IN PARTNERSHIP WITH:
CNRS

Université de Lorraine

Activity Report 2019

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

Keywords:

Computer Science and Digital Science:

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, Visitors, External Collaborators

Research Scientist

Axel Hutt [Inria, Senior Researcher, secondment at Deutscher Wetterdienst, until Oct 2019, HDR]

Faculty Members

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

PhD Students

Amélie Aussel [Univ de Lorraine, PhD Student, until Sep 2019]
Oleksii Avilov [Univ de Lorraine, PhD Student]
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Interns and Apprentices
Rahaf Al-Chwa [Inria, from Feb 2019 until Jul 2019]
Anais Coster [Univ de Lorraine, from Apr 2019 until Jun 2019]
Nicolas Descouens [Univ de Lorraine, from Jul 2019 until Sep 2019]
Remi Gauchotte [Univ de Lorraine, from Apr 2019 until Jul 2019]
Augustin Giovinazzo [Univ de Lorraine, from Apr 2019 until Aug 2019]
Elina Ortega Herrera [Inria, from May 2019 until Aug 2019]
Nicolas Rault [Univ de Lorraine, from Jul 2019 until Aug 2019]

Administrative Assistants
Hélène Cavallini [Inria, Administrative Assistant]
Antoinette Courrier [CNRS, Administrative Assistant]

Visiting Scientists
Hiroaki Wagatsuma [Univ de Lorraine, from Jun 2019 until Jul 2019]
Asako Watanabe [Univ de Lorraine, until Jun 2019]

External Collaborators
Radu Ranta [Univ Lorraine, HDR]
Patrick Hénaff [Univ Lorraine, Professor, HDR]
Dominique Martinez [CNRS, Senior Researcher, HDR]
Abderrahman Iggidr [Inria, Researcher, HDR]

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 utilizing 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 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 and (ii) build specific devices in accordance with 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 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. Highlights of the Year

Laurent Bougrain is the coordinator of the 4-years ANR project Grasp-IT on the design and the evaluation of a tangible and haptic brain-computer interface for upper limb rehabilitation after stroke including 4 research teams, 3 centers or hospital departments for physical medicine and rehabilitation and one manifacturer of 3D printers (see Sec. 8.2.1).

6. New Software and Platforms

6.1. 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-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 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.

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

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 Harry Tran (Univ. Lorraine, CRAN), Louise Tyvaert (Univ. Lorraine, CRAN, CHRU Nancy), Olivier Aron (Univ. Lorraine, CRAN, CHRU Nancy), Sylvain Contassot-Vivier (Univ. Lorraine),

7.1.1. Hippocampal oscillatory activity

7.1.1.1. Healthy hippocampus

We proposed a detailed anatomical and mathematical model of the hippocampal formation for the generation of healthy hippocampal activity, especially sharp-wave ripples and theta-nested gamma oscillations [24], [25]. Indeed, the mechanisms underlying the broad variety of oscillatory rhythms measured in the hippocampus during the sleep-wake cycle are not yet fully understood. We proposed a computational model of the hippocampal formation based on a realistic topology and synaptic connectivity, and we analyzed the effect of different changes on the network, namely the variation of synaptic conductances, the variations of the CAN channel conductance and the variation of inputs. By using a detailed simulation of intracerebral recordings, we showed 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 measured during slow-wave sleep. The results of our simulations support the idea that the functional connectivity of the hippocampus, modulated by the sleep-wake variations in Acetylcholine concentration, is a key factor in controlling its rhythms [24].

We further extended this work with an extensive study of the parameter range of the healthy hippocampus activity and showed that the "healthy model" was unable to reproduce pathological hippocampal oscillations observed in temporal lobe epilepsy.

7.1.1.2. Modeling LFP measures

The development of this model was also the opportunity to extend our model of the measure of the local field potential (LFP) and to study the contribution of spikes (not only synaptic currents) to the generation of the LFP. Indeed, simulating extracellular recordings of neuronal populations is a challenging task for understanding the nature of extracellular field potentials (LFPs), investigating specific brain structures and mapping cognitive functions. In general, it is assumed that extracellular recording devices (micro and/or macro-electrodes) record a mixture of low frequency patterns, mainly attributed to the synaptic currents and high-frequency components reflecting action potential (APs) activity. Simulating such signals often requires a high computational burden due to the multicompartmental neuron models used. Therefore, different LFP proxies coexist in the literature, most of them only reproducing some of the features of experimental signals. This may be an issue in producing and validating computational models of phenomena where the fast and slow components of neural activity are equally important, such as hippocampal oscillations. In this part of the work, we proposed an original approach for simulating large-scale neural networks efficiently while computing a realistic approximation of the LFP signal including extracellular signatures of both synaptic and action potentials [26]. We applied this method on the hippocampal network we developed earlier and compared the simulated signal with intracranial measurements from human patients.

7.1.1.3. Epilepsy of the mesial temporal lobe

The model described above has then been extended 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. In this article, based on our previous computational modeling work of the hippocampal formation based on realistic topology and synaptic connectivity, 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 in preparation for the Journal of Neuroscience.

7.1.2. Synchronization phenomena in neuronal network models

From a more computational point of view, we got interested in interneuronal gamma oscillations and synchronization in hippocampus-like networks via different models, especially in adaptive exponential integrate-and-fire neurons. Fast neuronal oscillations in gamma frequencies are observed in neocortex and hippocampus during essential arousal behaviors. Through a four-variable Hodgkin–Huxley type model, Wang and Buzsáki have numerically demonstrated that such rhythmic activity can emerge from a random network of GABAergic interneurons via minimum synaptic inputs. In this case, the intrinsic neuronal characteristics and network structure act as the main drive of the rhythm. We investigate inhibitory network synchrony with a low complexity, two-variable adaptive exponential integrate-and-fire (AdEx) model, whose parameters possess strong physiological relevances, and provide a comparison with the two-variable Izhikevich model and Morris–Lecar model. Despite the simplicity of these three models, the AdEx model shares two important results with the previous biophysically detailed Hodgkin–Huxley type model: the minimum number of synaptic inputs necessary to initiate network gamma-band rhythms remains the same, and this number is weakly dependent on the network size. Meanwhile, Izhikevich and Morris–Lecar neurons demonstrate different results in this study. We further investigated the necessary neuronal, synaptic and connectivity properties, including gap junctions and shunting inhibitions, for AdEx model leading to sparse and random network synchrony in gamma rhythms and nested theta gamma rhythms. These findings suggest a computationally more tractable framework for studying synchronized networks in inducing cerebral gamma band activities.

7.1.3. *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 this work, 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 (an article has been submitted to Frontiers in Neuroinformatics) [23].

7.2. From the Mesoscopic to the Macroscopic Scale

Participants: Laurent Bougrain, Sébastien Rimbert, Oleksii Avilov, Rahaf Al-Chwa, Anais Coster, Elina Ortega Herrera, Nicolas Rault, Radu Ranta (univ. Lorraine).
In collaboration with Stéphanie Fleck (Univ. Lorraine)

7.2.1. *On source space resolution in EEG brain imaging for motor imagery*

Brain source localization accuracy is known to be dependent on the EEG sensor placement over the head surface. In Brain-Computer Interfaces (BCI), according to the paradigm used, Motor Imagery (MI) and Steady-State Visual Evoked Potential (SSVEP) in particular, electrodes are not well distributed over the head, and their number is not standardized as in classical clinical applications. We proposed a method for quantifying the expected quality of source localization with respect of the sensor placement, known as EEG montage. Our method, based on a subspace correlation metric, can be used to assess which brain sources can be distinguished (as they generate sufficiently different potentials on the electrodes), and also to identify regions/volumes in which precise source localization is impossible (i.e. all sources inside those regions could generate similar electrode potentials). In particular, for a MI dedicated montage, we show that source localization is less precise than for standard montages, although the local density of electrodes over the areas of interest is higher [13].

7.2.2. *Median nerve stimulation based BCI: a new approach to detect intraoperative awareness during general anesthesia*

Hundreds of millions of general anesthesia are performed each year on patients all over the world. Among these patients, 0.2 to 1.3% are victims of Accidental Awareness during General Anesthesia (AAGA), i.e. an unexpected awakening of the patient during a surgical procedure under general anesthesia. This terrifying experience may be very traumatic for the patient and should be avoided by the anesthesiologists. Out of all the techniques used to reduce these awakenings, there is currently no solution based on the EEG signal to detect this phenomenon efficiently. Since the first reflex for a patient during an AAGA is to move, a passive BCI based on the intention of movement is conceivable. However, the challenge of using such BCI is that the intention to move from the waking patient is not initiated by a trigger that could be used to guide a classifier. We proposed a solution based on Median Nerve Stimulation (MNS), which causes specific modulations in the motor cortex and can be altered by an intention of movement. We showed that MNS may provide a foundation for an innovative BCI that would allow the detection of an AAGA [15], [7].

Moreover the way in which propofol (i.e., an anesthetic commonly used for the general anesthesia induction) affects motor brain activity within the electroencephalographic (EEG) signal has been poorly investigated and is not clearly understood. For this reason, a detailed study of the motor activity behavior with a step-wise increasing dose of propofol is required and would provide a proof of concept for such an innovative BCI. We started a study to highlight the occurrence of movement attempt patterns, mainly changes in oscillations called event-related desynchronization (ERD) and event-related synchronization (ERS), in the EEG signal over the motor cortex, in healthy subjects, without and under propofol sedation, during four different motor tasks [8], [12].

7.2.3. Can a subjective questionnaire be used as a brain-computer interface performance predictor?

Predicting a subject's ability to use a Brain Computer Interface (BCI) is one of the major issues in the BCI domain. Relevant applications of forecasting BCI performance include: the ability to adapt the BCI to the needs and expectations of the user; assessing the efficiency of BCI use in stroke rehabilitation; and finally, homogenizing a research population. A limited number of recent studies have proposed the use of subjective questionnaires, such as, the Motor Imagery Questionnaire Revised-Second Edition (MIQ-RS). However, further research is necessary to confirm the effectiveness of this type of subjective questionnaire as a BCI performance estimation tool. We aimed to answer the following questions: can the MIQ-RS be used to estimate the performance of an MI-based BCI? If not, can we identify different markers that could be used as performance estimators? To answer these questions, we recorded EEG signals from 35 voluntary healthy subjects during BCI use. The subjects previously had completed the MIQ-RS questionnaire. We conducted an offline analysis to assess the correlation between the questionnaire scores related to Kinesthetic and Motor imagery tasks and the performances of four classification methods. Our results show no significant correlation between BCI performance and the MIQ-RS scores. However, we revealed that BCI performance is correlated to habits and frequency of practicing manual activities [6].

7.2.3.1. Hypnotic State Modulates Sensorimotor Beta Rhythms During Real Movement and Motor Imagery

Hypnosis techniques are currently used in the medical field and directly influence the patient's state of relaxation, perception of the body, and its visual imagination. There is evidence to suggest that a hypnotic state may help patients to better achieve tasks of motor imagination, which is central in the rehabilitation protocols after a stroke. However, the hypnosis techniques could also alter activity in the motor cortex. To the best of our knowledge, the impact of hypnosis on the EEG signal during a movement or an imagined movement is poorly investigated. In particular, how event-related desynchronization (ERD) and event-related synchronization (ERS) patterns would be modulated for different motor tasks may provide a better understanding of the potential benefits of hypnosis for stroke rehabilitation. To investigate this purpose, we recorded EEG signals from 23 healthy volunteers who performed real movements and motor imageries in a closed eye condition. Our results suggest that the state of hypnosis changes the sensorimotor beta rhythm during the ERD phase but maintains the ERS phase in the mu and beta frequency band, suggesting a different activation of the motor cortex in a hypnotized state [14], [9].

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

8.2. National Initiatives

8.2.1. 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.

8.3. International Research Visitors

8.3.1. Visits of International Scientists

- Hiroaki Wagatsuma, Ass. Prof, 11-28 Jun. 2019, Kyutech (Japan). Methodological design for integration of human EEG data with behavioral analyses into human-human/robot interactions in a real-world context.

8.3.1.1. Internships

- Asako Watanabe, Master Student, Jan-Mar 2019, Kyutech (Japan). Feature Extraction of EEG Signals Using Power Spectral Entropy.

8.3.2. Visits to International Teams

L. Bougrain, A. Aussel and S. Rimbert participated in the Kyutech-LORIA workshop organized jointly by University of Lorraine and Kyutech (4-8 March 2019).

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.

9.1.1. Scientific Events: Organisation

Laurent Bougrain is a member of the organization committee of the scientific days of the research network in neuroscience of the university of Lorraine, April 25th 2019 (topic: emotions, motivation and addictions) & December 5th 2019.

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.

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

Engineering school: A. Aussel, Python, Ecole des Mines, Nancy, France

Master: L. Buhry, Algorithms for Articifial Inteligence, 31h, Master of cognitive science, M1, University of Lorraine, France

Master: L. Buhry, Fondamental Artificial Intelligence and data mining, 18h, Master of cognitive science, M1, University of Lorraine, France

Master: L. Buhry, Formalisms for representation and reasoning, 25h, 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, Computationnal 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

Master: S. Rimbert, Brain-Computer Interface, 17h, Master of cognitive sciences, M2, University of Lorraine, France

Master: A. Aussel, Computational Neuroscience, Master of cognitive sciences, M2, University of Lorraine, France

Licence: S. Rimbert, Introduction to Neurosciences, 15h, Licence of cognitive sciences, L1 University of Lorraine, France

Licence: L. Buhry, Programmation Python, 37h, level L1 MIASHS, University of Lorraine, France

Licence: L. Buhry, Probability and statistics, 30h, L1 MIASHS, University of Lorraine, France

Licence: L. Buhry, Artificial Intelligence and problem solvinges, 25h, L3 MIASHS, University of Lorraine, France

Licence: L. Bougrain, programming on mobile devices, 17h, Licence of computer science, L3, University of Lorraine, France

Licence: N. Azevedo Carvalho, Mathematics, 64h, L1 SPI, University of Lorraine, France

9.2.2. Supervision

PhD: Amélie Aussel, Extraction of electrophysiological markers and mathematical modelling of the epileptic hippocampus, October 14 2019, 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.

PhD in progress: Oleksii Avilov, methods for on-line detection of neural rythm changes in the motor system: application 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

Amélie Aussel, Extraction of electrophysiological markers and mathematical modelling of the epileptic hippocampus, October 14 2016, Univ Lorraine, (Laure Buhry and Radu Ranta, supervisors)

Committee of selection for an assistant professor position MCF69/19 University of Toulouse (2019), Laurent Bougrain

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