performance of SRELM in reducing feature dimension for different classes, ranging from five up to ten classes. Table 1 presents the classes involved in the experiment. The SRELM’s performance is compared to other well-known methods such as ULDA, SRDA, ONFDA, PCA, USELM and baseline. In addition, all experiments employed AW-ELM as a classifier. Fig 3 presents the experimental result.

As shown in Fig. 3, the accuracy of the system is decreasing as the number of classes is increasing. The trends happen to all methods. The characteristic of SRELM is comparable to the state-of-the-art of linear discriminant analysis. All supervised dimensionality reductions such as ULDA, SRDA, SRELM, and OFNDA attain similar accuracy in all class numbers. Even, SRELM is better than all methods tested. Its accuracy is ranging from 95.67 % to 86.73 % from 5 to 10 classes of movement.

SRELM and SRDA employ same spectral regression. Nevertheless, SRELM has more precise class separation than SRDA as shown in fig. 4. The class separability of SRELM is similar to ULDA and OFNDA (fig. 4). Class separability helps the classifier in classifying the movement type. Hence, the accuracy of the system using SRELM exceeds the others (fig. 3). Despite having better class separation performance, SRELM takes more processing time than SRDA, as seen in fig. 5. However, its processing time is still reasonable and

### Table 1: Various classes involved in the experiment

<table>
<thead>
<tr>
<th>#Classes</th>
<th>Classes</th>
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<tbody>
<tr>
<td>5</td>
<td>T, I, M, R, L</td>
</tr>
<tr>
<td>6</td>
<td>T, I, M, R, L, T-I</td>
</tr>
<tr>
<td>7</td>
<td>T, I, M, R, L, T-I, T-M</td>
</tr>
</tbody>
</table>

Figure 3. The performance of SRELM and others across eight subjects

Figure 4. Scatter plot of two first discriminant data using (a). SRDA, (b). SRELM, (c) ULDA and (d) OFNDA on five-class trial from the first subject
less than ULDA’s processing time.

C. Classifier experiments

Various types of classifiers were involved to test the performance of SRELM. Fig. 6 presents the result. It indicates that SRELM works well across five classifiers. It has similar performance to other LDA extension. In addition, it outperforms PCA and the baseline. Analysis of variance (ANOVA) test was also conducted to find out the true comparison of SRELM and other methods. Fig. 7 presents the ANOVA test for p is set at 0.05. It indicates that there is a significant difference between the performance of SRELM and PCA, USELM, and Baseline (p<0.05). On the other hand, the performance of SRELM is comparable to the well-known dimensionality reduction LDA and its variation (p>0.05).

IV. CONCLUSION

This paper proposes a new extreme learning machine and at the same time a new dimensionality reduction called SRELM for finger movement classification. The experiment results show that SRELM is comparable to ULDA and OFNDA and better than SRDA. Moreover, it has better class separability than SRDA. SRELM can also work well on different classifiers and various numbers of classes with an average accuracy ranging from 95.67 % to 86.73 % from 5 to 10 classes of movement across eight subjects using two EMG channels.

REFERENCES


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Dear Colleagues,

It is a great pleasure to welcome you to the 7th International IEEE EMBS Conference on Neural Engineering, which for the first time is being held in France. Neural Engineering is an emerging core discipline, which coalesces neuroscience with engineering. The conference will highlight the emerging engineering innovations in the restoration and enhancement of impaired sensory, motor, and cognitive functions, novel engineering for deepening knowledge of brain function, and advanced design and use of neurotechnologies.

Neural engineering draws expertise from computational neuroscience, neurology, neurosurgery, electrical engineering, materials engineering, and cell and molecular neuroscience. Through innovations in neurotechnology the community seeks to synergize scientists, engineers, and clinicians toward improved medical therapies.

The conference will provide a unique global networking opportunity with leading researchers, medical and industry professionals, policy makers in innovative healthcare technologies, as well as students. Plenary and invited talks will be presented by internationally renowned researchers, industry leaders and policy makers. Poster presentations will facilitate exchange of ideas in a highly interactive environment.

The IEEE EMBS has been promoting the field of Neural Engineering for decades, and this conference will further promote this important field. The large number of presentations will reflect state of the art in neural engineering research. The Conference shall also address questions including what are the current and future trends, and what are the major obstacles and challenges in the field of neural engineering.

Considerable attention has been given to paper quality and reviewing, with the rejection rate of papers doubling in comparison to previous conferences and with each paper receiving on average more than three reviews.

On behalf of the Organizing Committee, we welcome you to Montpellier, trust you will benefit from and contribute to the scientific interactions and enjoy the remarkable culture, history and cuisine the city and surrounds have to offer.

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Nigel Lovell, PhD
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Plenary Speakers

Professor John A. Rogers  
Seitz Materials Research Laboratory

Biographical Sketch: Professor John A. Rogers obtained BA and BS degrees in chemistry and in physics from the University of Texas, Austin, in 1989. From MIT, he received SM degrees in physics and in chemistry in 1992 and the PhD degree in physical chemistry in 1995. From 1995 to 1997, Rogers was a Junior Fellow in the Harvard University Society of Fellows. He joined Bell Laboratories as a Member of Technical Staff in the Condensed Matter Physics Research Department in 1997, and served as Director of this department from the end of 2000 to 2002. He is currently Swanlund Chair Professor at University of Illinois at Urbana/Champaign, with a primary appointment in the Department of Materials Science and Engineering, and joint appointments in several other departments, including Chemistry. He is Director of the Seitz Materials Research Laboratory.

Rogers’ research includes fundamental and applied aspects of materials for unusual electronic and photonic devices, with an emphasis on bio-integrated and bio-inspired systems. He has published more than 450 papers and is inventor on over 80 patents, more than 50 of which are licensed or in active use. Rogers is a Fellow of the IEEE, APS, MRS and AAAS, and he is a member of the National Academy of Engineering and the American Academy of Arts and Sciences. His research has been recognized with many awards, including a MacArthur Fellowship in 2009, the Lemelson-MIT Prize in 2011, the MRS Mid-Career Researcher Award, the ASME Robert Henry Thurston Award and the Smithsonian Award for Ingenuity in the Physical Sciences, all in 2013.

Presentation Title: Materials for Soft Optoelectronic Interfaces to the Brain

Abstract: Successful integration of optoelectronic and microfluidic systems with the brain has the potential to accelerate basic scientific discoveries and their translation into clinically relevant technologies. Specifically, an ability to insert light sources, detectors, multiplexed sensors, programmable microfluidic networks and other components into precise locations of the deep brain, or to laminate them onto targeted surfaces of the brain could yield unique and important types of function. In this talk, we describe materials and assembly techniques that enable injectable, flexible and 3D classes of cellular-scale optoelectronic and microfluidic systems, with examples of use in optogenetics and pharmacological studies, including wireless, programmed complex behavioral control over freely moving, unthethered animals. The ability of these ultrathin, mechanically compliant, biocompatible systems to afford minimally invasive operation in or on the soft tissues of the mammalian brain foreshadow applications in other organ systems, with potential for broad utility in biomedical science and engineering.
Professor Karlheinz Meier
Professor (Chair) Experimental Physics
Department of Physics and Astronomy


Presentation Title: Computing like the Brain - Physical Copies of Brain Circuits

Abstract: Alan Turings theory and John von Neumanns computer architecture constitute the foundations of information technology. Despite the tremendous success of modern computers their limitations are evident. The increasing hunger for energy and the complexity of software are an ever burden for computer users. The brain is fundamentally different. It operates on a very low energy budget and does not require engineered software. It is doing badly in arithmetics but outperforms modern computers in interpreting complex and noisy data, finding causal relations and making predictions based on previous experience.

The lecture will introduce the idea of implementing synthetic neural circuits as physical models which offer several orders of magnitude advantages over the traditional computing approach in terms of energy and time. Such neuromorphic circuits can contribute to a better understanding of brain function but also be the basis for a fundamentally different way of processing and interpreting information.
Professor Hugues Duffau  
Montpellier University Medical Hospital

Biographical Sketch: Hugues DUFFAU (MD, PhD) is Professor and Chairman of the Neurosurgery Department in the Montpellier University Medical Hospital and Head of the INSERM 1051 Team “Plasticity of the central nervous system, human stem cells and glial tumors” at the Institute for Neurosciences of Montpellier (France). He is the world leader in the wide-awake cognitive neurosurgery of slow-growing brain tumors, a routine which he has developed since twenty years. During this type of surgery, the patient is awake and collaborates actively with the neurosurgeon, while a direct functional mapping of the patient’s brain is systematically performed using electrical stimulation, to prevent resections of critical and eloquent areas. Thus, his approach can be also considered as an alternative brain functional imaging based on awake responses to electrical stimulation of cortex areas and networked structures. His fundamental approach is centered on the concepts of the hodotopic brain and neuroplasticity, breaking with the traditional localizationist view of cerebral processing. For his innovative work in neurosurgery and neurosciences, he was awarded Doctor Honoris Causa several times, and he was the youngest recipient of the prestigious Herbert Olivecrona Award from the Karolinska Institute in Stockholm. He has written four textbooks and over 265 publications in international journals ranging from neurosurgery to fundamental neurosciences, including cognitive sciences and brain plasticity for a total of more than 13,000 citations. He is Ad-hoc reviewer for 82 journals including: New England Journal of Medicine, Lancet Oncology, Nature Medicine, Nature Reviews Neuroscience, Nature Reviews Neurology; Annals of Neurology, Brain, Cerebral Cortex, Trends in Cognitive Science, Current Biology, etc. He is also very stimulating for the many collaborators he has and is always supportive to younger ones.

Presentation Title: The brain connectome revisited: Insight from electrical stimulation mapping in awake surgery

Abstract: Despite advances in the new science of connectomics, which aims to comprehensively map neural connections at both structural and functional levels, techniques to directly study the function of white matter tracts in vivo in humans have proved elusive. Direct electrical stimulation (DES) mapping of the subcortical fibres, in addition to the cortical mapping, offers a unique opportunity to investigate the functional connectivity of the brain. This original method permits real-time anatomo-functional correlations, especially with regard to neural pathways, in awake patients undergoing brain surgery. The goal is to review new insights, gained from axonal DES, into the functional connectivity underlying the sensorimotor, visuospatial, language and sociocognitive systems. Interactions between these neural networks and multimodal systems, such as working memory, attention, executive functions and consciousness, can also be investigated by cortical and axonal stimulation. In this networking model of conation and cognition, brain processing is not conceived as the sum of several subfunctions, but results from the integration and potentiation of parallel—though partially overlapping—subnetworks. This hodotopical account, supported by axonal DES, improves our understanding of neuroplasticity and its limitations. The clinical implications of this paradigmatic shift from localizationism to hodotopy, in the context of brain surgery, neurology, neurorehabilitation and psychiatry, will be discussed.
Symposium Speakers

Title: The Future of BMI: BMI Control of Functional Electrical Stimulation

Symposium Summary: Recent advances in neural engineering have demonstrated that it is possible to record the neuronal activity in the brain, decode information about the intention of a paralyzed patient to move their limb and then use that information to control a robotic device or exoskeleton (BMI). At the same time, great strides have been made in developing improved stimulators that can activate nerves or muscles and restore movement (FES). However, it is becoming increasingly evident that coordinating the intention to move via BMI with the application of FES will induce neuroplasticity that optimizes functional outcomes. This symposium will describe the future of BMI that controls FES to restore volitional movements of a patient’s own limbs after neurological injury or disease (BMI-FES). Vivian Mushahwar will provide an overview of the latest advances in FES that serve as a critical platform for BMI-FES. Kathryn Atwell will describe a BMI-FES system that can provide a powerful new therapeutic intervention for patients with stroke. Karen Moxon will demonstrate a novel BMI-FES in a rat model of complete spinal cord injury that provides insight into neural encoding.

Speakers:

Speaker #1: Vivian Mushahwar  
Department of Bioengineering, University of Alberta

Speaker #2: Kathryn Atwell  
Institute of Biomaterials and Biomedical Engineering, University of Toronto

Speaker #3: Karen Moxon  
School of Biomedical Engineering, Science and Health Systems, Drexel University
Title: Neuromodulation for Seizure Control

Symposium Summary: Ranked as the 20th leading cause of disability globally in 2010 and contributing to 8% of the 92 million disability-adjusted years (DALY) that are caused by neurological disorders and are projected to increase by 12% in the year 2030 (according to WHO), epilepsy continues to challenge both the scientific and the patient community with its severe consequences on mental health, re-hospitalization rates, and social engagement. About 2.8 million people have been diagnosed with epilepsy (1) and the cost to the society is about $15.5B/year (2). Antiepileptic drugs (AED) help control seizure frequency in most patients. Only a fraction of the intractable patients are candidates for surgical resection based on presurgical functional assessment. Neuro-ablative surgery can treat epilepsies refractory to conventional pharmacotherapy but for many patients electrical stimulation is the only alternative. The last few years have seen significant improvements in the control of abnormal neural activity with electrical stimulation. Deep Brain Stimulation has been highly effective at controlling motor disorders in patient with Parkinson’s disease. In the field of epilepsy, neuromodulation has been applied with some success. Several new methods have now gone through Phase II clinical trials and new methods have under development. In this symposium we will review some of the basic mechanisms of the generation of seizures using computer simulation and experimentation. We will also review the basic principles of neuromodulation and the mechanisms of seizure control from in-vitro experiments to human clinical trials. The faculty includes a clinician, neuroscientist and biomedical engineer with significant experience in epilepsy.

Speakers:

Speaker #1: Fabrice Wendling, - Mechanisms of seizure generation

LTSI – UMR Inserm – Head SESAME Team (Epileptogenic Systems: Signals and Models)
Université de Rennes 1, France

Speaker #2: Paul Boon - Seizure Suppression with high Frequency Stimulation

Professor and Chairman Department of Neurology – Division of Head, Neck and Nervous System Director Institute for Neuroscience, Ghent University Hospital, Holland

Speaker #3 Dominique Durand - Mechanism of seizure control with low frequency stimulation

Dept of Biomedical Engineering and Neurosciences, Case Western Reserve University, USA
Title: Electrical and Optical Interfaces for Small Peripheral Nerves

Symposium Summary: The symposium will be organized as a discussion panel with one moderator and seven panelists. Ahead of the conference, the moderator will communicate with the panelists to formulate a set of five questions focused on key technological challenges.

Moderator:

Kristoffer Famm
Vice President, Bioelectronics R&D, GlaxoSmithKline
https://www.linkedin.com/pub/kristoffer-famm/2/2b4/84a

Speakers:

Speaker #1: Warren Grill - Interfacing with autonomic nerves to decipher signaling changes and deliver treatment in lower urinary tract disorders
Professor, Biomedical Engineering, Duke University, USA
http://bme.duke.edu/faculty/warren-m-grill

Speaker #2: Walter Voit - Softening bioelectronics for chronic interface with small nerves via cuff electrodes, penetrating probes, and blanket arrays
Assistant Professor, Materials Science and Engineering, University of Texas, Dallas, USA
www.voitlab.com

Speaker #3: Chew - High resolution nerve recording through nerve microdissection and microchannel implantation
Neural Interface Manager, Bioelectronics, GlaxoSmithKline and Senior Research Associate, University of Cambridge, UK
**Speaker #4: Tim Gardner** - High-density carbon-fiber electrode array for long-term neural recording
Assistant Professor, Dept. of Biology, Boston University, USA
http://www.bu.edu/biology/people/faculty/gardner/

**Speaker #5: Victor Pikov** - Electrical blocking of activity in small unmyelinated nerves
(HMRI), Senior Scientist, HMRI and Consultant, Bioelectronics, GlaxoSmithKline
www.linkedin.com/pub/victor-pikov/31/bb2/90b

**Speaker #6: Simon Schultz** - Optical recording of activity patterns in myelinated and unmyelinated nerves and evaluating their optical scattering properties
Reader, Department of Bioengineering, Imperial College London, Director, Centre for Neurotechnology, Imperial College London, UK - www.schultzlab.org

**Speaker #7: David Holder** - Imaging fascicular traffic within peripheral nerve using Electrical Impedance Tomography with a flexible cuff electrode array
Professor of Biophysics and Clinical Neurophysiology, UCL Hon. Consultant in Clinical Neurophysiology, UCL Hospitals-http://www.ucl.ac.uk/medphys/staff/people/dholder
Symposium Summary: The Brain, by essence, and by function, has to gather informations and, after processing, emits orders of action. To fulfill this mission, it received from Mother Nature sensory receptors to probe the external world (vision, hearing, smelling, tasting, and touching) and effectors to act on the internal as well as on the external worlds (glands and muscles). In both directions the Brain is in contact with receptors and effectors through specific interfaces called synapses. When, particularly for medical reasons, it is necessary to create artificial routes to introduce data from the external world, devices have to be developed which convey either chemical or electrical signals, which are the basis of the method of neurostimulation (peripheral, or deep brain). Similarly, orders generated by the brain have to be translated, most of the time by electrical recordings to effectors mimicking the human features such as sound (as voice synthesizers) or motion (motors mimicking muscles). In the first situation (inbound), deep brain stimulation has been one of the earliest application of this type, because electrical stimulation is the universal language which can be interpreted by the neuronal structures, the first order of magnitude of modulation being intensity of the stimulating current and the frequency of emitted waveforms. In the second situation (outbound) the structural design in related to the specificity of the action, and simultaneously the code of the brain activity used to trigger these effectors is poorly understood and then difficult to decode.

The technological progresses and particularly the advances of micro-nano technologies, changed the rules of the game allowing miniaturization, data processing, energy delivery and storage. Paradoxically, but quite naturally, this is at the contact between biological brain tissues and the non-organic components of the devices that the problems are. Finally one can see the DBS and BCI as a global problem where at the interface with tissues we need: higher resolution, higher compatibility, upstream to the increasing need for high throughput, high-speed, online processing and multivariate mathematics, which might not be all currently available.

Speakers:

**Speaker #1: Pr A.L. Benabid** - Interfacing the brain: Deep brain stimulation and invasive BCI technologies
Chairman of CEA CLINATEC

**Speaker #2: Bin He, PhD** - Noninvasive brain-computer interface: Challenges and opportunities
Director, Institute for Engineering in Medicine
Distinguished McKnight University Professor of Biomedical Engineering
Medtronic-Bakken Endowed Chair for Engineering in Medicine – University of Minnesota

**Speaker #3: Jose M. Carmena, Ph.D.** - Closed-Loop Design Strategies for Neuroprosthetic Control
Associate Professor of Electrical Engineering & Computer Sciences
Co-Director, Neuroengineering Center, University of California, Berkeley
### Program in Chronological Order

* – Corresponding Author

**Wednesday, 22 April 2015**

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<td><strong>Brain Computer Interfaces-Poster Session</strong> (Poster Session)</td>
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| 08:20-11:00| **Comparing Decoding Performance between Functionally Defined Neural Populations**  
Best, Matthew (Univ. of Chicago);  
Takahashi, Kazutaka* (Univ. of Chicago);  
Hatsopoulos, Nicholas (Univ. of Chicago) | WeAT1.1 |
| 08:20-11:00| **Hybrid Fnirs-EEG based Discrimination of 5 Levels of Memory Load**  
Herff, Christian* (Karlsruhe Institute of Technology);  
Fortmann, Ole (Karlsruhe Institute of Technology);  
Tse, Chun-Yu (Department of Psychology & Center for Cognition and Brain Studie);  
Cheng, Xiaoqin (Department of Psychology, National University of Singapore, Sing);  
Putze, Felix (Karlsruhe Institute of Technology);  
Heger, Dominic (Karlsruhe Institute of Technology, Cognitive Systems Lab);  
Schultz, Tanja (Karlsruhe Institute of Technology, Cognitive Systems Lab) | WeAT1.2 |
| 08:20-11:00| **Sequential Power per Area Optimization of Multichannel Neural Recording Interface based on Dual Quadratic Programming**  
Zjajo, Amir* (Delft Univ. of Technology);  
Galuzzi, Carlo (Delft Univ. of Technology);  
Van Leuken, Rene (Delft Univ. of Technology) | WeAT1.3 |
| 08:20-11:00| **Robustness of Movement Detection Techniques from Motor Execution: Single Trial Movement Related Cortical Potential**  
Aliakbaryhosseinabadi, Susan* (the Center for Sensory-Motor Intraction, Department of Health Sc);  
Jiang, Ning (Univ. Medical Center Goettingen);  
Pettrini, Laura (the Center for Sensory-Motor Intraction, Department of Health Sc);  
Farina, Dario (Bernstein Center for Computational Neuroscience, Univ. Medic);  
Dremstrup, Kim (Aalborg Univ.);  
Mrachacz-Kersting, Natalie (Aalborg Univ.) | WeAT1.4 |
| 08:20-11:00| **Towards Improvement of MI-BCI Performance of Subjects with BCI Deficiency**  
Bamdadian, Atieh* (Institute for Infocomm Research, Agency for Science, Technology and);  
Guan, Cuntai (Institute for Infocomm Research);  
Ang, Kai Keng (Institute for Infocomm Research);  
Xu, Jian-Xin (National University of Singapore) | WeAT1.5 |
### Modeling Functional Adaptation to Sudden Onset of Electrical Stimulation in Vestibular Prostheses

DiGiovanna, Jack* (EPFL); Nguyen, Thuy Anh Khoa (EPF Lausanne); Londono, Naik (Ecole Polytechnique Fédérale de Lausanne (EPFL)); Guinand, Nils (University of Geneva); Guyot, Jean-Philippe (ENT Department, Geneva University Hospital); Pérez-Fornos, Angelica (Cochlear Implant Center for French Speaking Switzerland, Service); Micera, Silvestro (Scuola Superiore Sant'Anna)

### Human Performance-Poster Session (Poster Session)
**Chair:** Strauss, Daniel J. (Saarland University, Medical Faculty)

####Effect of Internal Model Development on Effort and Error during EMG Control of Three Functional Tracking Tasks

Daigle, Sophie* (Institute of Biomedical Engineering, University of New Brunswick); Johnson, Reva (Northwestern University); Sensinger, Jonathon W. (University of New Brunswick)

####A Novel Approach to Driving Fatigue Detection using Forehead EOG

Zhang, Yu-Fei (Shanghai Jiao Tong University); Gao, Xiangyu (Shanghai Jiao Tong University); Zhu, Jia-Yi (Shanghai Jiao Tong University); Zheng, Wei-Long (Shanghai Jiao Tong University); Lu, Bao-Liang* (Shanghai Jiao Tong University)

####A Personalized Balance Measurement for Home-Based Rehabilitation

Gonzalez, Alejandro (LIRMM); Fraisse, Philippe (University of Montpellier 2, France); Hayashibe, Mitsuhiro* (INRIA)

####Alpha and Theta Intensive Neurofeedback Protocol for Age-Related Cognitive Deficits

Reis, Joana (Life and Health Sciences Research Institute (ICVS)); Silva, Ana Maria (Life and Health Sciences Research Institute (ICVS)); Pereira, Mariana (Life and Health Sciences Research Institute (ICVS) / ICVS/3B's); Dias, Nuno S. * (Life and Health Science Research Institute / ICVS/3B's – PT Gove)

####Haptic SLAM for Context-Aware Robotic Hand Prosthetics – Simultaneous Inference of Hand Pose and Object Shape using Particle Filters

M.P. Behbahani, Feryal (Imperial College London); Taunton, Ruth (Imperial College London); Thomik, Andreas A.C. (Imperial College London); Faisal, A. Aldo* (Imperial College London)

####Effects of Surface Width on Quantitative Depth Perception in Surface Edges from Temporal Interocular Unmatched Features

Zhuang, Siqi (Shanghai Jiao Tong University); Chen, Yao* (Shanghai Jiao Tong University)
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**Assessing the Acquisition of a New Skill with Electroencephalography**  
Gutierrez, David* (Cinvestav Monterrey);  
Ramírez-Moreno, Mauricio Adolfo (Cinvestav Monterrey);  
Lazcano-Herrera, Alicia Guadalupe (Technological Institute of Tlalnepantla)

08:30-11:00  
**Recognition of Postures and FOG in Parkinson's Disease Patients using Microsoft Kinect Sensor**  
Amini Maghsoud Bigy, Amin* (Brunel University London);  
Banitsas, Konstantinos (Brunel University);  
Badii, Atta (University of Reading);  
Cosmas, John (Brunel University London)

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**Cortical Networks for Audiovisual Interactions during Visual-Affected Auditory Discrimination**  
Guo, Xiaoli (Shanghai Jiao Tong Univ.);  
Li, Xuan (Shanghai Jiao Tong Univ.);  
Tong, Shanbao* (Shanghai Jiao Tong Univ.)

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**Web-Enabled Software for Clinical Telegaming Evaluation of Multisensory Integration and Response to Auditory and Visual Stimuli**  
Xu, Linda (Brain Health Alliance);  
Loh, Stephan (Brain Health Alliance);  
Taswell, Carl* (Brain Health Alliance)

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**Methodology for Automatic Movement Cycle Extraction using Switching Linear Dynamic System**  
Baptista, Roberto de Souza (Univ. de Brasilia);  
Padilha Lanari Bó, Antônio (Univ. de Brasilia);  
Hayashibe, Mitsuhiro* (INRIA)

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**Correlation between Cortical Inhibition and Auditory Stream Segregation in a Driving Environment**  
Gonzalez-Trejo, Ernesto* (Systems Neuroscience and Neurotechnology Unit);  
Kohl, Manuel (Saarland Univ. of Applied Sciences);  
Steinbach, Alexander (Saarland Univ. of Applied Sciences);  
Mögeler, Hannes (AEV);  
Pfleger, Norbert (Semvox);  
Strauss, Daniel J. (Saarland Univ., Medical Faculty)

08:30-11:00  
**Gaze based Robot Control: The Communicative Approach**  
Fedorova, Anastasia A.* (NRC "Kurchatov Institute");  
Shishkin, Sergei L. (NRC Kurchatov Institute);  
Nuzhdin, Yury (NRC "Kurchatov Institute");  
Velichkovsky, Boris Mitrofanovich (NRC "Kurchatov Institute")
Continuous Prediction of Shoulder Joint Angle in Real-Time
Aung, Yee Mon* (University of Technology, Sydney);
Anam, Khairul (University of Technology Sydney);
Al-Jumaily, Adel (University of Technology Sydney)

Ergonomics of the Control by a Quadriplegic of Hand Functions
Tigra, Wafa* (DEMAR Axonic);
azevedo, Christine (INRIA);
Fattal, Charles (PROPARA);
Guiraud, David (INRIA)

Implementation of Feature Extraction Methods and Support Vector Machine for
Classification of Partial Body Weight Supports in Overground Robot-Aided Walking
Figueiredo, Joana (University of Minho);
Santos, Cristina (University of Minho);
Urendes, Eloy (Neural Rehabilitation Group, Cajal Institute, Spanish National R);
Pons, Jose Luis* (Cajal Institute, Spanish Research Council);
Moreno, Juan C. (CSIC)

Evaluating Driving Fatigue Detection Algorithms using Eye Tracking Glasses
Gao, Xiangyu (Shanghai Jiao Tong Univ.);
Zhang, Yu-Fei (Shanghai Jiao Tong Univ.);
Zheng, Wei-Long (Shanghai Jiao Tong Univ.);
Lu, Bao-Liang* (Shanghai Jiao Tong Univ.)

Error Correction in Essential Tremor Patients and Healthy Subjects during a
Constant Torque Task
Luft, Frauke* (University of Twente);
Mugge, Winfred (VU University Amsterdam);
Schouten, Alfred (Delft University of Technology);
Bour, Lo (Academic Medical Centre, University of Amsterdam);
Heida, Tjitske (University of Twente)

Improving Functional Electrical Stimulation for Drop Foot Correction in Hemiplegic
Patients by Nonlinear Model Predictive Control
Aram, Maedeh* (Optimization in Robotics and Biomechanics, IWR, Univ. of He);
Mombaur, Katja (Univ. of Heidelberg);
Froger, Jérôme (CHU Nîmes);
Azevedo-Coste, Christine (DEMAR INRIA/LIRMM)

Using Acceleration Sensors to Identify Rigidity Release Threshold during Deep Brain
Stimulation Surgery
Shah, Ashesh* (Univ. of Applied Sciences and Arts, Northwestern Switzerland);
Coste, Jérôme (Centre Hospitalier Universitaire de Clermont-Ferrand, Image-Guid);
Lemaire, Jean-Jacques (Centre Hospitalier Universitaire de Clermont-Ferrand, Image-Guid);
Schkommodau, Erik (Institute for Medical and Analytical Technologies, Univ. of);
Guzman, Raphael (Departments of Neurosurgery and Biomedicine, Univ. of Basel);
Taub, Ethan (Departments of Neurosurgery and Biomedicine, Univ. of Basel);
Hemm-Ode, Simone (Univ. of Applied Sciences)
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<td>Sijobert, Benoît* (INRIA); Pissard, Roger (INRIA); Froger, Jérôme (CHU Nîmes); Azevedo-Coste, Christine (DEMAR INRIA/LIRMM)</td>
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<td>Google Glass Application that Reduces Freezing of Gait in Parkinson's Patients</td>
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<td>Using Real Time Visual Feedback to Understand Dynamic Stability of the Knee with Lyapunov Exponents</td>
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<td>A Computational Model of Locomotion Integrating the Central Pattern Generator, MusculoSkeletal System, and External Sensory Input to Study the Mechanism of a Neuromuscular Electrical Stimulation Therapy</td>
<td>Tong, Lin* (California State Univ. Los Angeles); Perez, Ismael (California State Univ., Los Angeles); Daneshgaran, Giulia (Univ. of California, Los Angeles); Carussetta, Nastassja (California State Univ., Los Angeles); Nataraj, Jaya (California State Univ., Los Angeles); Won, Deborah S. (California State Univ., Los Angeles)</td>
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<td>Distinguishing Connectivity Patterns from Walking Artifact during a Brooks Spatial Memory Task</td>
<td>Snyder, Kristine* (University of Michigan); Kline, Julia (University of Michigan); Huang, Helen (University of Michigan, Ann Arbor); Ferris, Daniel (University of Michigan)</td>
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**FrBT4: 08:30-11:00 | Joffre 1**
Neuromuscular Systems-Poster Session (Poster Session)

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<td>Similar Trial-By-Trial Adaptation Behavior across Transhumeral Amputees and Able-Bodied Subjects</td>
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<td>Sliding Mode Control of Intramuscular Functional Electrical Stimulation using Fuzzy Neural Network with Terminal Sliding Mode Learning</td>
<td>Sadat-Hosseini, Seyyed Hossein (IUST); Erfanian, Abbas* (Iran University of Science and Technology)</td>
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Sensory Synergy: Modeling the Neural Dynamics of Environmental Feedback to the Central Nervous System
Alnajjar, Fady SK* (BTCC, RIKEN);
Itkonen, Matti (Brain Science Institute (BSI), RIKEN);
Nagai, Chikara (RIKEN);
Shimoda, Shingo (RIKEN)

Lower-Limb Muscle Activity when Walking on Different Slippery Surfaces
Whitmore, Mariah* (Northwestern University);
Hargrove, Levi (Rehabilitation Institute of Chicago);
Perreault, Eric (Northwestern University)

Multimodal Virtual Reality Platform for the Rehabilitation of Phantom Limb Pain
Wake, Naoki* (Graduate School of Information Science and Technology, University);
Sano, Yuko (University of Tokyo);
Oya, Reishi (AP Communications);
Sumitani, Masahiko (University of Tokyo);
Kumagaya, Shin-ichiro (University of Tokyo);
Kuniyoshi, Yasuo (University of Tokyo)

A Versatile Fast-Development Platform Applied to Closed-Loop Diaphragmatic Pacing
Zbrzeski, Adeline* (Laboratory IMS-CNRS UMR 5218, Univ. of Bordeaux);
Siu, Ricardo (Florida International Univ.);
Bornat, Yannick (IMS Laboratory);
Hillen, Brian (Florida International Univ.);
Jung, Ranu (Florida International Univ.);
Renaud, Sylvie (Univ. of Bordeaux1, IMS, Enseirb)

An Investigation into the Reliability of Upper-Limb Robotic Exoskeleton Measurements for Clinical Evaluation in Neurorehabilitation
Fong, Justin (University of Melbourne);
Crocher, Vincent* (The University of Melbourne);
Oetomo, Denny (The University of Melbourne);
Tan, Ying (The University of Melbourne)

Modeling 3D Tremor Signals with a Quaternion Weighted Fourier Linear Combiner
Adhikari, Kabita (Newcastle Univ.);
Tatinati, Sivanagaraja (Kyungpook National Univ.);
Veluvolu, Kalyana C. (Kyungpook National Univ.);
Nazarpour, Kianoush* (Newcastle Univ.)

Adaptive Control of a Robotic Exoskeleton for Neurorehabilitation
Proietti, Tommaso* (Univ. Pierre et Marie Curie);
Jarrassé, Nathanael (UMR7222, Centre National de la Recherche Scientifique (CNRS));
Roby-Brami, Agnes (Univ. Pierre et Marie Curie);
Morel, Guillaume (Univ. Pierre et Marie Curie – Paris 6)
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**Frequency Domain Identification of Proprioceptive Evoked Potentials in Compliant Kinematic Experiments**

Akinin, Abraham* (UCSD);
Govil, Nikhil (Institute for Neural Computation, UCSD);
Poizner, Howard (UCSD);
Cauwenberghs, Gert (University of California San Diego)

08:30-11:00  FrBT4.11
**Video Game Speech Rehabilitation for Velopharyngeal Dysfunction: Feasibility and Pilot Testing**

Cler, Meredith* (Boston University);
Voysey, Graham (Boston University);
Stepp, Cara (Boston University)

08:30-11:00  FrBT4.12
**A Neuromuscular Electrical Stimulation Strategy based on Muscle Synergy for Stroke Rehabilitation**

Zhuang, Cheng (Shanghai Jiao Tong University);
Márquez Ruiz, Juan Carlos* (KTH Royal Institute of Technology);
Qu, Hongen (Shanghai Jiao Tong University);
He, Xin (Shanghai Jiao Tong University);
Lan, Ning (Shanghai Jiao Tong University)

08:30-11:00  FrBT4.13
**Rate-Dependent Hysteresis in the EMG-Force Relationship: A New Discovery in EMG-Force Relationship**

Zhang, Dingguo* (Shanghai Jiao Tong University);
Pan, Lizhi (Shanghai Jiao Tong University)

08:30-11:00  FrBT4.14
**A Novel Extreme Learning Machine for Dimensionality Reduction on Finger Movement Classification using Semg**

Anam, Khairul* (University of Technology Sydney);
Al-Jumaily, Adel (University of Technology Sydney)

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**On the Control of a Muscular Force Model including Muscular Fatigue**

Maillard, Aurore* (Université de Bourgogne, Le2I, Dijon);
Yochum, Maxime (Université de Bourgogne);
Bakir, Toufik (LE2I UMR CNRS 5158 Université de Bourgogne);
Binczak, Stéphane (Université de Bourgogne)

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**Computational Studies on Urinary Bladder Smooth Muscle: Modeling Ion Channels and Their Role in Generating Electrical Activity**

Mahapatra, Chitaranjan* (Indian Institute of Technology Bombay);
Brain, Keith L. (Univ. of Birmingham);
Manchanda, Rohit (IIIT Bombay)

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**Intuitive Motion Classification from EMG for the 3-D Arm Motions Coordinated by Multiple DoFs**

Zhang, Qin* (Huazhong Univ. of Science and Technology);
Xiong, Caihua (Huazhong Univ. of Science and Technology);
Zheng, Chengfei (Huazhong Univ. of Science and Technology)
Fatigue-Related Alterations to Intra-Muscular Coherence
McManus, Lara* (University College Dublin);
Hu, Xiaogang (Rehabilitation Institute of Chicago);
Rymer, William Zev (Northwest & Rehab Inst of Chicago);
Suresh, Nina (Rehabilitation Institute of Chicago);
Lowery, Madeleine (University College Dublin)

Current Perception Threshold through Sinusoidal Electrical Stimulation at Different Frequencies in a Comparative Assessment for Subjects Affected and Non-Affected by Diabetes Mellitus
Oliveira, Franassis Barbosa (University of Brasilia/State University of Goias);
Fachin-Martins, Emerson* (Project-Team DEMAR, LIRMM-INRIA and University of Brasilia);
Couto-Paz, Clarissa Cardoso dos Santos (University of Brasilia);
Martins, Henrique Resende (Universidade Federal de Belo Horizonte);
Tierra-Criollo, Carlos Julio (Universidad Federal de Minas Gerais);
Azevedo-Coste, Christine (DEMAR INRIA/LIRMM)

The Contribution of Trained Parameters to the Goodness of Fit of a Bayesian Neural Encoding Model for the Auditory System
Plourde, Eric* (Univ. de Sherbrooke);
Rode, Thilo (Hörzentrum Hannover GmbH);
Lim, Hubert (Univ. of Minnesota)

Mutual Information between Inter-Hemispheric EEG Spectro-Temporal Patterns: A New Feature for Automated Affect Recognition
Clerico, Andrea* (INRS);
Gupta, Rishabh (INRS-EMT);
Falk, Tiago (Institut National de la Recherche Scientifique)

Validating Online Recursive Independent Component Analysis on EEG Data
Hsu, Sheng-Hsiou* (University of California, San Diego);
Mullen, Tim (University of California, San Diego, Swartz Center for Computation a);
Jung, Tzyy-Ping (University of California San Diego);
Cauwenberghs, Gert (University of California San Diego)

The Interface between the Brain Microwave Radiation and Autonomic Nervous System
Kublanov, Vladimir* (Ural Federal University);
Borisov, Vasilii (Ural Federal University);
Dolganov, Anton (Ural Federal University)
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Modulated High Frequency Oscillations Can Identify Regions of Interest in Human iEEG using Hidden Markov Models
Guirgis, Mima* (Univ. of Toronto);
Chinvarun, Yotin (Director of Comprehensive Epilepsy Program and Neurology Unit, P);
del Campo, Martin (Univ. Health Network);
Carlen, Peter L. (Univ. of Toronto);
Bardakjian, Berj Luther (Univ. of Toronto)

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Online Learning of Neural Network Structure from Spike Trains
Hall, Eric* (Duke University);
Willett, Rebecca (University of Wisconsin – Madison)

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Detection of High Frequency Oscillations in Epilepsy with K-Means Clustering Method
Liu, Su* (Univ. of Houston);
Ince, Nuri Firat (Univ. of Houston);
Sabanci, Akin (Istanbul Univ.);
Aydoseli, Aydin (Istanbul Univ.);
Aras, Yavuz (Istanbul Univ.);
Sencer, Altay (Istanbul Univ.);
Bebek, Nerses (Istanbul Univ.);
Sha, Zhiyi (Univ. of Minnesota, Department of Neurology);
Gurses, Candan (Istanbul Univ.)

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Thomik, Andreas Alexander Christian (Imperial College London);
Fenske, Sonja (Imperial College, London);
Faisal, A. Aldo* (Imperial College London)

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Jackson, Jadin C.* (Medtronic, Inc.);
Corey, Robert (Medtronic, Inc.);
Loxtercamp, Greg (Medtronic, Inc.);
Stanslaski, Scott (Medtronic);
Orser, Heather (Medtronic, Inc.);
Denison, Timothy (Medtronic)

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Data-Efficient Hand Motor Imagery Decoding in EEG-BCI by using Morlet Wavelets and Common Spatial Pattern Algorithms
Ferrante, Andrea (Imperial College London);
Gavriel, C. (Imperial College London);
Faisal, A. Aldo* (Imperial College London)
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Relating Auditory Evoked Responses to the Laminar Phase Dynamics in Rats using Mutual Information
Mortezapouraghdam, Zeinab (Saarland Univ.); Haab, Lars (Saarland Univ. Hospital); Schwerdtfeger, Karsten (Saarland Univ. Hospital); Strauss, Daniel J.* (Saarland Univ., Medical Faculty)

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Multichannel Real Time Spike Sorting for Decoding Ripple Sequences
Sethi, Ankit* (Rice University); Kemere, Caleb (Rice University)

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Recurrence Network Analysis of Wide Band Oscillations of Local Field Potentials from the Primary Motor Cortex Reveals Rich Dynamics
Puthanmadam Subramaniyam, Narayan* (Tampere University of Technology); Hyttinen, Jari (Tampere University of Technology); Takahashi, Kazutaka (University of Chicago); Hatsopoulos, Nicholas (University of Chicago)

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Behavior Discrimination using a Discrete Wavelet based Approach for Feature Extraction on Local Field Potentials in the Cortex and Striatum
Belic, Jovana* (Royal Institute of Technology KTH); Halje, Pär (Lund University); Richter, Ulrike (Lund University); Petersson, Per (Lund University, NRC); Hellgren Kotaleski, Jeanette (Royal Institute of Technology KTH)

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A Scalable High Performance Client/server Framework to Manage and Analyze High Dimensional Datasets Recorded by 4096 CMOS-MEAs
Zordan, Stefano* (Univ. of Genoa); Zanotto, Matteo (Istituto Italiano di Tecnologia); Nieus, Thierry (Istituito Italian Tecnologia); Di Marco, Stefano (Istituito Italiano di Tecnologia); Amin, Hayder (Istituito Italiano di Tecnologia (IIT)); Maccione, Alessandro (Istituito Italiano di Tecnologia); Berdondini, Luca (Istituito Italiano di Tecnologia)

12:45-15:15
Directional Brain Functional Interaction Analysis in Patients with Amyotrophic Lateral Sclerosis
Shahriari, Yalda (Old Dominion Univ.); Sellers, Eric (East Tennessee State Univ.); McCane, Lynn (Wadsworth Center); Vaughan, Theresa (Wadsworth Center, New York State Department of Health); Krusinski, Dean* (Old Dominion Univ.)

12:45-15:15
Comparison between Adjar and Xdawn Algorithms to Estimate Eye-Fixation Related Potentials Distorted by Overlapping
Kristensen, Emmanuelle* (Univ. of Grenoble, CNRS, Gipsa-lab); Guerin-Dugue, A. (GIrPSA-lab); Rivet, Bertrand (Grenoble Univ.)
12:45-15:15
How Networked Brain Changes when Working Memory Load Reaches the Capacity?
Zhang, Dan (Tianjin Medical University, School of Biomedical Engineering);
Tian, Xin* (Tianjin Medical University)

12:45-15:15
LFPs Network of Hippocampal-Prefrontal Circuit during Working Memory Task
Liu, Tiaotiao (Tianjin Medical University, School of Biomedical Engineering);
Tian, Xin* (Tianjin Medical University)

12:45-15:15
Characteristics of the Right Cervical Vagal Activity during Baseline and Valsalva-Like Manoeuvre
Gallet, Clément* (Université de Rennes, LTSI);
Bonnet, Stéphane (CEA Léti MINATEC);
Le Rolle, Virginie (University of Rennes 1);
Laporte, Laure (Sorin Group);
Bonnet, Jean-Luc (Sorin Group);
Karam, Nicole (INSERM UMR970 Paris Cardiovascular Research Center, Paris);
Hagège, Albert (Assistance Publique – Hôpitaux de Paris, Hôpital Européen George);
Malbert, Charles-Henri (AniScan Unit, INRA);
Mabo, Philippe (Université de Rennes 1);
Maubert, Sandrine (CEA);
Hernández, Alfredo I (Univ. of Rennes 1 and INSERM U642);
Carrault, Guy (Université de Rennes 1)

12:45-15:15
Maximum Contrastive Networks for Multi-Channel SSVEP Detection
Embrandiri, Sharat* (Indian Institute of Technology Madras, India);
M, Ramasubba Reddy (Indian Institute of Technology Madras)

12:45-15:15
Segmentation of Neuron and Measurement of Optically Programed Neurite Growth: Fast Automation via Bayesian Thresholding
Reddy, Puneeth (IIT Hyderabad);
Shukla, Saurabh (IIT Hyderabad);
Karunaratne, Ajit (University of Toledo);
Jana, Soumya (Indian Institute of Technology Hyderabad);
Giri, Lopamudra* (Indian Institute of Technology, Hyderabad)

12:45-15:15
High-Density MEAs Reveal Lognormal Firing Patterns in Neuronal Networks for Short and Long Term Recordings
Amin, Hayder* (Istituto Italiano di Tecnologia (IIT));
Maccione, Alessandro (Istituto Italiano di Tecnologia);
Zordan, Stefano (University of Genoa);
Nieus, Thierry (Istituto Italiano Tecnologia);
Berdondini, Luca (Istituto Italiano di Tecnologia)

12:45-15:15
PCA-SIR: A New Nonlinear Supervised Dimension Reduction Method with Application to Pain Prediction from EEG
Tu, Yiheng* (The University of Hong Kong);
Hung, Y.S. (The University of Hong Kong);
Hu, Li (Southwest University);
Zhang, Zhiguo (The University of Hong Kong)
12:45-15:15
**Systematic Characterization of Stochastic Activity in Non-Invasively Recorded Neural Signals**
Stamoulis, Catherine* (Harvard Medical School); Chang, Bernard (Harvard Medical School/Beth Israel Deaconess Medical Center)

12:45-15:15
**Self-Supervised Learning Model for Skin Cancer Diagnosis**
Masood, Ammara* (University of Technology Sydney); Al-Jumaily, Adel (University of Technology Sydney); Anam, Khairul (University of Technology Sydney)

12:45-15:15
**On the Threshold based Neuronal Spike Detection, and an Objective Criterion for Setting the Threshold**
Tanskanen, Jarno Mika Antero* (Tampere University of Technology); Kapucu, Fikret Emre (Tampere University of Technology); Hyttinen, Jari (Tampere University of Technology)

12:45-15:15
**A Theoretical Limit and Simulation of Time-Domain Event Detection in the EEG**
Watkins, Paul (Washington University); Doolittle, Luke (Natus Medical); Krusienski, Dean (Old Dominion University); Anderson, Nicholas* (Washington University)

12:45-15:15
**ToolConnect: A Functional Connectivity Toolbox for In-Vitro Cortical Networks**
Pastore, Vito Paolo* (University of Genova); Poli, Daniele (University of Genova); Martinoia, Sergio (University of Genova); Massobrio, Paolo (University of Genova)

12:45-15:15
**Robust Detection Algorithm for Movement-Related Cortical Potentials through Outlier-Resisting Manifold Learning**
Lin, Chuang* (Georg-August University); Pang, Meng (Dalian University of Technology); Jiang, Ji feng (Dalian University of Technology); Xu, Ren (University Medical Center Göttingen, Georg-August University, Gö); Jiang, Ning (University Medical Center Goettingen); Farina, Dario (Bernstein Center for Computational Neuroscience, University Medic)

12:45-15:15
**Locality Preserving Projection via Spectral Regression in Detection of Movement-Related Cortical Potentials**
Lin, Chuang* (Georg-August University); Jiang, Ji feng (Dalian University of Technology); Pang, Meng (Dalian University of Technology); Xu, Ren (University Medical Center Göttingen, Georg-August University, Gö); Jiang, Ning (University Medical Center Goettingen); Farina, Dario (Bernstein Center for Computational Neuroscience, University Medic)