Activity Report 2013

Team NEUROSYS

Analysis and modeling of neural systems by a system neuroscience approach

RESEARCH CENTER
Nancy - Grand Est

THEME
Computational Neuroscience and Medecine

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Team NEUROSYS

Keywords: Brain Computer Interface, Computational Neurosciences, Data Analysis, Multiscale Models, Stochastic Models

Creation of the Team: 2013 January 01.

1. Members

Research Scientist
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Faculty Members
Laurent Bougrain [Univ. Lorraine, Associate Professor]
Laure Buhry [Univ. Lorraine, Associate Professor]

Engineers
Eric Nichols [Inria, FP7 MATHANA project]
Guillaume Serriere [Inria, ADT OpenVibe, from Nov 2013]

PhD Students
Maxime Rio [Inria, CORDI-S, until Aug 2013]
Mariia Fedotenkova [Inria, CORDI-S, from Nov 2013]
Meysam Hashemi [Inria, FP7 MATHANA project]
Cecilia Lindig Leon [Inria, CORDI-S, from Nov 2013]
Carolina Saavedra [Inria, CINV - Univ. Valparaiso, until Aug 2013]

Post-Doctoral Fellows
Pedro Garcia Rodriguez [Inria, FP7 MATHANA project]
Tamara Tosic [Inria, from Nov 2013]

Visiting Scientists
Peter Beim Graben [Humboldt University Berlin, from Sep 2013 until Oct 2013]
James Wallace Sleigh [University of Auckland, from Sep 2013 until Oct 2013]

Others
Louis Korczowski [ESSTIN, student project, from Jan 2013 until Mar 2013]
Alexandre Martin [Ecoles de Mines, student project, from Jun 2013 until Sep 2013]
Pierre-Jean Morieux [Univ. Lorraine, Master thesis, from Feb 2013 until Jun 2013]

2. Overall Objectives

2.1. General objectives

The team aims at understanding the dynamics of neural systems and develops methods to invent monitoring devices. The approach is inspired by systems neuroscience, which relates microscopic modifications in neural systems to macroscopic changes in behavior. The team employs this systems neuroscience approach and develops models and data analysis tools in order to bridge the gap between microscopic and mesoscopic, and mesoscopic and macroscopic/behavior activity. These bridges are necessary to better understand neural systems and, in turn, control the neural systems. They also may allow to develop data monitors utilising the derived principles. As a long-term goal, the team shall develop such devices in medicine with application in general anaesthesia.

2.2. Highlights of the Year

In the last years we have been working on models of anaesthetic action on neural populations based on published experiments of other research groups. This year we have been able to participate in the analysis of experimental animal data measured under anaesthesia by the University of North Carolina-Chape Hill [9]. The corresponding common publication with this experimental laboratory is a perfect basis for a future international cooperation.

3. Research Program

3.1. Main Objectives

The main challenge in computational neuroscience is the high complexity of neural systems. The brain is a complex system and exhibits a hierarchy of interacting subunits. On a specific hierarchical level, such subunits evolve on a certain temporal and spatial scale. The interactions of small units on a low hierarchical level build up larger units on a higher hierarchical level evolving on a slower time scale and larger spatial scale. By virtue of the different dynamics on each hierarchical level, until today the corresponding mathematical models and data analysis techniques on each level are still distinct. Only few analysis and modeling frameworks are known which link successfully at least two hierarchical levels.

Once having extracted models for different description levels, typically they are applied to obtain simulated activity which is supposed to reconstruct features in experimental data. Although this approach appears straight-forward, it implies various difficulties. Usually the models involve a large set of unknown parameters which determine the dynamical properties of the models. To optimally reconstruct experimental features, it is necessary to formulate an inverse problem to extract optimally such model parameters from the experimental data. Typically this is a rather difficult problem due to the low signal-to-noise ratio in experimental brain signals. Moreover, the identification of signal features to be reconstructed by the model is not obvious in most applications. Consequently an extended analysis of the experimental data is necessary to identify the interesting data features. It is important to combine such a data analysis step with the parameter extraction procedure to achieve optimal results. Such a procedure depends on the properties of the experimental data and hence has to be developped for each application separately.

3.2. Challenges

Eventually the implementation of the models and analysis techniques achieved promises to be able to construct novel data monitor. This construction involves additional challenges and stipulates the contact to realistic environments. By virtue of the specific applications of the research, the close contact to hospitals and medical enterprises shall be established in a longer term in order to (i) gain deeper insight into the specific application of the devices and (ii) build specific devices in accordance to the actual need. First collaborations with hospitals and the pharmaceutical industry already exist.

3.3. Research Directions

- From the microscopic to the mesoscopic scale:
  One research direction focusses on the relation of single neuron activity on the microscopic scale to the activity of neuronal populations. To this end, the team investigates the stochastic dynamics of single neurons subject to external random inputs and involving random microscopic properties, such as random synaptic strengths and probability distributions of spatial locations of membrane ion channels. Such an approach yields a stochastic model of single neurons and allows the derivation of a stochastic neural population model.
  This bridge between the microscopic and mesoscopic scale may be performed via two pathways. The analytical and numerical treatment of the microscopic model may be called a *bottom-up approach*, since it leads to a population activity model based on microscopic activity. This approach allows

to compare theoretical neural population activity to experimentally obtained population activity. The *top-down approach* aims at extracting signal features from experimental data gained from neural populations which give insight into the dynamics of neural populations and the underlying microscopic activity. The work on both approaches represents a well-balanced investigation of the neural system based on the systems properties.

- From the mesoscopic to the behavior scale:
  The other research direction aims to link neural population dynamics to macroscopic activity and behaviour or, more generally, to phenomenological features. This link is more indirect but very powerful to understand the brain, e.g., in the context of medical applications. Since real neural systems, such as in mammals, exhibit an interconnected network of neural populations, the team is studying analytically and numerically the network dynamics of neural populations to gain deeper insight into possible phenomena, such as traveling waves or enhancement and diminution of certain neural rhythms. Electroencephalography (EEG) is a wonderful brain imaging technique to study the overall brain activity in real time noninvasively. However it is necessary to develop robust techniques based on stable features by investigating the time and frequency domains of brain signals. Two types of information are typically used in EEG signals: (i) transient events such as evoked potentials, spindles and K-complexes and (ii) the power in specific frequency bands.

4. Application Domains

4.1. General anaesthesia

During general anaesthesia, the EEG on the scalp changes characteristically: increasing the anaesthetic drug concentration the amplitudes of fast EEG-oscillations in the α-band ($\sim 8-12$Hz) in frontal electrodes decrease and the amplitudes of slow oscillations in the $\delta-$band ($2-8$Hz) increase. This characteristic change in the power is the basis of today's EEG-monitors that assist the anaesthesist in the control of the anaesthesia depths of patients during surgery. However, the conventional monitors detect a large variability between the patients and are not able to detect the real depth of anaesthesia. Moreover, a certain number of patients re-gain consciousness during surgery (about $1-2$ out of 1000) and suffer from diverse after-effects, such as nausea or long-lasting cognitive impairments (from days to weeks). Since surgery under general anaesthesia is part of a hospital's everyday practice, a large number of patients suffer from these events everyday. One reason for the occurrence of these disadvantageous effects in hospital practice is the dramatic lack of understanding on what is going on in the brain during general anaesthesia leading to sometimes poorly controllable situations of patients. Consequently, to improve the situation of patients and to develop improved anaesthetic procedures or drugs, it is necessary to perform research in order to learn more about the neural processes in the brain.
The EEG originates from coherent neural activity of populations in the cortex. Hence to understand better the characteristic power changes in EEG during anaesthesia, it is necessary to study neural population dynamics subject to the concentration of anaesthetic drugs and their action on receptors on the single neuron level. We develop computational models which are constrained by the signal features extracted from experimental EEG and behavior. This methodology will reveal new knowledge on the neural origin of behavioral features, such as the loss of consciousness or the un-controlled gain of consciousness during surgery.

4.2. Motor behavior

An improved understanding of the link between single neuron activity and neural population data allows to understand the planning and action of motor behavior. To this end we extract signal features in experimental neural population data obtained in the motor cortex in animals. Synchronously theoretical population models based on single neuron activity aim to understand the typical decoding of motor action by neural populations. Experimental single neuron data assists this model approach.

In addition, we employ and integrate numerically a neural population model whose activity features are compared to the signal features observed in experiments. In addition, we link the signal features to experimental behavioral data.

5. Software and Platforms

5.1. Software and Platform

5.1.1. Visualization

- The NeuralFieldSimulator [1] computes numerically activity in two-dimensional neural fields by solving integral-differential equations involving transmission delays and visualizes the spatio-temporal activity. The tool includes a GUI that allows the user to choose field parameters. It is written in Python, open-source and is aimed to be promoted to become a major graphical visualization tool in the domain of neural field theory.
- *A*naesthesiaSimulator [2] simulates the activity of networks of spiking neurons subject to specific receptor dynamics. The tool is a platform to test effects of anaesthetics on neural activity and is still in its first stage of development. The neural activity is planned to be visualized in a 2D and 3D-plot evolving in time. It is written in Python, open-source and involves heavily the simulation package BRIAN [3].

5.1.2. Platforms

OpenViBE [4] is a C++ open-source software devoted to the design, test and use of Brain-Computer Interfaces. The OpenViBE platform consists of a set of software modules that can be integrated easily and efficiently to design BCI applications. Key features of the platform are its modularity, high-performance, portability, its multiple-users facilities and its connection with high-end/Virtual Reality displays. The designer tool of the platform enables to build complete scenarios based on existing software modules using a dedicated graphical language and a simple Graphical User Interface (GUI). This software is available on the Inria Forge [5] under the terms of the LGPL-V2 license. The development of OpenVibe is done in association with other Inria research teams (Hybrid, Athena, Potioc) for the national Inria project: ADT OpenViBE-NT. Neurosys is in charge of machine learning techniques and the interoperability with other tools such as Matlab, BCI2000, or TOBI.

5.1.3. Others

The package DEvariants [6] includes Matlab routines which implements new variants of the Differential Evolution (an evolutionary algorithm) strategies. The novelty lies in the selection process where we proposed to use a multinomial law to recombine the individuals/vectors. Compared to the standard strategies, our variants allow a faster convergence and a better avoidance of local minima. The different variants are provided with a test sample of functions, the DeJong benchmark. The audience is any scientific user familiar with evolutionary optimization.

6. New Results

6.1. From the microscopic to the mesoscopic scale

Participants: Axel Hutt, Laure Buhry, Meysam Hashemi, Pedro Garcia Rodriguez, Peter beim Graben, James Wallace Sleigh.

[1] https://gforge.inria.fr/projects/nfsimulator/
[2] https://gforge.inria.fr/projects/anasim/
[3] http://briansimulator.org/
[4] http://openvibe.inria.fr/
[5] https://gforge.inria.fr/projects/openvibe/
[6] https://sites.google.com/site/laurebuhry/publications/optimization-algorithms

Several previous studies focus on the derivation of neural population models. However most of these studies do not consider explicitly the microscopic properties of neurons, such as synaptic receptor dynamics or ion-channel distributions, although they may be implicit. The resulting models in some previous studies are poorly tractable analytically due to their complexity. Moreover, the complexity of previous models makes it difficult to discover those elements in the model that induce certain dynamical features as observed in experiments. Essentially most of previous studies do not consider the spatial interactions of neurons and, importantly, neglect delays present in biological networks. We aim to improve some previous models and a first step to a new statistical approach has been developed [11], [18], [17], [22] to bridge the scales between the network activity of coupled spiking single neurons and statistical quantities of populations, e.g., the mean membrane potential in the network and the networks population firing rate. Our work considers the specific effect of anaesthetics and takes into account the physiological effects of extra-synaptic $GABA_A$-receptors at single neurons, which are highly sensitive to anaesthetic drugs, such as propofol. We find numerically by simulation of a spiking neural network that propofol on single neuron level diminishes the network oscillation power in the $\alpha-$frequency band and affects strongly the spike coherence in the population. Such effects have been shown in previous experimental data obtained during propofol anaesthesia demonstrating the importance of extra-synaptic receptor dynamics in the understanding of experimental phenomena in anaesthesia.
The neural origin of generation and planning of motor action in humans is still unknown. In this context, psychophysical experiments and the neural modeling of the gained results may lead to further insight. We have participated in an experimental and theoretical study [8] to reveal the effect of temporal attention on non-conscious prime processing. Our stochastic accumulator model improves extensively the standard accumulator model for reaction time by involving additional stochastic neural accumulators, which permits an almost perfect fit to experimental data. The model indicates that motor action, which is generated on a population level, obeys a stochastic accumulation of activity of single neuron activity.

6.2. From the mesoscopic to the behavior scale

Participants: Axel Hutt, Laurent Bougrain, Eric Nichols, Maxime Rio, Carolina Saavedra, Louis Korczkovsky, Alexandre Martin, Pierre-Jean Morieux.
To link neural population activity to behavior, it is necessary to understand well the dynamic properties of population models which we have studied in general models [5], [14], [15], [16], [24]. To this end, we have analyzed a neural mass model [4] describing the neural population activity subject to synaptic anaesthetic action to explain characteristic signal features in measured EEG. The model explains the gain of power in the $\alpha-$ and $\delta-$frequency observed experimentally by a dynamic oscillatory instability (Hopf instability). The model considers a cortical population only and hence the result indicates that the experimental feature observed may originate in the cortex.

An extended population model considers not only the cortex but a feedback-loop to the thalamus. This model involves a delayed interaction. At first, we have studied the dynamics of delayed dynamical systems subject to additive stimuli [23], [7], [6] to learn more about the expected activity. Our first study of a linear thalamo-cortical feedback model [21], [20] reveals the descriptive power of neural mass models to describe EEG under anaesthesia.

In order to learn more about the effect of anaesthetics on neural populations, we have participated in the data analysis of an experimental study on anaesthesia in animals [9]. Moreover we have started developing new data analysis techniques to extract novel features from EEG. In his doctoral thesis, Maxime Rio has developed a new method to detect transient amplitude synchronization in multi-variate time series in a subset of time series [1]. Carolina Saavedra has conducted wavelet analysis in her thesis to improve the denoising in BCI-relevant measured signals [2]. Another study [3] proposes a new recurrence plot-technique based on symbolic dynamics. It extracts spatio-temporally recurrence patterns in a multivariate dataset which reflect underlying neural recurrent dynamics.

The event-related potentials (ERP) in EEG are important markers of cognitive processes in the brain and serve as features to control interfaces in BCI. We have performed advanced studies to improve the detection of ERP [13], [12].

7. Partnerships and Cooperations

7.1. Regional Initiatives

In the *Contrat de Projet État Région (CPER) Action Modeling, Simulation and Interaction* (2009-2014), we are contributing to the axis *Situed Informatic* through the project CoBras for controlling a jaco robotic arm using EEG. Contact in Neurosys is Laurent Bougrain.

7.2. National Initiatives

7.2.1. ANR

We participate in the project *Keops:* Algorithms for modeling the visual system: From natural vision to numerical applications (2011-2014).

A recent description in the retina of non-standard ganglion cells types, beside a complex repertoire of standard ganglion cells, responses in front of natural stimulus and conveys important questions about the real, early processing capacity of the retina. This leads to revisit both the neural coding of the information the eye is sending to the brain, and also sheds light to engineering applications from the understanding of such encoding, as detailed in the sequel. At the modeling level, retinal cells are mainly formalized using a LN (Linear spatio-temporal filtering followed by a static Non-linear transduction), while an important fraction of non-standard cells response cannot be represented in such a model class. This is a challenge to develop an innovative formalism that takes such complex behaviors into account, with such immediate applications as new dynamical early-visual modules. Proposing new innovative bioinspired formalisms in order to perform dynamical visuo-perceptual tasks adapted to natural environment is a main goal of this project, with a special focus to scenes including complex visual motion interacting with light.

The project is a cooperation between the University of Nice (France), the University of Valparaiso (Chile), the Pontifical Catholic University of Chile in Santiago de Chile, the Inria teams NeuroMathComp, Mnemosyne, Cortex and Neurosys.

7.2.2. Others

- Inria Technological development action (ADT): OpenViBE-NT
  This is a two-year multi-site project (2012–2014) to develop OpenViBE further on several fronts such as usability, new algorithms and scope of applicability. Teams of the ADT are Hybrid(Rennes), Athena (Sophia), Potioc (Bordeaux) and Neurosys. Coordinator is Laurent Bougrain.
- Multidisciplinary Exploratory Project (PEPS 2013) Bio-Maths-Info (BMI): *Characterising the laminar profile of motor cortical oscillatory synchronization during visuomotor behavior with new analysis tools.*
  Oscillations are omnipresent in the brain, but their function is still disputed. In motor cortex, beta and gamma oscillations are often observed, but their proposed roles in sensorimotor behavior are largely overlapping. While much is known on the laminar distribution of oscillations in sensory areas, the very sparse data on the laminar profile of motor cortical oscillations largely limits their functional interpretations. The 2-years project studies the layer specificity of monkey motor cortical oscillations and oscillatory interactions between M1 and PMd during visuomotor behavior. Extending conventional tools, such as coherency analysis, Neurosys develops a new method to quantify short-lasting partial amplitude and phase synchronization in single-trial data, based on wavelets, exploiting the predefined vicinity of contacts on the laminar probes. The application of this new method to the data recorded in Marseille will reveal instantaneous amplitude and phase synchronization between cortical layers and between the brain areas $M1$ and PMd, providing novel insights into the functional roles of beta and gamma oscillations in visuomotor behavior. The experimental partner at the *Institut de Neurosciences de la Timone* in Marseille is Bjork Kilavik, the contact in Neurosys is Axel Hutt.

7.3. European Initiatives

7.3.1. FP7 Projects

The *ITN*-project *Neural Engineering Transformative Technologies (NETT)* (2012-2016) is a Europe-wide consortium of 18 universities, research institutes and private companies which together hosts 17 PhD students and 3 postdoctoral researchers over the next 4 years. Neural Engineering brings together engineering, physics, neuroscience and mathematics to design and develop brain-computer interface systems, cognitive computers and neural prosthetics. Neurosys will host a PhD-student for three months in winter 2014/2015. Contact is Axel Hutt.

7.3.2. Collaborations in European Programs, except FP7

Program: ERC Starting Grant
Project acronym: MATHANA
Project title: Mathematical Modeling of Anaesthesia
Duration: January 2011 – December 2015
Coordinator: Axel Hutt
Abstract: MATHANA aims to study mathematically spatially extended neural systems and reveal their spatio-temporal dynamics during general anaesthesia.

7.4. International Initiatives

7.4.1. Informal International Partners

- We collaborate with Jamie Sleigh (University of Auckland, New Zealand), who provides us with experimental EEG-data obtained in humans during anaesthesia (A. Hutt).
- In the collaboration with Flavio Frohlich (University of North Carolina - Chapel Hill), we receive experimental data measured intracranially in ferrets and analyse them on spectral properties (A. Hutt).
- The collaboration with Matthias Munk (Max Planck Institute for Biological Cybernetics in Tuebingen) lasts for over 10 years now and provides us with experimental Local Field Potentials measured during a visuomotor task of monkeys (A. Hutt).
- The collaboration with Linghai Zhang (Lehigh University, USA) on the mathematical analysis of neural field equations led to a publication in 2013 [6] (A.Hutt).
- In the collaboration with Jeremy Lefebvre (University in Geneva), we have been working out together a novel stochastic center manifold analysis method for delayed differential equations leading to new insights into the effects of additive noise close to bifurcation points (A. Hutt).
- The collaboration with Marina Palazova and Torsten Schubert (Humboldt University Berlin) on priming effects of subliminal visual stimuli has led to a publication in 2013 [8] (A. Hutt).
- The collaboration with Peter beim Graben (Humboldt University Berlin) on recurrence data analysis stimulated us to intensify our work on meta-stable states in neural systems (A. Hutt).
- An Inria Internship proposal has been submitted on topics that will involve Pr. Motoharu Yoshida at the Ruhr University Bochum, Germany, to study the role of persistent firing neurons in memory and more specifically in neural network synchronization. M. Yoshida provides us with biological data that we combine with simulations to test hypotheses on memory formation (L. Buhry).
- We also collaborate with Pr. John Rinzel (New York University, USA) and Pr. LieJune Shiau (University of Houston, Texas, USA) on more theoretical approaches concerning the role intrinsic neuronal dynamics in network synchronization and brain oscillations (L. Buhry).

7.5. International Research Visitors

7.5.1. Visits of International Scientists

We have hosted the visiting professors Peter beim Graben (Humboldt University Berlin, September–October) and Jamie Sleigh (September–October) to join forces in our common project on the analysis of multivariate EEG-data obtained during anaesthesia.

7.5.2. Visits to International Teams

Pedro Garcia Rodriguez works on stochastic transitions in neural systems and he has visited the group of Prof. Schimansky-Geier at Humboldt University Berlin in December for one week to start a future collaboration.

8. Dissemination

8.1. Scientific Animation

8.1.1. Scientific responsibilities

- Responsibility of Master 2-program (speciality TAL) at UFR Math-Info, University of Lorraine (L. Buhry)
- Local coordinator of the Erasmus Mundus program *LCT (Language and Communication Technologies)* (L. Buhry)
- Responsibility of Master program in Computer Science (speciality *Recherche IPAC*), University of Lorraine (L. Bougrain)
- Head of Professional Master Internships in Computer Science, University of Lorraine (L. Bougrain)
- Member of committee IST (L. Bougrain)
- Head of the Communication team of the Computer Science Department of FST (L. Bougrain)
- Member of the Program Committee of the conference on Automatic Learning (CAP) (L. Bougrain)
- Member of the Board of Directors in Organization of Computation Neuroscience (A. Hutt)
- Editor of Journal *ISRN Probability and Statistics* and *Dataset Papers in Medicine – Anesthesiology* (A.Hutt)

8.1.2. Review activity

- For journals: Frontiers in Computational Neuroscience, Cerebral Cortex, New Journal of Physics, Physical Review Letters, Physical Review X, Physical Review E, Cognitive Neurodynamics, Advances in Difference Equations, SIAM Journal of Applied Dynamical Systems, ISRN Probability and Statistics, Scholarpedia (A. Hutt); Journal of Neural Engineering, Neurocomputing, CSSP (Circuits, Systems and Signal Processing) (L. Buhry)
- Programme FP7-PEOPLE (L. Buhry)
- Programme FP7-FET *Human Brain Project* (A. Hutt)

8.1.3. Conference organization and participation

- Organization of the g.tec-workshop at LORIA (L. Bougrain)
- Organization of a workshop at the Computational Neuroscience Conference in Paris (A. Hutt)
- Organization of a one-day tutorial at the Computational Neuroscience Conference in Paris (A. Hutt)
- Member of the organization commitee of *Forum des Sciences Cognitives* at Nancy (L. Buhry)

8.2. Teaching - Supervision - Juries

8.2.1. Teaching

Licence : L. Buhry, *Artificial Intelligence and solution of problems*, 25h, level L3 MIASHS, University of Lorraine

Licence: L. Bougrain, *Artificial intelligence and mobile development - Licence of Computer Science*, 70h, level L3, University of Lorraine

Licence: L. Bougrain, *Optimization - Licence of Computer Science*, 37.5h, level L3, University of Lorraine

Licence: L. Bougrain, *Computer Networks - Licence of Computer Science*, 20h, level L2, University of Lorraine

Licence: L. Bougrain, *Artificial intelligence*, 59h, level L3, Telecom Nancy/ESIAL - University of Lorraine

Licence: L. Bougrain, *Immersive and innovative interfaces*, 3h, level L3, Supélec Metz

Master: L. Buhry, *Algorithms for Artificial Intelligence*, 31h, level Master 1 SCA (Sciences Cognitives et Applications), University of Lorraine

Master: L. Buhry, *Fundamentals in Artificial Intelligence and Data Search*, 18h, level Master 1 SCA (Cognitive Science and Applications), University of Lorraine

Master: L. Buhry, *Computational Neuroscience*, 25h, level Master 2 SCMN, University of Lorraine

Licence: L. Bougrain, *Artificial neural networks - Master of mathematics speciality pro. mathematical engineering and computing tools*, 24h, level M3, University of Lorraine

Master: L. Bougrain, *Ergonomics - Master of Computer Science*, 18h, level M1, University of Lorraine

Master : Axel Hutt, *Algorithm Perls*, 9h, level M1, École des Mines Nancy

8.2.2. Supervision

PhD: Maxime Rio, *Bayesian model for the detection of synchronisation in electro-cortical signals*, Université de Lorraine, July 16 2013, Bernard Girau and Axel Hutt

PhD: Carolina Saavedra, *Analysis and multi-channel denoising methods based on wavelets to improve the detection of evoked potentials without averaging: application to BCI*, Université de Lorraine, 14 December 2013, Bernard Girau and Laurent Bougrain

PhD in progress: Meysam Hashemi, *Analysis of a cortico-thalamic model in the context of general anaesthesia*, May 2012, Axel Hutt

PhD in progress: Mariia Fedotenkova, *Analysis of single-channel EEG-data by a recurrence analysis*, November 2013, Axel Hutt

PhD in progress: Cecilia Lindig Leon, *Multilabel classification for a 3D control of a robotic arm using band-specific EEG markers associated with a motor task*, November 2013, Laurent Bougrain and Axel Hutt

8.2.3. Juries

- PhD defense of Muhammad Yousaf, Norwegian University of Life Sciences, 22 February 2013, reviewer (Axel Hutt)
- PhD defense of Merdan Sarmis, Université de Mulhouse, 4 December 2013, reviewer (Axel Hutt)

8.3. Popularization

- Nancy Renaissance 2013 *Moments d'Invention* with stand and talk on conference (L. Bougrain).
- Fête de la Science à Nancy, October 2013 (L. Bougrain et A. Hutt).
- Science Slam Talk on *Sleep and Anaesthesia* at University of Frankfurt / Main, February 2013 (A. Hutt).

9. Bibliography

Publications of the year

Doctoral Dissertations and Habilitation Theses

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[2] C. SAAVEDRA. , *Méthodes d'analyse et de de bruitage multicanaux a partir d'ondelettes pour améliorer la détection de potentiels évoqués sans moyennage: application aux interfaces cerveau-ordinateur*, Université de Lorraine, November 2013, http://hal.inria.fr/tel-00914720

Articles in International Peer-Reviewed Journals

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