RESEARCH CENTRE

Nancy - Grand Est

IN PARTNERSHIP WITH:

CNRS, Université de Lorraine

2020

ACTIVITY REPORT

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)

DOMAIN

Digital Health, Biology and Earth

THEME

Computational Neuroscience and Medicine

Contents

Project-Team NEUROSYS

Creation of the Team: 2013 January 01, updated into Project-Team: 2015 July 01, end of the Project-Team: 2020 December 31

Keywords

Computer sciences and digital sciences

A3.3. – Data and knowledge analysis

A3.4.1. – Supervised learning

A3.4.2. – Unsupervised learning

A3.4.4. – Optimization and learning

A3.4.6. – Neural networks

A3.4.8. – Deep learning

A5.1.3. – Haptic interfaces

A5.1.4. – Brain-computer interfaces, physiological computing

A5.9.2. – Estimation, modeling

A5.11.1. – Human activity analysis and recognition

A6.1.1. – Continuous Modeling (PDE, ODE)

A6.1.2. – Stochastic Modeling

A6.1.4. – Multiscale modeling

A6.2.1. – Numerical analysis of PDE and ODE

A6.3.4. – Model reduction

A9.2. – Machine learning

A9.3. – Signal analysis

A9.6. – Decision support

Other research topics and application domains

B1.2. – Neuroscience and cognitive science

B1.2.1. – Understanding and simulation of the brain and the nervous system

B1.2.2. – Cognitive science

B1.2.3. – Computational neurosciences

B2.2.2. – Nervous system and endocrinology

B2.2.6. – Neurodegenerative diseases

B2.5.1. – Sensorimotor disabilities

B2.6.1. – Brain imaging

B2.8. – Sports, performance, motor skills

1 Team members, visitors, external collaborators

Faculty Members

- Laurent Bougrain [Team leader, Univ de Lorraine, Associate Professor]
- Laure Buhry [Univ de Lorraine, Associate Professor]

PhD Students

- Oleksii Avilov [Ambassade de France]
- Nathalie Azevedo Carvalho [Inria]

Interns and Apprentices

- Cecile Aprili [Univ de Lorraine, until Jun 2020]
- Linxue Lai [Univ de Lorraine, from Jun 2020 until Sep 2020]
- Djessy Rossi [Univ de Lorraine, from Apr 2020 until May 2020]

Administrative Assistants

- Helene Cavallini [Inria]
- Antoinette Courrier [CNRS]

External Collaborator

- Sébastien Rimbert [Univ de Lorraine]

2 Overall objectives

2.1 General Objectives

The team aims at understanding the dynamics of neural systems at multiple scales and designs 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 system 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 under healthy and pathological conditions and, in turn, discover new therapeutic targets and control the neural systems. They also may allow to develop data monitors utilizing the derived principles. As a long-term goal, the team shall develop such devices in medicine with application in general anesthesia and neuronal pathological conditions.

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 have 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

Techniques for the implementation and analysis of models 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, close contact to hospitals and medical companies shall be established over a longer term in order to (i) gain deeper insight into the specific application of the devices, (ii) build specific devices in accordance with the actual need, (iii) develop/compare biologically realistic models from/to data recorded in vivo. 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 powerful 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 Medical applications

Our research directions are motivated by applications with a high healthcare or social impact. They are developed in collaboration with medical partners, neuroscientists and psychologists. Almost all of our applications can be seen as neural interfaces which require the analysis and modeling of sensorimotor rhythms.

4.1.1 Per-operative awareness during general anesthesia

Collaborators: Univ. Hospital of Nancy-Brabois/dept. Anesthesia & Resuscitation
During general anesthesia, brain oscillations change according to the anesthetic drug concentration. Nowadays, 0.2 to 1.3% of patients regain consciousness during surgery and suffer from post-traumatic disorders. Despite the absence of subject movements due to curare, an electroencephalographic analysis of sensorimotor rhythms can help to detect an intention of movement. Within a clinical protocol, we are working on a brain-computer interface adapted to the detection of intraoperative awareness.

4.1.2 Recovery after stroke

Collaborators: Regional Institute of Physical Medicine and Rehabilitation/Center for Physical Medicine and Rehabilitation (Lay St Christophe), Univ. of Lorraine/PErSEUs.
Stroke is the main cause of acquired disability in adults. Neurosys aims at recovering limb control by improving the kinesthetic motor imagery (KMI) generation of post-stroke patients. We propose to design a KMI-based EEG neural interface which integrates complementary modalities of interactions such as tangible and haptic ones to stimulate the sensorimotor loop. This solution would provide a more engaging and compelling stroke rehabilitation training program based on KMI production.

4.1.3 Modeling Parkinson's disease

Collaborators: Center for Systems Biomedicine (Luxembourg), Institute of Neurodegenerative Diseases (Bordeaux), Human Performance & Robotics laboratory (California State Univ., Long Beach).
Effective treatment of Parkinson's disease should be based on a realistic model of the disease. We are currently developing a neuronal model based on Hodgkin-Huxley neurons reproducing to a certain extent the pathological synchronization observed in basal ganglia in Parkinsonian rats. Moreover, our mesoscopic models of plastic Central Pattern Generator neural circuitries involved in rhythmic movements will allow us to reproduce incoherent coordination of limbs observed on humans affected by Parkinson's diseases like frozen gait, crouch gait. Our long-term objective is to understand how oscillatory activity in the basal ganglia affects motor control in spinal structures.

4.1.4 Modeling propagation of epileptic spikes

Collaborators: Epileptology Unit of the CHRU Nancy (University hospital), CRAN (Research Center in Automation and Signal Processing of Nancy). Effective treatment of patients with refractory epilepsy requires a better understanding of the underlying neuronal mechanisms. In particular, it has been observed that epileptic spikes propagate more easily during stage III sleep (slow wave sleep) than during wakefulness, but the origin of these behaviours still remains misunderstood. At least both, a combination of anatomical structure/connectivity changes and changes in level of neurotransmitters, namely functional connectivity, can cause the propagation. A better knowledge of the functional and structural circuitry could allow a better targetting of structures to be treated, either surgically or pharmacologically, and to better individually adapt the pharmacology to each patient according to their symptomatology.

5 Highlights of the year

5.1 Awards

Sébastien Rimbert received the award for best student paper from IEEE and the Brain initiative at the Brain-Machine Interfaces workshop of the 2020 IEEE International Conference on Systems, Man, and Cybernetics (SMC'20). The article presents a comparative study based on guided and trial-and-error approaches to generate kinesthetic motor imagery using a BCI-based learning environment [6].

6 New software and platforms

6.1 New software

6.1.1 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-user facilities and its connection with high-end/VR displays. The designer of the platform enables users 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 60000 times, and it is used by numerous laboratories, projects, or individuals worldwide. More information, downloads, tutorials, videos, documentations are available on the OpenViBE website.

Release Contributions: Python2 support dropped in favour of Python3 New feature boxes: - Riemannian geometry - Multimodal Graz visualisation - Artefact detection - Features selection - Stimulation validator

Support for Ubuntu 18.04 Support for Fedora 31

Contributions: - Encephalan driver: Alexey Minin from (UrFU) - GTec Unicorn driver: Anton Andreev (Gipsa-Lab) - Box pybox-manager: Jimmy Leblanc & Yannis Bendi-Ouis (Polymont ITS)

News of the Year: Python2 support dropped in favour of Python3 New feature boxes: - Riemannian geometry - Multimodal Graz visualisation - Artefact detection - Features selection - Stimulation validator

Support for Ubuntu 18.04 Support for Fedora 31

URL: http://openvibe.inria.fr

Authors: Charles Garraud, Jérôme Chabrol, Thierry Gaugry, Cedric Riou, Yann Renard, Anatole Lécuyer, Jozef Legény, Laurent Bonnet, Jussi Tapio Lindgren, Fabien Lotte, Thomas Prampart, Thibaut Monseigne

Contacts: Anatole Lécuyer, Ana Bela Leconte

Participants: Cedric Riou, Thierry Gaugry, Anatole Lécuyer, Fabien Lotte, Jussi Tapio Lindgren, Laurent Bougrain, Maureen Clerc, Théodore Papadopoulo

Partners: INSERM, GIPSA-Lab

6.1.2 SIRENE

Name: Neural network simulator

Keywords: Neural networks, Numerical simulations, Neurosciences

Scientific Description: SiReNe is a biological networks simulator that is based on a hybrid simulation scheme that combines time-stepping second-order integration of Hodgkin-Huxley (HH) type neurons with event-driven updating of the synaptic currents. As the HH model is a continuous model, there is no explicit spike events. Thus, in order to preserve the accuracy of the integration method, a spike detection algorithm is developed that accurately determines spike times. This approach allows us to regenerate the outgoing connections at each event, thereby avoiding the storage of the connectivity. Consequently, memory consumption is significantly reduced while preserving execution time and accuracy of the simulations.

Functional Description: SiReNe is a biological neural network simulator. The simulator engine can simulate any type of spiking neural network and is indeed more dedicated to the simulation of biologically detailed models of neurons, such as conductance-based neurons, and synapses.

Release Contributions: Initial version of the software.

News of the Year: Design and implementation of the hybrid simulation scheme and the regeneration of the connectivity.

URL: `https://sirene.gitlabpages.inria.fr/sirene/`

Publication: hal-03041616

Contacts: Sylvain Contassot-Vivier, Dominique Martinez

Participants: Sylvain Contassot-Vivier, Dominique Martinez, Nathalie Azevedo Carvalho, Laure Buhry

Partners: Loria, CNRS, Université de Lorraine

7 New results

7.1 From the microscopic to the mesoscopic scale

Participants: Laure Buhry, Amélie Aussel, Nathalie Azevedo Carvalho, Dominique Martinez (CNRS), Radu Ranta (Univ. Lorraine, CRAN).
In collaboration with Louis Maillard (Univ. Lorraine, CRAN, CHRU Nancy), Louise Tyvaert (Univ. Lorraine, CRAN, CHRU Nancy), Olivier Aron (Univ. Lorraine, CRAN, CHRU Nancy), Sylvain Contassot-Vivier (Univ. Lorraine), Jérome Baufreton (Institut des Maladies Neurodégénératives, Bordeaux)

7.1.1 Hippocampal oscillatory activity

Healthy hippocampus We have extensively studied the parameter space of the detailed anatomical and mathematical model of the hippocampal formation for the generation of healthy hippocampal activity we developed in [8] using design of experiment techniques in order to refine the parameter choices for a more realistic modeling. A paper is under preparation.

Epilepsy of the mesial temporal lobe We have then extended the "healthy hippocampus model" to include pathological changes observed in temporal lobe epilepsy, the future goal being to better understand the generation and propagation of epileptic activity throughout the brain, and therefore to investigate new potential therapeutic targets.

The mechanisms underlying the generation of hippocampal epileptic seizures and interictal events during the sleep-wake cycle are not yet fully understood. Based on our previous computational modeling work of the hippocampal formation based on realistic topology and synaptic connectivity[8], we study the role of network specificity and channel pathological conditions of the epileptic hippocampus in the generation and maintenance of seizures and interictal oscillations. Indeed, the epilepsies of the mesial temporal lobe are associated with hippocampal neuronal and axonal loss, mossy fiber sprouting and channelopathies, namely impaired potassium and chlore dynamics. We show, through the simulations of hippocampal activity during slow-wave sleep and wakefulness that: (i) both mossy fiber sprouting and sclerosis account for epileptic seizures, (ii) high hippocampal sclerosis with low sprouting suppresses seizures, (iii) impaired potassium and chloride dynamics have little influence on the generation of seizures, (iv) but do have an influence on interictal spikes that decreases with high mossy fiber sprouting. A manuscript is currently under revision for the Journal of Computational Neuroscience.

7.1.2 Event-driven simulation of large scale neural models with on-demand connectivity generation

Accurate simulations of brain structures is a major problem in neuroscience. Many works are dedicated to design better models or to develop more efficient simulation schemes. In the article [2], we propose to combine time-stepping numerical integration of Hodgkin-Huxley type neurons with event-driven updating of the synaptic currents. A spike detection method was also developed to determine the spike time more precisely in order to preserve the second-order Runge-Kutta methods. This hybrid approach allows us to regenerate the outgoing connections at each event, thereby avoiding the storage of the connectivity. Consequently, memory consumption and execution time are significantly reduced while preserving accurate simulations, especially spike times of detailed point neuron models. The efficiency of the method has been demonstrated on the simulation of 10^6 interconnected MSN neurons with Parkinson disease. The resulting SiReNe software is available on GitLab `https://sirene.gitlabpages.inria.fr/sirene`.

7.1.3 Modeling and simulation of basal ganglia

In close collaboration with neurophysiologists in Bordeaux who provided us with in vitro and in vivo data in rats, we developed a mathematical model of two neuron types, namely the arkypallidal and prototypic neurons, that are characteristic from the external globus pallidus (GPe), structure involved in the generation and amplification of Parkinson's pathological oscillations.

In order to optimize the parameters of the model, we adapted the stochastic optimization methods proposed by Laure Buhry in [10].

These neuron models where then included into a large-scale model of the basal ganglia we simulated with SiReNe. We are currently comparing and fitting our simulation results with biological experimental data.

7.2 From the Mesoscopic to the Macroscopic Scale

Participants: Laurent Bougrain, Sébastien Rimbert, Oleksii Avilov, Geoffrey Canron.
In collaboration with Stéphanie Fleck (Univ. Lorraine), Fabien Lotte (POTIOC, Inria Bordeaux).

7.2.1 Learning How to Generate Kinesthetic Motor Imagery Using a BCI-based Learning Environment: a Comparative Study Based on Guided or Trial-and-Error Approaches

Kinesthetic Motor Imagery (KMI) is a mental task which, if performed properly, can be very relevant in sports training or rehabilitation with a Brain-Computer Interface (BCI). Unfortunately, this mental task is generally complex to perform and can lead to a high degree of variability in its execution, reducing its potential benefits. The reason why the task of KMI is so difficult to perform is because there is no standardized way of instructing the subject in this mental task. In [6], we present an innovative BCI called Grasp-IT thought to support the learning of the KMI task, and the evaluation of two different learning methods: (i) a first one guided by an experimenter and based on the notion of progressiveness and (ii) a second one where the learners are alone and practice by trial and error. Our findings based on EEG analyses and subjective questionnaires validate the design of the Grasp-IT BCI and open up perspectives on KMI learning modalities.

7.2.2 Multiclass Classification Based on Combined Motor Imageries

Motor imagery (MI) allows the design of self-paced brain–computer interfaces, which can potentially afford an intuitive and continuous interaction. However, the implementation of non-invasive MI-based BCIs with more than three commands is still a difficult task. First, the number of MIs for decoding different actions is limited by the constraint of maintaining an adequate spacing among the corresponding sources, since the electroencephalography (EEG) activity from near regions may add up. Second, EEG generates a rather noisy image of brain activity, which results in a poor classification performance. In [3], we propose a solution to address the limitation of identifiable motor activities by using combined MIs (i.e., MIs involving 2 or more body parts at the same time). And we propose two new multilabel uses of the Common Spatial Pattern (CSP) algorithm to optimize the signal-to-noise ratio, namely MC2CMI and MC2SMI approaches. We recorded EEG signals from seven healthy subjects during an 8-class EEG experiment including the rest condition and all possible combinations using the left hand, right hand, and feet. The proposed multilabel approaches convert the original 8-class problem into a set of three binary problems to facilitate the use of the CSP algorithm. In the case of the MC2CMI method, each binary problem groups together in one class all the MIs engaging one of the three selected body parts, while the rest of MIs that do not engage the same body part are grouped together in the second class. In this way, for each binary problem, the CSP algorithm produces features to determine if the specific body part is engaged in the task or not. Finally, three sets of features are merged together to predict the user intention by applying an 8-class linear discriminant analysis. The MC2SMI method is quite similar, the only difference is that any of the combined MIs is considered during the training phase, which drastically accelerates the calibration time. For all subjects, both the MC2CMI and the MC2SMI approaches reached a higher accuracy than the classic pair-wise (PW) and one-vs.-all (OVA) methods. Our results show that, when brain activity is properly modulated, multilabel approaches represent a very interesting solution to increase the number of commands, and thus to provide a better interaction.

7.2.3 Deep Learning Techniques to Improve Intraoperative Awareness Detection from Electroencephalographic Signals

Every year, millions of patients regain consciousness during surgery and can potentially suffer from post-traumatic disorders. We recently showed that the detection of motor activity during a median nerve stimulation from electroencephalographic signals could be used to alert the medical staff that a patient is waking up and trying to move under general anesthesia [11, 12]. In [4] and [9], we measure the accuracy and false positive rate in detecting motor imagery of several deep learning models (EEGNet, deep convolutional network and shallow convolutional network) directly trained on filtered EEG data. We compare them with efficient non-deep approaches, namely, a linear discriminant analysis based on common spatial patterns, the minimum distance to Riemannian mean algorithm applied to covariance matrices, a logistic regression based on a tangent space projection of covariance matrices (TS+LR). The EEGNet improves significantly the classification performance comparing to other classifiers (p-value < 0.01); moreover, it outperforms the best non-deep classifier (TS+LR) by 7.2% in accuracy. This approach promises to improve intraoperative awareness detection during general anesthesia.

7.2.4 Guidelines to use Transfer Learning for Motor Imagery Detection

Brain-Computer Interfaces based on Motor imagery have shown promising results for motor recovery, intraoperative awareness detection or assistive technology control. However, they suffer from several limitations due to the high variability of electroencephalographic signals, mainly lengthy and tedious calibration times usually required for each new day of use, and a lack of reliability for all users. Such problems can be addressed, to some extent, using transfer learning algorithms. However, the performance of such algorithms has been very variable so far, and when they can be safely used is still unclear. Therefore, we studied in [5] the performance of various state-of-the-art Riemannian transfer learning algorithms on a MI-BCI database (30 users), for various conditions: 1) supervised and unsupervised transfer learning; 2) for various amount of available training EEG data for the target domain; 3) intra-session or inter-session transfer; 4) for both users with good and less good MI-BCI performance. From such experiments, we derived guidelines about when to use which algorithm. Re-centering the target data is effective as soon as a few samples of this target set are taken into account. This is true even for an intra-session transfer learning. Likewise, re-centering is particularly useful for subjects who have difficulty producing stable motor imagery from session to session.

8 Partnerships and cooperations

8.1 National initiatives

8.1.1 ANR

- Program: PRCE CES 33 (interaction, robotics)
- Project acronym: Grasp-IT
- Project title: Design and evaluation of a tangible and haptic brain-computer interface for upper limb rehabilitation after stroke
- Duration: Jan 2020 - Jan 2024
- Coordinator: Laurent Bougrain (Neurosys)
- Other partners: 4 research teams (UL/Perseus, Inria/Camin, Inria/Hybrid) and 3 centers or hospital departments for physical medicine and rehabilitation (IRR/CMPR Lay St Christophe, CHU Rennes, CHU Toulouse) and 1 manufacturer of 3D printers (Alchimies/OpenEdge)
- Abstract: This project aims to recover upper limb control improving the kinesthetic motor imagery (KMI) generation of post-stroke patients using a tangible and haptic interface within a gamified Brain-Computer Interface (BCI) training environment. (i) This innovative KMI-based BCI will integrate complementary modalities of interactions such as tangible and haptic interactions in a 3D printable flexible orthosis. We propose to design and test usability (including efficacy towards the stimulation of the motor cortex) and acceptability of this multimodal BCI. (ii) The GRASP-IT project proposes to design and integrate a gamified non-immersive virtual environment to interact with. This multimodal solution should provide a more meaningful, engaging and compelling stroke rehabilitation training program based on KMI production. (iii) In the end, the project will integrate and evaluate neurofeedbacks, within the gamified multimodal BCI in an ambitious clinical evaluation with 75 hemiplegic patients in 3 different rehabilitation centers in France.
  The GRASP-IT project represents a challenge for the industrial 3D printing field. The materials of the 3D printable orthosis, allowing the integration of haptic-tangible interfaces, will come from a joint R & D work performed by the companies Alchimies and Open Edge.

8.2 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. The acquisition of a new 64-channel EEG system has been approved.

9 Dissemination

9.1 Promoting scientific activities

9.1.1 Invited talks

Workshop on brain-machine interfaces organized by the NeurotechX community (May 13, 2020): Laurent Bougrain presented OpenViBE as an open-source software to work with EEG and other bioelectric signals.

Workshop on brain-machine interfaces and disabilities organized by the French task force on Robotics and health (On July 2, 2020): Laurent Bougrain presented machine learning techniques to characterize motor brain electrical activity for control and rehabilitation.

Workshop on brain-machine interfaces organized jointly by the CNRS, the Academy of Technologies and the National Academy of Medicine (November 2, 2020): Laurent Bougrain presented two projects on the detection of peroperative awareness and the design and evaluation of a haptic and tangible brain-computer interface for stroke patients.

9.1.2 Leadership within the scientific community

Laurent Bougrain is a member of the Board of Directors of the scientific society CORTICO for the promotion of Brain-Computer Interfaces in France.

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

9.1.3 Research administration

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

9.2 Teaching - Supervision - Juries

9.2.1 Teaching

- Engineering school: L. Bougrain, Brain-Computer Interfaces, 4.5h, 3rd year, Supelec, France
- Engineering school: L. Bougrain, Artificial Intelligence, 61h, 3rd year, Telecom Nancy, France
- Master: L. Buhry, Algorithms for Artificial Inteligence, 31h, Master of cognitive science, M1, University of Lorraine, France
- Master: L. Buhry, Fundamental Artificial Intelligence and data mining, 18h, Master of cognitive science, M1, University of Lorraine, France
- Master: L. Buhry, Memory and Machine Learning, 38h, Master of cognitive science, M1, University of Lorraine, France
- Master: L. Buhry, Computational Neurosciences, 25h, Master of cognitive science/SCMN, M2, University of Lorraine, France
- Master: L. Bougrain, Learning and reasoning in the uncertain, 32h, Master of computer science, M2, University of Lorraine, France
- Licence: L. Buhry, Probability and statistics, 30h, L1 MIASHS, University of Lorraine, France
- Licence: L. Buhry, Artificial Intelligence and problem solving, 25h, L3 MIASHS, University of Lorraine, France
- Licence: L. Bougrain, programming on mobile devices, 17h, Licence of computer science, L3, University of Lorraine, France

9.2.2 Supervision

- PhD in progress (defense 18 February 2021): Oleksii Avilov, Deep learning methods for motor imagery detection from raw EEG: applications to brain-computer interfaces, June 1st 2018, Patrick Hénaff, Laurent Bougrain and Anton Popov (Kiev Polytechnic institute).
- PhD in progress: Nathalie Azevedo Carvalho, a biologically plausible computer model of pathological neuronal oscillations observed in Parkinson's disease, November 1st 2018, Dominique Martinez and Laure Buhry.

9.2.3 Juries

- Marouane Arrais, "Stimulation cérébrale multi-sites: Modèles dynamiques et applications aux crises d'épilepsie", Ph.D. thesis Rennes 1 Univ., LTSI-INSERM UMR S1099, 15-12-2020 (Laure Buhry examiner)

9.3 Popularization

9.3.1 Articles and contents

Inria News and events (13 Nov. 2020). Grasp-IT: a brain-computer interface for improving stroke rehabilitation. Sébastien Rimbert et Laurent Bougrain. https://www.inria.fr/en/grasp-it-brain-computer-interface-improving-stroke-rehabilitation

10 Scientific production

10.1 Major publications

[1] S. Rimbert. 'Apport de la stimulation du nerf médian dans la conception d'une BCI basée sur l'activité cérébrale motrice : vers l'amélioration de la détection des réveils peropératoires au cours de l'anesthésie générale'. Theses. Université de Lorraine, July 2020. URL: https://hal.univ-lorraine.fr/tel-02949285.

10.2 Publications of the year

International journals

[2] N. Azevedo Carvalho, S. Contassot-Vivier, L. Buhry and D. Martinez. 'Simulation of Large Scale Neural Models With Event-Driven Connectivity Generation'. In: *Frontiers in Neuroinformatics* 14 (14th Oct. 2020), p. 14. DOI: 10.3389/fninf.2020.522000. URL: https://hal.archives-ouvertes.fr/hal-03041616.

[3] C. Lindig-León, S. Rimbert and L. Bougrain. 'Multiclass Classification Based on Combined Motor Imageries'. In: *Frontiers in Neuroscience* 14 (19th Nov. 2020). DOI: 10.3389/fnins.2020.559858. URL: https://hal.inria.fr/hal-03013795.

International peer-reviewed conferences

[4] O. Avilov, S. Rimbert, A. Popov and L. Bougrain. 'Deep Learning Techniques to Improve Intraoperative Awareness Detection from Electroencephalographic Signals'. In: IEEE Engineering in Medicine and Biology Society 2020. Montreal, Canada, 20th July 2020. URL: https://hal.inria.fr/hal-02920320.

[5] L. Bougrain, S. Rimbert, P. L. C. Rodrigues, G. Canron and F. Lotte. 'Guidelines to use Transfer Learning for Motor Imagery Detection: an experimental study'. In: 10th International IEEE/EMBS Conference on Neural Engineering (NER). virtually, United States, 4th May 2021. URL: https://hal.inria.fr/hal-03147055.

[6] S. Rimbert, L. Bougrain and S. Fleck. 'Learning How to Generate Kinesthetic Motor Imagery Using a BCI-based Learning Environment: a Comparative Study Based on Guided or Trial-and-Error Approaches'. In: SMC 2020 - International IEEE Conference on Systems, Man and Cybernetics. Toronto, Canada: http://smc2020.org/, 7th Oct. 2020. URL: https://hal.inria.fr/hal-02920306.

Doctoral dissertations and habilitation theses

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10.3 Cited publications

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