IN PARTNERSHIP WITH:
CNRS
Université de Lorraine

Activity Report 2017

Project-Team NEUROSYS

Analysis and modeling of neural systems by a system neuroscience approach

IN COLLABORATION WITH: Laboratoire lorrain de recherche en informatique et ses applications (LORIA)

RESEARCH CENTER
Nancy - Grand Est

THEME
Computational Neuroscience and Medicine

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Project-Team NEUROSYS

Creation of the Team: 2013 January 01, updated into Project-Team: 2015 July 01

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A5.1.3. - Haptic interfaces
A5.1.4. - Brain-computer interfaces, physiological computing
A5.9.2. - Estimation, modeling
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Other Research Topics and Application Domains:

B1.2. - Neuroscience and cognitive science
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B1.2.2. - Cognitive science
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B2.8. - Sports, performance, motor skills

1. Personnel

Research Scientist

Axel Hutt [Inria, Senior Researcher, secondment at Deutscher Wetterdienst, HDR]

Faculty Members

Laurent Bougrain [Team leader, university of Lorraine, Associate Professor]
Laure Buhry [Univ de Lorraine, Associate Professor]
Tamara Tošić [university of Lorraine, Temporary Associate Professor, until Aug 2017]

PhD Students

Amélie Aussel [university of Lorraine]
Francesco Giovannini [Inria]
Cecilia Lindig-León [Inria, until Jan 2017]
Sébastien Rimbert [Inria]

Interns

Rahaf Al-Chwa [Inria, Jan-Feb, Jul-Aug and Nov-Dec 2017]
Oleksii Avilov [Erasmus+, until Jul 2017]

Ivan Kotiuchi [Erasmus+, until Jul 2017]
Romain Orhand [Inria, from Apr 2017 until Sep 2017]

Administrative Assistants
Hélène Cavallini [Inria]
Antoinette Courrier [CNRS]
Christelle Lévèque [university of Lorraine]

Visiting Scientists
Widodo Budiharto [university of Binus, Indonesia, Jan 2017]
Yevgeniy Karplyuk [Kiev Polytechnic Institute, Ukraine, May 2017]
Anton Popov [Kiev Polytechnic Institute, May 2017]

External Collaborators
Patrick Hénaff [university of Lorraine]
Abderrahman Iggidr [Inria]
Dominique Martinez [CNRS]
Radu Ranta [university of Lorraine, from Apr 2017]

2. Overall Objectives

2.1. General Objectives

The team aims at understanding the dynamics of neural systems on multiple scales 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 anesthesia.

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.

After extracting models for different description levels, they are typically applied to obtain simulated activity which is supposed to reconstruct features in experimental data. Although this approach appears straightforward, it presents 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 developed for each application separately. Machine learning approaches that attempt to mimic the brain and its cognitive processes had a lot of success in classification problems during the last decade. These hierarchical and iterative approaches use non-linear functions, which imitate neural cell responses, to communicate messages between neighboring layers. In our team, we work towards developing polysomnography-specific classifiers that might help in linking the features of particular interest for building systems for sleep signal classification with sleep mechanisms, with the accent on memory consolidation during the Rapid Eye Movement (REM) sleep phase.

3.2. Challenges

Eventually the implementation of the models and analysis techniques achieved promises to be able to construct novel data monitors. This construction involves additional challenges and requires contact with 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. Collaborations with local and national hospitals and the pharmaceutical industry already exist.

3.3. Research Directions

- From the microscopic to the mesoscopic scale:
  One research direction focuses 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 theoretical neural population activity to be compared 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 macroscopic scale:
  The other research direction aims to link neural population dynamics to macroscopic activity and behavior or, more generally, to phenomenological features. This link is more indirect but a very powerful approach 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 studies 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 non-invasively. 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 remarks

The research directions of the team are motivated by general anesthesia that has attracted our attention in the last years. The following paragraphs explain in some detail the motivation of our work on the four major phenomena of general anesthesia: loss of consciousness, immobility, amnesia and analgesia.
During general anesthesia, the electroencephalogram (EEG) on the scalp changes characteristically: increasing the anesthetic drug concentration the amplitudes of oscillations in the α-band ($\sim 8-12$Hz) and in the $\delta-$band ($2-8$Hz) increase amplitudes in frontal electrodes at low drug concentrations whereas the spectral power decreases in the $\gamma-$band ($\sim 20-60$Hz). This characteristic change in the power is the basis of today's EEG-monitors that assist the anesthetist in the control of the anesthesia depths of patients during surgery. However, the conventional monitors exhibit a large variability between the detected anesthetic depth and the real depth of patients. Moreover, a certain number of patients re-gain consciousness during surgery (about $1-2$ out of 1000) and a large percentage of patients suffer from diverse after-effects, such as nausea or long-lasting cognitive impairments such as partial amnesia (from days to weeks). Since surgery under general anesthesia is part of a hospital's everyday practice, a large number of patients suffer from these events every day. One reason for the lacking control of such disadvantageous effects is the dramatic lack of knowledge on what is going on in the brain during general anesthesia and a weak EEG-online monitoring system during anesthesia. Consequently, to improve the situation of patients during and after surgery and to develop improved anesthetic procedures or even drugs, research is necessary to learn more about the neural processes in the brain and develop new monitoring machines.

4.2. Level of consciousness

The EEG originates from coherent neural activity of populations in the cortex. Hence to understand better the characteristic power changes in EEG during anesthesia, it is necessary to study neural population dynamics subject to the concentration of anesthetic drugs and their action on receptors on the single neuron level. We study mathematical models which will be constrained by the signal features extracted from experimental data, such as EEG (data provided by Jamie Sleigh, university of Auckland and Christoph Destrieux, university of Tours), Local Field Potentials (data provided by Flavio Fröhlich, university of North Carolina - Chapel Hill) and behavior. The combination of model and analysis of experimental data provides the optimal framework to reveal new knowledge on the neural origin of behavioral features, such as the loss of consciousness or the uncontrolled gain of consciousness during surgery. For instance, modeling studies show that the characteristic changes of spectral power (second-order statistics) are not sufficient to deduce all underlying neural mechanisms. Consequently, additional higher-order statistical measures may provide additional insight into underlying neural mechanisms and may provide a novel marker for the loss of consciousness.

Moreover, the constant supervision of anesthetized patients in intensive care is a demanding task for the personnel in hospital practice. It is almost not possible to take care of a patient constantly and hence the todays' medicine demands monitoring devices that control automatically the level of anesthetic drugs based on the patients' neural activity (e.g., EEG). Brain-Computer-Interfaces (BCI) have already demonstrated their potential for the detection of consciousness in non-responsive patients. We will apply the data analysis techniques known in BCI to extract new markers for the depth of anesthesia. More specifically, for deeper anesthesia, auditory-evoked and Event-Related Desynchronization/Event-Related Synchronization (ERD/ERS) BCI could be used to better identify the state of consciousness in patients under anesthesia. In this context, we have established a first contact to the university of Würzburg. Another research direction will link intracranial EEG and scalp EEG by characterising micro-awake episodes during sleep.

4.3. Immobility

A research direction will be to take benefit of the relationship between the motor activity and anesthesia. Indeed, even if no movement is visually perceptible, a study by electroencephalographic recordings of brain activity in motor areas, quantifying the characteristics of amplitude and phase synchronization observed in the alpha and beta frequency bands, may reveal an intention of movement. This feature is important because it demonstrates that the patient is aware. Thus, we will develop an experimental protocol in collaboration with an anesthesiologist of the regional hospital on stimulating the median nerve at forearm level to track the evolution of the shape of the beta rebound in the motor cortex for various doses of the anesthetic agent.

4.4. Amnesia

Patients sometimes develop post-traumatic disorders associated with the surgery they underwent because they either woke up during the surgery or because the amnesiant effect of the general anesthesia was only partial, declarative memory being maintained in some unexplained cases. It is still unknown how memory can be maintained under general anesthesia and it needs to be investigated to improve the recovery from anesthesia and to avoid as much as possible post-traumatic disorders. To learn more about memory under anesthesia, we will focus our theoretical studies on the oscillation regimes observed in the hippocampus, mainly in the theta and gamma ranges, which are correlated with memory formation and retrieval.

4.5. Analgesia

One of the most important aspect in general anesthesia is the loss of pain. During surgery, it is very difficult to find out whether the anesthetized patient feels pain and hence will develop cognitive impairment after surgery. Today, the anesthesiologist knows and detects physiological signs of pain, such as sweat, colour of skin or spontaneous involuntary movements. However, more objective criteria based on EEG may assist the pain detection and hence improve the patients' situation. To this end, we analyze large sets of patient EEG-data observed during surgery and aim to extract EEG signal features of pain.

5. Highlights of the Year

5.1. Highlights of the Year

- Laurent Bougrain is one of the three members of the committee, with Laurent Koessler and Stéphanie Caharel, that has successfully valued and amplified Neuroscience in Lorraine building a network of research in neuroscience at university of Lorraine. Neuroscience is currently being developed in different laboratories at the university of Lorraine in different institutes such as Inria, CNRS, INSERM, INRA and the university hospital of Nancy. The network will bring together more than 80 researchers in neuroscience to propose common researchers and to give national and international visibilities to neuroscience in Lorraine.
- Neurosys is the leader of the Brain-Computer Interface (BCI) for stroke platform in the Inria Project Lab BCI LIFT (see section 8.2). We developed Grasp'it, an innovative Brain-Computer Interface designed to enhance the motor rehabilitation of stroke patients with Stéphanie Fleck from Perseus lab at university of Lorraine [7], [11], [14]. Our system records users' cerebral activity during the kinesthetic motor imageries (KMI) execution using an electroencephalographic system and gives patients some visual feedback according to the accuracy of the performed imagined task. The graspIT platform was ranked second in the IHM2017 conference demonstrations and first in terms of utility. Grasp'it tends to become a serious game, whose aim is to support the learning and the practice of the KMI tasks in playful and motivating conditions. A French national (ANR) project has been submitted with two other Inria teams (Hybrid and Camin), three rehabilitation centers and an industrial partner, OpenEdge.

6. New Software and Platforms

6.1. BrianModel

Library of Brian Neuron Models
KEYWORDS: Spiking neural networks - Neurosciences - Numerical simulations
FUNCTIONAL DESCRIPTION: BrianModel is a library of neuron models and ionic currents for the BRIAN simulator. The purpose of BrianModel is to speed up simulation set-up and reduce code duplication across simulation scripts. Template neurons are defined by the ionic currents that flow through their membrane. Implemented templates include: Hodgkin-Huxley pyramidal neuron, Hodgkin-Huxley pyramidal neuron with CAN receptors, Hodgkin-Huxley fast-spiking inhibitory hippocampal. The current library is easily extensible by third-party users due to its hierarchical design. The template neurons and their currents are defined as YAML files, which are conveniently parsed by a Python library which acts as an interface to the BRIAN simulator API's.

- Contact: Francesco Giovannini
- URL: https://github.com/JoErNanO/brianmodel

6.2. OpenVIBE

KEYWORDS: Neurosciences - Interaction - Virtual reality - Health - Real time - Neurofeedback - Brain-Computer Interface - EEG - 3D interaction
FUNCTIONAL DESCRIPTION: OpenViBE is a free and open-source software platform devoted to the design, test and use of Brain-Computer Interfaces (BCI). The platform consists of a set of software modules that can be integrated easily and efficiently to design BCI applications. The key features of OpenViBE software are its modularity, its high-performance, its portability, its multiple-users facilities and its connection with high-end/VR displays. The designer 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 under the terms of the AGPL licence, and it was officially released in June 2009. Since then, the OpenViBE software has already been downloaded more than 40000 times, and it is used by numerous laboratories, projects, or individuals worldwide. More information, downloads, tutorials, videos, documentations are available on the OpenViBE website.

- Participants: Cédric Riou, Thierry Gaugry, Anatole Lécuyer, Fabien Lotte, Jussi Tapio Lindgren, Laurent Bougrain, Maureen Clerc Gallagher and Théodore Papadopoulo
- Partners: INSERM - CEA-List - GIPSA-Lab
- Contact: Anatole Lécuyer
- URL: http://openvibe.inria.fr

6.3. Platforms

6.3.1. EEG experimental room

A room at Inria Nancy - Grand Est is dedicated to electroencephalographic recordings. An umbrella agreement and several additional experiment descriptions have been approved by the Inria Operational Legal and Ethical Risk Assessment Committee (COERLE). Our Biosemi EEG amplifier has been extended this year to record 128 channels (Regional initiative *Contrat de Projet État Région (CPER) IT2MP* see section 8.1).

7. New Results

7.1. From the microscopic to the mesoscopic scale

Participants: Laure Buhry, Axel Hutt, Francesco Giovannini, Mélanie Aussel, Ivan Kotiuchi.

Figure 1. Electroencephalographic Experimental room at Inria Nancy-Grand Est

In collaboration with Radu Ranta (university of Lorraine), Beate Knauer and Motoharu Yoshida (Ruhr university) and LieJune Shiau (university of Houston)

7.1.1. Memory and anesthesia

7.1.1.1. Modeling effects of propofol anesthesia

Neural oscillations are thought to be correlated with the execution of cognitive functions. Indeed, gamma oscillations are often recorded in functionally-coupled brain regions for cooperation during memory tasks, and this rhythmic behavior is thought to result from synaptic GABAergic interactions between interneurons. Interestingly, GABAergic synaptic and extrasynaptic receptors have been shown to be the preferred target of the most commonly used anesthetic agents. We presented a in-depth computational study [1] [1] of the action of anesthesia on neural oscillations by introducing a new mathematical model which takes into account the four main effects of the anesthetic agent propofol on GABAergic hippocampal interneurons. These are: the action on synaptic $GABA_A$ receptors, which includes an amplification and an extension of the duration of the synaptic currents, as well as an increase in current baseline, and the action on extrasynaptic $GABA_A$ receptors mediating a tonic inhibitory current. Our results indicate that propofol-mediated tonic inhibition contributes to an unexpected enhancement of synchronization in the activity of a network of hippocampal interneurons. This enhanced synchronization could provide a possible mechanism supporting the occurrence of intraoperative awareness, explicit memory formation, and even paradoxical excitation under general anesthesia, by transiently facilitating the communication between brain structures which should supposedly be not allowed to do so when anesthetized.

7.1.1.2. Stability Analysis in a model of hippocampal place cells

Ring networks, a particular form of Hopfield neural networks, can be used to model the activity of place cells, a type of cells in the hippocampus that are involved in the building and memorization of a cognitive map of one's environment. The behavior of these models is highly dependent on their recurrent synaptic connectivity matrix and on individual neurons' activation function, which must be chosen appropriately to obtain physiologically meaningful conclusions. In [4], we proposed several simpler ways to adjust this synaptic connectivity matrix compared to existing literature so as to achieve stability in a ring attractor network with a piece-wise affine activation functions, and we link these results to the possible stable states the network can converge to.

[1] F. Giovannini and L. Buhry, Tonic inhibition mediates a synchronization enhancement during propofol anesthesia in a network of hippocampal interneurons: a modeling study Journal of computational neuroscience (Submitted) 2017

7.1.1.3. Modeling of the hippocampal formation over the sleep-wake cycle :

The hippocampus can exhibit different oscillatory rhythms within the sleep-wake cycle, each of them being involved in cognitive processes. For example, theta-nested gamma oscillations, consisting of the coupling of theta (4-12Hz) and gamma (40-100Hz) rhythms, are produced during wakefulness and are associated with spatial navigation tasks, whereas Sharp-Wave-Ripple (SWR) complexes, consisting of fast (140-200Hz) oscillatory events occurring at low ($\leq$ 0.5Hz) frequencies, are produced during slow-wave sleep and play an important role in memory consolidation. The mechanisms underlying the generation and switch between each of these rhythms is not yet fully understood, but Acetylcholine is thought to play a key role in it.

In an article in preparation, we propose a computational model of the hippocampal formation based on a realistic topology and synaptic connectivity, influenced by the changing concentration of Acetylcholine between wakefulness and sleep. By using a detailed estimation of intracerebral recordings, we show that this model is able to reproduce both the theta-nested gamma oscillations that are seen in awake brains and the sharp-wave ripple complexes that appear during slow-wave sleep. The results of our simulations support the idea that the functional connectivity of the hippocampus is a key factor in controlling its rhythms.

7.2. From the Mesoscopic to the Macroscopic Scale

Participants: Laurent Bougrain, Axel Hutt, Tamara Tošić, Cecilia Lindig-León, Romain Orhand, Sébastien Rimbert, Oleksii Avilov, Rahaf Al-Chwa.
In collaboration with Stéphanie Fleck (Univ. Lorraine)

7.2.1. Motor system

In collaboration with Stéphanie Fleck (Univ. Lorraine)
Kinesthetic motor imagery (KMI) tasks induce brain oscillations over specific regions of the primary motor cortex within the contralateral hemisphere of the body part involved in the process. This activity can be measured through the analysis of electroencephalographic (EEG) recordings and is particularly interesting for Brain-Computer Interface (BCI) applications.

7.2.1.1. Continuous and discrete

In most BCI experimental paradigms based on Motor Imagery (MI), subjects perform continuous motor imagery (CMI), i.e., a repetitive and prolonged intention of movement, for a few seconds. To improve efficiency such as detecting faster a motor imagery and thus avoid fatigue and boredom, we proposed to show the difference between discrete motor imagery (DMI), i.e., a single short MI, and CMI. The results of the experiment involving 13 healthy subjects suggest that DMI generates a robust post-MI event-related synchronization (ERS). Moreover event-related desynchronization (ERD) produced by DMI seems less variable in certain cases compared to CMI [10], [12]. We showed the difference, in term of classification, between a DMI and a CMI. The results of the experiment involving 16 healthy subjects show that a BCI based on DMI is as effective as a BCI based on CMI and could be used to allow a faster detection [6].

7.2.1.2. Profiling

The most common approach for classification consists of analyzing the signal during the course of the motor task within a frequency range including the alpha band, which attempts to detect the Event-Related Desynchronization (ERD) characteristics of the physiological phenomenon. However, to discriminate right-hand KMI and left-hand KMI, this scheme can lead to poor results on subjects for which the lateralization is not significant enough. To solve this problem, we proposed to analyze the signal at the end of the motor imagery within a higher frequency range, which contains the Event-Related Synchronization (ERS). We showed that 6 out of 15 subjects have a higher classification rate after the KMI than during the KMI, due to a higher lateralization during this period. Thus, for this population we obtained a significant improvement of 13% in classification taking into account the users lateralization profile [9].

7.2.1.3. Combined motor imageries

Combined motor imageries can be detected to deliver more commands in a Brain-Computer Interface for controlling a robotic arm. Nevertheless only a few systems use more than three motor imageries: right hand, left hand and feet. Combining them allows to get four additional commands. We presented an electrophysiological study to show that i) simple motor imageries have mainly an electrical modulation over the cortical area related the body part involved in the imagined movement and that ii) combined motor imageries reflect a superposition of the electrical activity of simple motor imageries. A shrinkage linear discriminant analysis has been used to test as a first step how a resting state and seven motor imageries can be detected. 11 healthy subjects participated in the experiment for which an intuitive assignment has been done to associate motor imageries and movements of the robotic arm with 7 degrees of freedom [2], [5].

7.2.1.4. Anesthesia

Each year, several million of general anesthesia are realized in France. A recent study shows that, between 0.1-0.2 % of patients are victims of intraoperative awareness. This kind of awakening could cause post-traumatic syndromes for the patient. Unfortunately, today, no monitoring system is able to avoid the intraoperative awareness phenomenon. Interestingly, if there is no subject movement due to curare, an electroencephalographical study of the motor cortex can help to detect an intention of movement. The dynamic study of motor cerebral activity during general anesthesia is essential if we want to create a brain-computer interface adapted to the detection of intraoperative awareness. We wrote a clinical protocol to allow EEG data recording during general anesthesia with propofol. Then, the development of temporal analysis specific methods allows us to quantify patterns of desynchronization and synchronization phases observed in delta, alpha and beta frequency bands to prevent intraoperative awareness [8].

8. Partnerships and Cooperations

8.1. Regional Initiatives

Within the *Contrat de Projet État Région (CPER) IT2MP* 2015-2020 on *Technological innovations, modeling and Personalized Medicine*, we are contributing on platform SCIARAT (*cognitive stimulation, Ambient Intelligence, Robotic assistance" and Telemedicine*) observing electroencephalographic activity of humans during motor tasks. Contact in Neurosys is Laurent Bougrain.

8.2. National Initiatives

Inria project-Lab BCI-LIFT, Brain-Computer Interfaces: Learning, Interaction, Feedback, Training, Maureen Clerc, 2015-2018, 7 Inria project-teams (Aramis, Athena, Demar, Hybrid, Mjolnir, Neurosys, Potioc), university of Rouen, Dycog team at Centre de Recherche en Neurosciences de Lyon.

BCI-LIFT is a research initiative to reach a next generation of non-invasive Brain-Computer Interfaces (BCI), more specifically BCI that are easier to appropriate, more efficient, and suit a larger number of people. With this concern of usability as our driving objective, we build non-invasive systems that benefit from advanced signal processing and machine learning methods, from smart interface design, and where the user immediately receives supportive feedback. What drives this project is the concern that a substantial proportion of human participants is currently categorized “BCI-illiterate” because of their apparent inability to communicate through BCI. Through this project we aim at making it easier for people to learn to use BCI, by implementing appropriate machine learning methods and developing user training scenarios.

8.3. International Initiatives

8.3.1. Inria International Partners

8.3.1.1. Informal International Partners

- We have an ongoing collaboration with Prof. Motoharu Yoshida at Ruhr university Bochum, Germany, aiming 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 Prof. LieJune Shiau (university of Houston, Texas, USA) on more theoretical approaches concerning the role of intrinsic neuronal dynamics in network synchronization and brain oscillations (L. Buhry).
- We also collaborate with Anton Popov (Kiev Polytechnic Institute, Ukraine) on feature extraction of brain signal and deep learning (L. Bougrain).

8.4. International Research Visitors

8.4.1. Visits of International Scientists

- Anton Popov, Ass. Prof, Kiev Polytechnic Institute, Ukraine, 5 weeks (May 2017)
- Yevgeniy Karplyuk, Ass. Prof, Kiev Polytechnic Institute, Ukraine, 3 weeks (May 2017)
- Widodo Budiharto, Full Prof, university of Binus, Indonesia, 1 week (Jan 2017)

8.4.1.1. Internships

- Oleksii Avilov, Erasmus+, Kiev Polytechnic Institute, Ukraine, Jan-Jul 2017
- Ivan Kotiuchi, Erasmus+, Kiev Polytechnic Institute, Ukraine, Jan-Jul 2017

9. Dissemination

9.1. Promoting Scientific Activities

Laurent Bougrain is a member of the steering committee of the research network in neuroscience of the university of Lorraine.

Laure Buhry is an elected member of the "Pôle Scientifique AM2I" council of university of Lorraine.

Sébastien Rimbert is an elected member of the doctoral school IAEM of university of Lorraine.

9.1.1. Scientific Events Organisation

9.1.1.1. Member of the Organizing Committees

- Member of the organization committee of the launch day of the French society of brain-computer interfaces, January 24th 2017, Paris (L. Bougrain) http://openvibe.inria.fr/the-2nd-international-openvibe-workshop-2016-contents/
- Member of the organization committee of the iPAC seminar (Image, Perception, Action et Cognition) (L. Buhry)
- Member of the organization committee of the scientific days of the research network in neuroscience of the university of Lorraine, June 9th & November 9th 2017, Nancy (L. Bougrain)

9.1.2. Journal

9.1.2.1. Reviewer - Reviewing Activities

PeerJ (S. Rimbert)

9.1.3. Research Administration

Juries for the recruitment of assistant professors: job MCF4289 IUT university of Cergy Pontoise (2017), L.Buhry

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

Engineering school: L. Bougrain, *Interfaces cerveau-ordinateur*, 4.5h, 3rd year, Supelec, France

Polytechnical university of Kiev: L. Bougrain, *Brain-Computer Interfaces*, 10h, master, Ukraine

Engineering School: F. Giovannini, *Artificial Intelligence*, 32h, 3rd year, Telecom Nancy, France

UFR Math/Info: S. Rimbert, *Brain-Computer Interface*, 17h, Master 2, UFR Math/Info, France

UFR Math/Info: S. Rimbert, *Introduction to Neurosciences*, 15h, 1st year, UFR Math/Info, France

UFR Math/Info: A. Aussel, *Computational Neurosciences*, 20h, Master 2, UFR Math/Info, France

Engineering school: A. Aussel, *Python Programming*, 40h, 1st year, Mines Nancy, France

9.2.2. Supervision

PhD: Francesco Giovannini, Mathematical modelling of neural oscillations in hippocampal memory networks during waking and under general anaesthesia, university of Lorraine, September 19th 2017, Laure Buhry and Axel Hutt [1]

PhD: Cecilia Lindig-León, Multilabel classification of EEG-based combined motor imageries implemented for the 3D control of a robotic arm, January 10th 2017, A. Hutt and L. Bougrain [2]

PhD in progress: Amélie Aussel, Extraction of electrophysiological markers and mathematical modelling of the epileptic hippocampus, October 1st 2016, Laure Buhry and Radu Ranta (CRAN)

PhD in progress: Sébastien Rimbert, Study of the dynamic of cerebral motor patterns during general anesthesia, January 1st 2016, Axel Hutt and Laurent Bougrain

9.2.3. Juries

Ph.D. thesis juries: Loïc Botrel, Brain-computer interfaces (BCIs) based on sensorimotor rhythms Evaluating practical interventions to improve their performance and reduce BCI inefficiency, university of Würzburg, September 27th 2017, L. Bougrain (member)

Ph.D. thesis juries: Marie-Caroline Schaeffer, Traitement du signal ECoG pour Interface Cerveau Machine à grand nombre de degrés de liberté pour application clinique, university Grenoble-Alpes, June 6th 2017, L. Bougrain (member)

9.3. Popularization

Talk during the National Brain Awareness Week: Brain-Robot interactions, Mar. 14th, 2017, middle school Ernest Bichat, Lunéville (L. Bougrain)

Expert for the MGEN (a French mutual benefit insurance company)'s day about "réparer les vivants", Mar. 15th, 2017, Maisons-Alfort (L. Bougrain)

Scientific education on Information Technologgy with Marie Duflot-Kremer in the Marcel Leroy elementary school (20-22 students per class: CM2, CE2 / CM1, CE1 / CE2), 3h (three times 1h), May 30th 2017 (Tamara Tošić)

Exhibit of the Grasp-IT system to improve motor activity at the Interactions Homme-Machine conference 2017, August 2017, Poitier (Sébastien Rimbert)

Exhibit of the Grasp-IT system to improve motor activity at Inria-Industry Meeting on data and their applications, October 18th 2017, Paris (L. Bougrain & Sébastien Rimbert)

10. Bibliography

Publications of the year

Doctoral Dissertations and Habilitation Theses

[1] F. GIOVANNINI. *Mathematical Modelling of Neural Oscillations in Hippocampal Memory Networks during Waking and under General Anaesthesia*, Université de Lorraine, September 2017, https://tel.archives-ouvertes.fr/tel-01661465

[2] C. LINDIG LEÓN. *Multilabel classification of EEG-based combined motor imageries implemented for the 3D control of a robotic arm*, Université de Lorraine, January 2017, https://tel.archives-ouvertes.fr/tel-01549139

Articles in International Peer-Reviewed Journals

[3] F. GIOVANNINI, B. KNAUER, M. YOSHIDA, L. BUHRY. *The CAN-In network: a biologically-inspired model for self-sustained theta oscillations and memory maintenance in the hippocampus* , in "Hippocampus", January 2017 [*DOI :* 10.1002/HIPO.22704], https://hal.archives-ouvertes.fr/hal-01426362

International Conferences with Proceedings

[4] A. AUSSEL, L. BUHRY, R. RANTA. *Stability conditions of Hopfield ring networks with discontinuous piecewise-affine activation functions*, in "56th IEEE Conference on Decision and Control, CDC 2017", Melbourne, Australia, December 2017, https://hal.archives-ouvertes.fr/hal-01645410

[5] C. LINDIG-LEON, S. RIMBERT, O. AVILOV, L. BOUGRAIN. *Scalp EEG Activity During Simple and Combined Motor Imageries to Control a Robotic Arm*, in "2017 IEEE First Ukraine Conference on Electrical and Computer Engineering", Kiev, Ukraine, May 2017, https://hal.inria.fr/hal-01519712

[6] S. RIMBERT, O. AVILOV, L. BOUGRAIN. *Discrete motor imageries can be used to allow a faster detection*, in "7th Graz Brain-Computer Interface Conference 2017", Graz, Austria, September 2017, https://hal.inria.fr/hal-01512407

[7] S. RIMBERT, L. BOUGRAIN, R. ORHAND, J. NEX, S. GABORIT, S. FLECK. *Grasp'it : une interface cerveau-ordinateur pour l'amélioration de l'apprentissage d'une tâche d'imagination motrice kinesthésique*, in "29ème conférence francophone sur l'Interaction Homme-Machine", Poitiers, France, August 2017, 2 p. , https://hal.archives-ouvertes.fr/hal-01568588

[8] S. RIMBERT. *Design of a brain-computer interface allowing intraoperative awarness detection during a general anesthesia*, in "29eme conférence francophone sur l'Interaction Homme-Machine", Poitiers, France, August 2017, https://hal.inria.fr/hal-01568596

Conferences without Proceedings

[9] S. RIMBERT, C. LINDIG-LEÓN, L. BOUGRAIN. *Profiling BCI users based on contralateral activity to improve kinesthetic motor imagery detection*, in "8th Internationl IEEE EMBS Conference On Neural Engineering", Shanghai, China, May 2017, https://hal.archives-ouvertes.fr/hal-01484636

[10] S. RIMBERT, C. LINDIG-LEÓN, M. FEDOTENKOVA, L. BOUGRAIN. *Modulation of beta power in EEG during discrete and continuous motor imageries*, in "8th International IEEE EMBS Conference On Neural Engineering", Shanghai, China, May 2017, https://hal.archives-ouvertes.fr/hal-01484503

Research Reports

[11] S. GABORIT, L. BOUGRAIN, S. RIMBERT. *Interfaces cerveau-ordinateur pour la reeducation post-AVC : apport d'un environnement de stimulation affordant*, Inria Nancy, Neurosys ; LORIA - Université de Lorraine ; Mines de Nancy, June 2017, https://hal.archives-ouvertes.fr/hal-01568179

Other Publications

[12] R. AL-CHWA. *Etude de l'activité cérébrale motrice lors de mouvements isolés successifs de l'index*, Inria, April 2017, 44 p. , https://hal.inria.fr/hal-01514998

[13] L. BUHRY, C. LANGLET, F. GIOVANNINI. *Modelling the effects of propofol on neuronal synchronization in network of interneurons*, July 2017, vol. 18, pp. 15 - 20, CNS 2017 - The Twenty Sixth Annual Computational Neuroscience Meeting, Poster, https://hal.inria.fr/hal-01646069

[14] R. ORHAND. *Haptic feedback prototype as part of a post-stroke rehabilitation device*, Telecom Nancy, September 2017, pp. 1-143, https://hal.inria.fr/hal-01653697