IN PARTNERSHIP WITH:
CNRS

INSERM

Université Rennes 1

Activity Report 2018

Project-Team VISAGES

Vision, Action and information manaGement System in health

IN COLLABORATION WITH: Institut de recherche en informatique et systèmes aléatoires (IRISA)

RESEARCH CENTER
Rennes - Bretagne-Atlantique

THEME
Computational Neuroscience and Medicine

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Project-Team VISAGES

Creation of the Project-Team: 2005 July 04, end of the Project-Team: 2018 December 31

Keywords:

Computer Science and Digital Science:

A3.1.2. - Data management, quering and storage
A3.1.3. - Distributed data
A3.1.7. - Open data
A3.1.8. - Big data (production, storage, transfer)
A3.2.4. - Semantic Web
A3.3.3. - Big data analysis
A3.4.1. - Supervised learning
A3.4.2. - Unsupervised learning
A3.4.3. - Reinforcement learning
A3.4.4. - Optimization and learning
A5.1.4. - Brain-computer interfaces, physiological computing
A5.2. - Data visualization
A5.3.2. - Sparse modeling and image representation
A5.3.3. - Pattern recognition
A5.3.4. - Registration
A5.4.1. - Object recognition
A5.4.6. - Object localization
A5.9.2. - Estimation, modeling
A6.2.3. - Probabilistic methods
A6.2.4. - Statistical methods
A6.3.3. - Data processing
A6.3.4. - Model reduction
A9.2. - Machine learning
A9.3. - Signal analysis

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
B2.1. - Well being
B2.2.2. - Nervous system and endocrinology
B2.2.6. - Neurodegenerative diseases
B2.5.1. - Sensorimotor disabilities
B2.5.2. - Cognitive disabilities
B2.6.1. - Brain imaging

1. Team, Visitors, External Collaborators

Research Scientists

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Visiting Scientist
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Florence Le Jeune [Univ de Rennes I]
Gabriel Robert [Univ de Rennes I]

2. Overall Objectives

2.1. Overall objectives

Medical Imaging, Neuroinformatics, Neuroimaging, Medical Image Computing, Modeling of normal and pathological behavior of the human brain, e-health & HealthGrids

The Unit/Project VISAGES U1228 is a research team jointly affiliated to INSERM (National Institute of Health and Scientific Research), Inria (National Institute of Research in Computer Sciences and Automation) and IRISA / UMR CNRS 6074, University of Rennes I. We are located in Rennes, France on both medical and sciences campus. The team was created in 2005. Our ambition is to set up a multidisciplinary team merging researchers in image processing and medical doctors. The goal of VISAGES is to constitute a multidisciplinary team. Even though, research in medical imaging could find motivation and recognition based on methodological breakthroughs alone, the ultimate goal, when dealing with medical imaging research, is to make the clinical practice benefit from the basic and applied research, while keeping the excellence of the methodological research. This objective entails the creation of teams encompassing clinical and scientific researchers to design and conduct research projects together. Our aim through the past period was to build a research team able to perform a research going from a novel and basic stage to original clinical experimentation with clear medical impact.

Our research activities are focused on the research and development of new algorithms in medical imaging in the context of the pathologies of the central nervous system. In this context, we are addressing the general problems of the improved understanding of normal and pathological brain organs and systems behavior, at different scales, as well as the promotion and the support of Virtual Organizations of biomedical actors by means of healthgrid's technologies. The medical application objectives are focused on pathologies of the central nervous system, with a particular effort on extraction of new imaging biomarkers for brain pathologies (e.g., Multiple Sclerosis, neuropaediatrics, stroke, psychiatry, ...). More generally, our application objectives concern the following diseases: Multiple sclerosis, epilepsy, dementia, neuro-degenerative brain diseases, brain vascular diseases.

3. Research Program

3.1. Research Program

The scientific foundations of our team concern the development of new processing algorithms in the field of medical image computing : image fusion (registration and visualization), image segmentation and analysis, management of image related information. Since this is a very large domain, which can be applied on numerous types of application; for seek of efficiency, the purpose of our methodological work primarily focuses on clinical aspects and for the most part on head and neck related diseases. In addition, we emphasize our research efforts on the neuroimaging domain. Concerning the scientific foundations, we have pushed our research efforts:

- In the field of image fusion and image registration (rigid and deformable transformations) with a special emphasis on new challenging registration issues, especially when statistical approaches based on joint histogram cannot be used or when the registration stage has to cope with loss or appearance of material (like in surgery or in tumor imaging for instance).
- In the field of image analysis and statistical modeling with a new focus on image feature and group analysis problems. A special attention was also to develop advanced frameworks for the construction of atlases and for automatic and supervised labeling of brain structures.
- In the field of image segmentation and structure recognition, with a special emphasis on the difficult problems of *i*) image restoration for new imaging sequences (new Magnetic Resonance Imaging protocols, 3D ultrasound sequences...), and *ii*) structure segmentation and labelling based on shape, multimodal and statistical information.
- Following past national projects where we had leading roles (e.g., Neurobase, NeuroLog, . . .), we wanted to enhance the development of distributed and heterogeneous medical image processing systems.

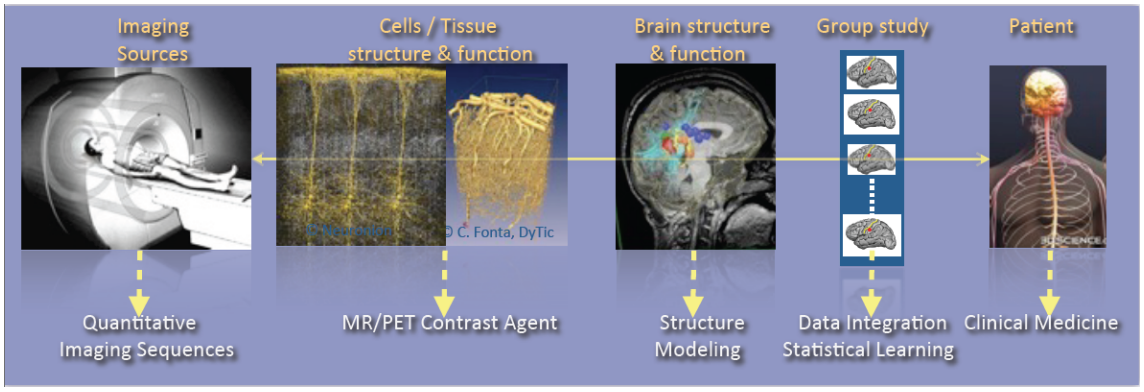

Figure 1. The major overall scientific foundation of the team concerns the integration of data from the Imaging source to the patient at different scales: from the cellular or molecular level describing the structure and function, to the functional and structural level of brain structures and regions, to the population level for the modelling of group patterns and the learning of group or individual imaging markers.

As shown in Fig. 1, research activities of the VISAGES U1228 team are tightly coupling observations and models through integration of clinical and multi-scale data, phenotypes (cellular, molecular or structural patterns). We work on personalized models of central nervous system organs and pathologies, and intend to confront these models to clinical investigation studies for quantitative diagnosis, prevention of diseases, therapy planning and validation. These approaches are developed in a translational framework where the data integration process to build the models inherits from specific clinical studies, and where the models are assessed on prospective clinical trials for diagnosis and therapy planning. All of this research activity is conducted in tight links with the Neurinfo imaging platform environments and the engineering staff of the platform. In this context, some of our major challenges in this domain concern:

- The elaboration of new descriptors to study the brain structure and function (e.g., variation of brain perfusion with and without contrast agent, evolution in shape and size of an anatomical structure in relation with normal, pathological or functional patterns, computation of asymmetries from shapes and volumes).
- The integration of additional spatio-temporal imaging sequences covering a larger range of observation, from the molecular level to the organ through the cell (Arterial Spin Labeling, diffusion MRI,

MR relaxometry, MR cell labeling imaging, PET molecular imaging, ...). This includes the elaboration of new image descriptors coming from spatio-temporal quantitative or contrast-enhanced MRI.

- The creation of computational models through data fusion of molecular, cellular, structural and functional image descriptors from group studies of normal and/or pathological subjects.
- The evaluation of these models on acute pathologies especially for the study of degenerative, psychiatric or developmental brain diseases (e.g., Multiple Sclerosis, Epilepsy, Parkinson, Dementia, Strokes, Depression, Schizophrenia, ...) in a translational framework.

In terms of methodological developments, we are particularly working on statistical methods for multidimensional image analysis, and feature selection and discovery, which include:

- The development of specific shape and appearance models, construction of atlases better adapted to a patient or a group of patients in order to better characterize pathologies;
- The development of advanced segmentation and modeling methods dealing with longitudinal and multidimensional data (vector or tensor fields), especially with the integration of new prior models to control the integration of multiscale data and aggregation of models;
- The development of new models and probabilistic methods to create water diffusion maps from MRI;
- The integration of machine learning procedures for classification and labeling of multidimensional features (from scalar to tensor fields and/or geometric features): pattern and rule inference and knowledge extraction are key techniques to help in the elaboration of knowledge in the complex domains we address;
- The development of new dimensionality reduction techniques for problems with massive data, which includes dictionary learning for sparse model discovery. Efficient techniques have still to be developed to properly extract from a raw mass of images derived data that are easier to analyze.

4. Application Domains

4.1. Neuroimaging

One research objective in neuroimaging is the construction of anatomical and functional cerebral maps under normal and pathological conditions. Many researches are currently performed to find correlations between anatomical structures, essentially sulci and gyri, where neuronal activation takes place, and cerebral functions, as assessed by recordings obtained by the means of various neuroimaging modalities, such as PET (Positron Emission Tomography), fMRI (Functional Magnetic Resonance Imaging), EEG (Electro-EncephaloGraphy) and MEG (Magneto-EncephaloGraphy). Then, a central problem inherent to the formation of such maps is to put together recordings obtained from different modalities and from different subjects. This mapping can be greatly facilitated by the use of MR anatomical brain scans with high spatial resolution that allows a proper visualization of fine anatomical structures (sulci and gyri). Recent improvements in image processing techniques, such as segmentation, registration, delineation of the cortical ribbon, modeling of anatomical structures and multi-modality fusion, make possible this ambitious goal in neuroimaging. This problem is very rich in terms of applications since both clinical and neuroscience applications share similar problems. Since this domain is very generic by nature, our major contributions are directed towards clinical needs even though our work can address some specific aspects related to the neuroscience domain.

4.2. Multiple sclerosis

Over the past years, a discrepancy became apparent between clinical Multiple sclerosis (MS) classification describing on the one hand MS according to four different disease courses and, on the other hand, the description of two different disease stages (an early inflammatory and a subsequently neurodegenerative phase). It is to be expected that neuroimaging will play a critical role to define in vivo those four different MS lesion patterns. An in vivo distinction between the four MS lesion patterns, and also between early and late stages of MS will have an important impact in the future for a better understanding of the natural history of MS and even more for the appropriate selection and monitoring of drug treatment in MS patients. MRI has a low specificity for defining in more detail the pathological changes which could discriminate between the different lesion types. However, it has a high sensitivity to detect focal and also widespread, diffuse pathology of the normal appearing white and gray matter. Our major objective within this application domain is then to define new neuroimaging markers for tracking the evolution of the pathology from high dimensional data (e.g., nD+t MRI) in the brain and the spinal cord. In addition, in order to complement MR neuroimaging data, we ambition to perform also cell labeling neuroimaging (e.g., MRI or PET) and to compare MR and PET data using standard and experimental MR contrast agents and radiolabeled PET tracers for activated microglia (e.g., USPIO or PK 11195). The goal is to define and develop, for routine purposes, cell specific and also quantitative imaging markers for the improved in vivo characterization of MS pathology.

4.3. Modeling of anatomical and anatomo-functional neurological patterns

The major objective within this application domain is to build anatomical and functional brain atlases in the context of functional mapping and for the study of developmental, neurodegenerative or even psychiatric brain diseases (Multiple sclerosis, Epilepsy, Parkinson, Dysphasia, Depression or even Alzheimer). This is a very competitive research domain; our contribution is based on our previous works in this field, and by continuing our local and wider collaborations. An additional objective within this application domain is to find new descriptors to study the brain anatomy and/or function (e.g., variation of brain perfusion, evolution in shape and size of an anatomical structure in relation with pathology or functional patterns, computation of asymmetries, etc.). This is also a very critical research domain, especially for many developmental or neurodegenerative brain diseases.

5. Highlights of the Year

5.1. Highlights of the Year

5.1.1. New permanent team members

- Julie Coloigner was recruited as CNRS Researcher, starting from October 2018.
- Michael Kain was recruited as Research Engineer, starting from December 2018.

5.1.2. New MRI at the Neurinfo platform

A new 3T Siemens Prisma MRI scanner was installed at the Neuroinfo platform in February 2018. An official ceremony was organised with all the funders in November 2018.

5.1.3. First neuroscience hackathon in Rennes

We organized the first hackathon in the Visages team, April 25-26 as part of the international event Brainhack Global 2018.

5.1.4. Award

Best paper award by the French Institute of Psychiatry for our communication at its annual Forum .

BEST PAPER AWARD:

[50]
J. COLOIGNER, J.-M. BATAIL, I. COROUGE, D. DRAPIER, C. BARILLOT. *White matter connectivity analysis in patients suffering from depression*, September 2018, 1 p. , 2018 - 7ème Forum de l'Institut de Psychiatrie, Poster, https://hal.archives-ouvertes.fr/hal-01890087

6. New Software and Platforms

6.1. Anima

KEYWORDS: Filtering - Medical imaging - Diffusion imaging - Registration - Relaxometry
SCIENTIFIC DESCRIPTION: Anima is a set of libraries and tools developed by the team as a common repository of research algorithms. As of now, it contains tools for image registration, statistical analysis (group comparison, patient to group comparison), diffusion imaging (model estimation, tractography, etc.), quantitative MRI processing (quantitative relaxation times estimation, MR simulation), image denoising and filtering, and segmentation tools. All of these tools are based on stable libraries (ITK, VTK), making it simple to maintain.

- Participants: Aymeric Stamm, Fang Cao, Florent Leray, Guillaume Pasquier, Laurence Catanese, Olivier Commowick, Renaud Hedouin and René-Paul Debroize
- Contact: Olivier Commowick
- URL: https://github.com/Inria-Visages/Anima-Public/wiki

6.2. autoMRI

KEYWORDS: FMRI - MRI - ASL - FASL - SPM - Automation
SCIENTIFIC DESCRIPTION: This software is highly configurable in order to fit to a wide range of needs. Pre-processing includes segmentation of anatomical data, as well as co-registration, spatial normalization and atlas building of all data types. The analysis pipelines perform either within-group analysis or between-group or one subject-versus-group comparison and produce statistical maps of regions with significant differences. These pipelines can be applied to structural data to exhibit patterns of atrophy or lesions, to ASL (both pulsed or pseudo-continuous sequences) or PET data to detect perfusion or metabolic abnormalities, to relaxometry data to detect deviations from a template, to functional data - either BOLD or ASL - to outline brain activations related to block or event-related paradigms. In addition to the standard General Linear Model approach, the ASL pipelines implement an a contrario approach and, for patient-specific perfusion study, an heteroscedastic variance model. Besides, the vascular pipeline processes 4D MRA data and enables accurate assessment of hemodynamic patterns.
FUNCTIONAL DESCRIPTION: AutoMRI Based on MATLAB and the SPM8 toolbox, autoMRI provides complete pipelines to pre-process and analyze various types of images (anatomical, functional, perfusion, metabolic, relaxometry, vascular).

- Participants: Camille Maumet, Cédric Meurée, Elise Bannier, Fang Cao, Isabelle Corouge, Pierre Maurel, Quentin Duche and Julie Coloigner
- Contact: Isabelle Corouge
- URL: https://team.inria.fr/visages/software/

6.3. MedInria

KEYWORDS: Visualization - DWI - Health - Segmentation - Medical imaging

SCIENTIFIC DESCRIPTION: medInria aims at creating an easily extensible platform for the distribution of research algorithms developed at Inria for medical image processing. This project has been funded by the D2T (ADT MedInria-NT) in 2010, renewed in 2012. A fast-track ADT was awarded in 2017 to transition the software core to more recent dependencies and study the possibility of a consortium creation.The Visages team leads this Inria national project and participates in the development of the common core architecture and features of the software as well as in the development of specific plugins for the team's algorithm.
FUNCTIONAL DESCRIPTION: MedInria is a free software platform dedicated to medical data visualization and processing.

- Participants: Maxime Sermesant, Olivier Commowick and Théodore Papadopoulo
- Partners: HARVARD Medical School - IHU - LIRYC - NIH
- Contact: Olivier Commowick
- URL: http://med.inria.fr

6.4. QtShanoir

KEYWORDS: Qt - Nifti - Medical imaging - Plug-in - DICOM - Health - C++ - Soap - Webservices - Shanoir
SCIENTIFIC DESCRIPTION: QtShanoir is based on Qt/C++ librairy. It interacts with the Shanoir server using SOAP web services provided. This application queries the server and displays hierarchical data extracted in tree view. Data could also be easily downloaded or uploaded on the server. In order to extend the Shanoir environment, QtShanoir is developed to contain two shared libraries: - « GUI » that represents all user interfaces. - « DAO » that takes in charge the data model. This library assures the connection to the server and provides all QtShanoir services : research, download and upload of Processed Dataset (NIfTI). QtShanoir dynamic libraries are already reused and integrated in other projects: in the software medInria and in an under development command line program.
FUNCTIONAL DESCRIPTION: QtShanoir is a graphical client application of the medical imaging database Shanoir. This application provides various functionalities to satisfy researchers' needs. It allows users to: - explore neuroimaging data derived from multicenter research trials. Through an intuitive user interface, users could easily visualize voluminous amount of structured data: studies, patients and datasets extracted from Shanoir - download and to upload data from the server. This application is available on Windows, UNIX, MacOs X. It is integrated as a plugin in medInria, a multi-plateform for medical image processing and visualization.

- Participants: Alexandre Abadie, Guillaume Renard, Nicolas Wiest Daessle, Olivier Commowick and Wefa Hakem
- Contact: Christian Barillot
- URL: http://qtshanoir.gforge.inria.fr

6.5. Shanoir

SHAring NeurOImaging Resources
KEYWORDS: Neuroimaging - Medical imaging - PACS - Nifti - Data Sharing - DICOM - Health - Shanoir - Webservices - Data base - Biology - Web Application
FUNCTIONAL DESCRIPTION: SHAring NeurOImaging Resources (Shanoir, Previously InriaNeuroTk) is an open source software platform designed to designed to share, archive, search and visualize neuroimaging data.

It provides a user-friendly secure web access and offers an intuitive workflow to facilitate the collecting and retrieving of neuroimaging data from multiple sources and a wizzard to make the completion of metadata easy. Shanoir comes along many features such as anonymization of data, support for multi-centric clinical studies on subjects or group of subjects.

Shanoir offers an ontology-based data organization (OntoNeuroLOG). Among other things, this facilitates the reuse of data and metadata, the integration of processed data and provides traceability trough an evolutionary approach. Shanoir allows researchers, clinicians, PhD students and engineers to undertake quality research projects with an emphasis on remote collaboration. As a secured J2EE web application, it therefore allows you safely storing and archiving, with no more requirements than a computer with an internet connection!

Furthermore, Shanoir is not only a web application: it is also a complete neuroinformatics platform in which you can easily integrate your existing processing tools or develop your own ones: see ShanoirTk.

The clinical scores resulting from instrument based assessments (e.g. neuropsychological tests) can also be entered and easily retrieved and exported in different formats (Excel, CSV, Xml). Scores and image acquisitions are bound together which makes relationship analysis possible. The instrument database is scalable an new measures can be added in order to meet specific project needs, by use of intuitive graphical interfaces.

Using cross-data navigation and advanced search criteria, the users can quickly point to a subset of data of data to be downloaded. Client side applications have as well been developed to illustrate how to locally access and exploit data through the available web services. With regards to security, the system requires authentication and user rights are tunable for each hosted studies. The person responsible for the study can define which users are allowed to see, download or import data.

Shanoir serves neuroimaging researchers in organizing efficiently their studies while cooperating with other laboratories. By managing patient privacy, Shanoir allows the exploitation of clinical data in a research context. It is finally a handy solution to publish and share data with a broader community.

- Participants: Adrien Férial, Anthony Baire, Bernard Gibaud, Christian Barillot, Guillaume Renard, Justine Guillaumont, Michael Kain and Yao Yao
- Partners: Université de Rennes 1 - CNRS - INSERM
- Contact: Christian Barillot
- URL: http://shanoir.gforge.inria.fr

6.6. ShanoirUploader

KEYWORDS: Webservices - PACS - Medical imaging - Neuroimaging - DICOM - Health - Biology - Java - Shanoir
SCIENTIFIC DESCRIPTION: ShanoirUploader is a desktop application on base of JavaWebStart (JWS). The application can be downloaded and installed using an internet browser. It interacts with a PACS to query and retrieve the data stored on it. After this ShanoirUploader sends the data to a Shanoir server instance in order to import these data. This application bypasses the situation, that in most of the clinical network infrastructures a server to server connection is complicated to set up between the PACS and a Shanoir server instance.
FUNCTIONAL DESCRIPTION: ShanoirUploader is a Java desktop application that transfers data securely between a PACS and a Shanoir server instance (e.g., within a hospital). It uses either a DICOM query/retrieve connection or a local CD/DVD access to search and access images from a local PACS or the local CD/DVD. After having retrieved the data, the DICOM files are locally anonymized and then uploaded to the Shanoir server. A possible integration of a hash creation application for patient identifiers is provided as well. The primary goals of that application are to enable mass data transfers between different remote server instances and therefore reduce the waiting time of the users, when importing data into Shanoir. Most of the time during import is spent with data transfers.

- Participants: Christian Barillot, Ines Fakhfakh, Justine Guillaumont, Michael Kain and Yao Yao
- Contact: Christian Barillot
- URL: http://shanoir.gforge.inria.fr

6.7. Shanoir-NG

KEYWORDS: Neuroimaging - DICOM - Nifti

FUNCTIONAL DESCRIPTION: Shanoir-NG provides a user-friendly secure web access and offers an intuitive workflow to facilitate the collecting and retrieving of neuroimaging data from multiple sources and a wizzard to make the completion of metadata easy. Shanoir-NG comes along many features such as anonymization of data, support for multi-centric clinical studies on subjects or group of subjects.

Shanoir-NG offers an ontology-based data organization (OntoNeuroLOG). Among other things, this facilitates the reuse of data and metadata, the integration of processed data and provides traceability through an evolutionary approach. Shanoir allows researchers, clinicians, PhD students and engineers to undertake quality research projects with an emphasis on remote collaboration. As a secured Jakarta EE web application, it therefore allows you safely storing and archiving, with no more requirements than a computer with an internet connection!

RELEASE FUNCTIONAL DESCRIPTION: Shanoir-NG is a complete technological remake of the first version of the Shanoir application, but maintaining the key concepts of Shanoir.
NEWS OF THE YEAR: Shanoir-NG is a complete technological remake of the first version of the Shanoir application, but maintaining the key concepts of Shanoir.

- Participants: Christian Barillot, Mathieu Simon, Michael Kain, Yao Yao, Aneta Morawin, Arnaud Touboulic, Ines Fakhfakh and Anthony Baire
- Contact: Michael Kain

6.8. Platforms

6.8.1. The Neurinfo Platform

VisAGeS is the founding actor of an experimental research platform which was installed in August 2009 at the University Hospital of Rennes. The University of Rennes 1, Inria, Inserm for the academic side, and the University Hospital of Rennes and the Cancer Institute “Eugene Marquis” for the clinical side, are partners of this neuroinformatics platform called Neurinfo (http://www.neurinfo.org). This platform has been supported under the “Contrat de Projets Etat-Région” (Christian Barillot is the PI) and has received a total amount of 4.01 M€ for the period 2007–2014. European (FEDER), National (through Ministry of research, Inria, Inserm and ANR) and local councils (Brittany Region, Ille et Vilaine, and Rennes Metropole) have joined their effort to support this operation for a total amount of 4 010 k€ (600 k€ for the infrastructures, 2 850 k€ for the equipments and 560 k€ for the functioning). This application was set up through the Regional PIMATGI initiative coordinated by INSERM in Brittany (C. Roux). The PIMATGI initiative participated to the funding of three complementary platforms: Neurinfo, TheraFONC as a technical platform dedicated to therapy guided by functional imaging especially in the oncology domain (Inserm U650 - LaTIM, Dir. Ch. Roux, Brest), and TherA-Image as a platform dedicated to image guided mini-invasive surgery and therapy especially in the domain of cardio-vascular diseases (U642 -LTSI, Dir. L. Senhadji, Rennes).

Concerning the Neurinfo Platform, the activity domain is a continuum between methodological and technological research built around specific clinical research projects. The ambition is to do innovation in science, technology and medical technology transfer for the implementation on the clinical field. On the medical field, the translational research domain mainly concerns medical imaging and more specifically the clinical neurosciences. Among them are multiple sclerosis, epilepsy, neurodegenerative, neurodevelopmental and psychiatric diseases, surgical procedures of brain lesions, neuro-oncology and radiotherapy planning. Beyond these CNS applications, the platform is also open to alternative applications. Neurinfo ambitions to support the emergence of research projects based on their level of innovation, their pluri-disciplinarity and their ability to foster collaborations between different actors (public and private research entities, different medical specialties, different scientific profiles).

In this context, a research 3T MRI system (Siemens Verio) was acquired in summer 2009 in order to develop the clinical research in the domain of morphological, functional, structural and cellular in-vivo imaging. In 2014 a new equipment for simultaneous recording of EEG and MRI images was acquired from Brain Product. In 2015, a mock scanner for experimental set-up was acquired as well as a new High Performance Computing environment made of one large computing cluster and a data center that is shared and operated by the Inria center at IRISA (UMR CNRS 6074). The computation cluster (240 cores) and the data center (up to 50 TB) are dedicated to host and process imaging data produced by the Neurinfo platform, but also by other research partners that share their protocols on the Neurinfo neuroinformatics system (currently more than 30 sites).

VisAGeS and its partners in the Neurinfo project are committed to use this new research platform for developing new regional, national and international collaborations around fundamental and applied clinical research projects dealing with in-vivo medical imaging.

In 2016, VisAGeS has been awarded by IBISA as a “Plateforme d’excellence”.

In 2017, funding was collected to replace the 3T Siemens Verio MRI that led to the installation of a new 3T Siemens Prisma in 2018.

In 2018, the INS2I institute of CNRS did awarded the neurinfo platform with a specific support for experimental platform that will be dedicated to the acquisition in 2019 of a EEG-compatible fNIRS system.

7. New Results

7.1. Research axis 1: Medical Image Computing in Neuroimaging

Extraction and exploitation of complex imaging biomarkers involve an imaging processing workflow that can be quite complex. This goes from image physics and image acquisition, image processing for quality control and enhancement, image analysis for features extraction and image fusion up to the final application which intends to demonstrate the capability of the image processing workflow to issue sensitive and specific markers of a given pathology. In this context, our objectives in the recent period were directed toward 4 major methodological topics:

7.1.1. Diffusion imaging

7.1.1.1. Optimal selection of diffusion-weighting gradient waveforms using compressed sensing and dictionary learning

Participants: Raphaël Truffet, Emmanuel Caruyer.

Acquisition sequences in diffusion MRI rely on the use of time-dependent magnetic field gradients. Each gradient waveform encodes a diffusion weighted measure; a large number of such measurements are necessary for the in vivo reconstruction of microstructure parameters. We proposed here a method to select only a subset of the measurements while being able to predict the unseen data using compressed sensing. We learnt a dictionary using a training dataset generated with Monte-Carlo simulations; we then compare two different heuristics to select the measures to use for the prediction. We found that an undersampling strategy limiting the redundancy of the measures allows for a more accurate reconstruction when compared with random undersampling with similar sampling rate [57].

7.1.1.2. A Bayes Hilbert Space for Compartment Model Computing in Diffusion MRI

Participant: O. Commowick.

The single diffusion tensor model for mapping the brain white matter microstructure has long been criticized as providing sensitive yet non-specific clinical biomarkers for neurodegenerative diseases because (i) voxels in diffusion images actually contain more than one homogeneous tissue population and (ii) diffusion in a single homogeneous tissue can be non-Gaussian. Analytic models for compartmental diffusion signals have thus naturally emerged but there is surprisingly little for processing such images (estimation, smoothing, registration, atlas-ing, statistical analysis). We propose to embed these signals into a Bayes Hilbert space that we properly define and motivate. This provides a unified framework for compartment diffusion image computing. Experiments show that (i) interpolation in Bayes space features improved robustness to noise compared to the widely used log-Euclidean space for tensors and (ii) it is possible to trace complex key pathways such as the pyramidal tract using basic deterministic tractography thanks to the combined use of Bayes interpolation and multi-compartment diffusion models [26]

This work was done in collaboration with A. Stamm, A. Menafoglio and S.K. Warfield.

7.1.2. Arterial Spin Labeling

7.1.2.1. Patch-Based Super-Resolution of Arterial Spin Labeling Magnetic Resonance Images
Participants: Cédric Meurée, Pierre Maurel, Jean-Christophe Ferré, Christian Barillot.

Arterial spin labeling is a magnetic resonance perfusion imaging technique that, while providing results comparable to methods currently considered as more standard concerning the quantification of the cerebral blood flow, is subject to limitations related to its low signal-to-noise ratio and low resolution. In this work, we investigated the relevance of using a non-local patch-based super-resolution method driven by a high-resolution structural image to increase the level of details in arterial spin labeling images. This method was evaluated by comparison with other image dimension increasing techniques on a simulated dataset, on images of healthy subjects and on images of subjects diagnosed with brain tumors, who had a dynamic susceptibility contrast acquisition. The influence of an increase of ASL images resolution on partial volume effects was also investigated in this work. [56]

The development of this super-resolution algorithm in the context of a thesis financed by Siemens Healthineers conducted to a stay of one month of the PhD candidate in Erlangen, during summer 2018. This immersion into the neuro-development team allowed to integrate the proposed solution with tools in use within this team. Part of the work also consisted in reducing the calculation time, a factor of 5 being achieved at the end of these four weeks.

7.1.2.2. Resting-state ASL : Toward an optimal sequence duration
Participants: Corentin Vallée, Pierre Maurel, Isabelle Corouge, Christian Barillot.

Resting-state functional Arterial Spin Labeling (rs-fASL) in clinical daily practice and academic research stay discreet compared to resting-state BOLD. However, by giving direct access to cerebral blood flow maps, rs-fASL leads to significant clinical subject scaled application as CBF can be considered as a biomarker in common neuropathology. Our work here focused on the link between overall quality of rs-fASL and duration of acquisition. To this end, we consider subject self-Default Mode Network (DMN), and assess DMN quality depletion compared to a gold standard DMN depending on the duration of acquisition [46].

7.1.3. Quantitative imaging

7.1.3.1. Identification of Gadolinium contrast enhanced regions in MS lesions using brain tissue microstructure information obtained from diffusion and T2 relaxometry MRI
Participants: S. Chatterjee, O. Commowick, C. Barillot.

A multiple sclerosis (MS) lesion at an early stage undergoes active blood brain barrier (BBB) breakdown. Identifying MS lesions in a patient which are undergoing active BBB breakdown is of critical importance for MS burden evaluation and treatment planning. However in non-contrast enhanced structural magnetic resonance imaging (MRI) the regions of the lesion undergoing active BBB breakdown cannot be distinguished from the other parts of the lesion. Hence gadolinium (Gd) contrast enhanced T1-weighted MR images are used for this task. However some side effects of Gd injection into patients have been increasingly reported recently. The BBB breakdown is reflected by the condition of tissue microstructure such as increased inflammation, presence of higher extra-cellular matter and debris. We have thus proposed a framework to predict enhancing regions in MS lesions using tissue microstructure information derived from T2 relaxometry and diffusion MRI (dMRI) multicompartment models. We showed that combination of the dMRI and T2 relaxometry microstructure information can distinguish the Gd enhancing lesion regions from the other regions in MS lesions [23].

7.1.3.2. A three year follow-up study of gadolinium enhanced and non-enhanced regions in multiple sclerosis lesions using a multi-compartment T_2 relaxometry model
Participants: S. Chatterjee, O. Commowick, B. Combes, C. Barillot.

Demyelination, axonal damage and inflammation are critical indicators of the onset and progress of neurodegenerative diseases such as multiple sclerosis (MS) in patients. Due to physical limitations of imaging such as acquisition time and imaging resolution, a voxel in a MR image is heterogeneous in terms of tissue microstructure such as myelin, axons, intra and extra cellular fluids and free water. We present a multi-compartment tissue model which estimates the water fraction (WF) of tissues with short, medium and high T_2 relaxation times in a T_2 relaxometry MRI voxel. The proposed method is validated on test-retest data of healthy controls. This model was then used to study longitudinal trends of the tissue microstructures for two sub-regions of the lesions: gadolinium enhanced (E+) and non-enhanced (L-) regions of MS lesions in 10 MS patients over a period of three years. The water fraction values in E+ and L- regions were found to be significantly different ($p < 0.05$) over the period of first three months. The results of this study also showed that the estimates of the proposed T_2 relaxometry model on brain tissue microstructures have potential to distinguish between regions undergoing active blood brain barrier breakdown from the other regions of the lesion [49].

This work was done in collaboration with Onur Afacan and Simon K. Warfield from Harvard Medical School.

7.1.3.3. Multi-Compartment Model of Brain Tissues from T2 Relaxometry MRI Using Gamma Distribution
Participants: S. Chatterjee, O. Commowick, C. Barillot.

The brain microstructure, especially myelinated axons and free fluids, may provide useful insight into brain neurodegenerative diseases such as multiple sclerosis (MS). These may be distinguished based on their transverse relaxation times which can be measured using T_2 relaxometry MRI. However, due to physical limitations on achievable resolution, each voxel contains a combination of these tissues, rendering the estimation complex. We presented a novel multi-compartment T_2 (MCT2) estimation based on variable projection, applicable to any MCT2 microstructure model. We derived this estimation for a three-gamma distribution model. We validated our framework on synthetic data and illustrated its potential on healthy volunteer and MS patient data [32].

This work was done in collaboration with Onur Afacn and Simon K. Warfield.

7.1.3.4. A 3-year follow-up study of enhancing and non-enhancing multiple sclerosis (MS) lesions in MS patients demonstrating clinically isolated syndrome (CIS) using a multi-compartment T_2 relaxometry (MCT2) model
Participants: S. Chatterjee, O. Commowick, B. Combes, A. Kerbrat, C. Barillot.

Obtaining information on condition of tissue microstructures (such as myelin, intra/extra cellular cells, free water) can provide important insights into MS lesion. However, MRI voxels are heterogeneous in terms of tissue microstructure due to the limited imaging resolution owing to existing physical limitations of MRI scanners. Here we evaluated a multi-compartment T_2 relaxometry model and then used it to study the evolution of enhancing (USPIO and gadolinium positive) and non-enhancing lesions in 6 MS patients with CIS characteristics over a period 3 years with 7 follow-up scans post baseline [31].

This work was done in collaboration with Onur Afacn and Simon K. Warfield.

7.1.4. Atlases

7.1.4.1. Anisotropic similarity, a constrained affine transformation: Application to brain development analysis
Participants: A. Legouhy, O. Commowick, C. Barillot.

The study of brain development provides insights in the normal trend of brain evolution and enables early detection of abnormalities. We proposed a method to quantify brain growth in three arbitrary orthogonal directions of the brain through linear registration. We introduced a 9 degrees of freedom transformation that gives the opportunity to extract scaling factors describing brain growth along those directions by registering a database of subjects in a common basis. We applied this framework to create longitudinal curves of scaling ratios along fixed orthogonal directions from 0 to 16 years highlighting anisotropic brain development [39].

This work was done in collaboration with François Rousseau under the ANR MAIA project.

7.1.5. Simultaneous EEG/fMRI

7.1.5.1. Automated Electrodes Detection during simultaneous EEG/fMRI
Participants: M. Fleury, C. Barillot, E. Bannier, P. Maurel.

The coupling of Electroencephalography (EEG) and functional magnetic resonance imaging (fMRI) enables the measure of brain activity at high spatial and temporal resolution. The localisation of EEG sources depends on several parameters including the knowledge of the position of the electrodes on the scalp. An accurate knowledge about this information is important for source reconstruction. Currently, when acquiring EEG and fMRI together, the position of the electrodes is generally estimated according to fiducial points by using a template. In the context of simultaneous EEG/fMRI acquisition, a natural idea is to use magnetic resonance (MR) images to localise EEG electrodes. However, most MR compatible electrodes are built to be almost invisible on MR Images. Taking advantage of a recently proposed Ultra short Echo Time (UTE) sequence, we introduce a fully automatic method to detect and label those electrodes in MR images. Our method was tested on 8 subjects wearing a 64-channel EEG cap. This automated method showed an average detection accuracy of 94% and the average position error was 3.1 mm. These results suggest that the proposed method has potential for determining the position of the electrodes during simultaneous EEG/fMRI acquisition with a very light cost procedure" [11], [35].

This work was done in collaboration with Marsel Mano from Biotrial.

7.1.6. Inference in neuroimaging

7.1.6.1. Validity of summary statistics-based mixed-effects group fMRI
Participant: Camille Maumet.

Statistical analysis of multi-subject functional Magnetic Resonance Imaging (fMRI) data is traditionally done using either: 1) a mixed-effects GLM (MFX GLM) where within-subject variance estimates are used and incorporated into per-subject weights or 2) a random-effects General linear model (GLM) (RFX GLM) where within-subject variance estimates are not used. Both approaches are implemented and available in major neuroimaging software packages including: SPM (MFX analysis; 2nd-Level statistics), FSL (FLAME; OLS) and AFNI (3dMEMA; 3dttest++). While MFX GLM provides the most efficient statistical estimate, its properties are only guaranteed in large samples, and it has been shown that RFX GLM is a valid alternative for one-sample group analyses in fMRI [1]. We recently showed that MFX GLM for image-based meta-analysis could lead to invalid results in small-samples. We investigated whether this issue also affects group fMRI [42].

This work was done in collaboration with Prof. Thomas Nichols from the Oxford Big Data Institute, UK.

7.1.6.2. Choosing a practical and valid Image-Based Meta-Analysis
Participant: Camille Maumet.

Meta-analysis provides a quantitative approach to summarise the rich functional Magnetic Resonance Imaging (fMRI) literature. When image data is available for each study, the optimal approach is to perform an Image-Based Meta-Analysis (IBMA) [1]. A number of IBMA approaches have been proposed including combination of standardised statistics (Z's), just effect estimates (E's) or both effect estimates and their standard errors (SE's). While using both E's & SE's and estimating between-study variance should be optimal, the methods are not guaranteed to work for small number of studies. Also, often only standardised estimates are shared, reducing the possible meta-analytic approaches. Finally, because the BOLD signal is non-quantitative care has to be taken in order to insure that E's are expressed in the same units [2,3], especially when combining data from different software packages. Given the growing interest in data sharing in the neuroimaging community there is a need to identify what is the minimal data to be shared in order to allow for future IBMAs. We investigated the validity of 8 IBMA approaches [41].

This work was done in collaboration with Prof. Thomas Nichols from the Oxford Big Data Institute, UK.

7.1.7. Machine learning

7.1.7.1. Learning sparse predictor from hybrid EEG-fMRI neurofeedback

Participants: C. Cury, C. Barillot, P. Maurel.

Electroencephalography (EEG) and functional magnetic resonance imaging (fMRI) both allow measurement of brain activity for neuro-feedback (NF), respectively with high temporal resolution for EEG and high spatial resolution for fMRI. Using simultaneously fMRI and EEG for NF training is very promising to devise brain rehabilitation protocols, however performing NF-fMRI is costly, exhausting and time consuming, and cannot be repeated too many times for the same subject. The original contribution of this work concerns the prediction of NF scores from EEG recordings only, using a training phase where both EEG and fMRI NF are available. We have proposed a model able to predict NF scores from coupling EEG-fMRI (NF-EEG-fMRI) of 17 subjects in motor imagery task. The prediction of NF-EEG-fMRI scores was found as satisfactory with a significant improved performance with respect to what EEG can provide alone, when adding to NF-EEG, the prediction of NF-fMRI from EEG signals. The prediction of NF-fMRI significantly adds information and increases the quality of the estimated NF-EEG-fMRI scores.

This work was done in collaboration with Remi Gribonval from the Inria/IRISA PANAMA team.

7.2. Research axis 2: Applications in Neuroradiology and Neurological Disorders

7.2.1. Bimodal EEG-fMRI Neurofeedback for Stroke Rehabilitation: a Case Report

Participants: Giulia Lioi, Mathis Fleury, Simon Butet, Christian Barillot, Isabelle Bonan.

Neurofeedback (NF) consists on training self-regulation of brain activity by providing real-time information about the participant brain function. Few works have shown the potential of NF for stroke rehabilitation however its effectiveness has not been investigated yet. NF approaches are usually based on real-time monitoring of brain activity using a single imaging technique. Recent studies have revealed the potential of combining EEG and fMRI to achieve a more efficient and specific self-regulation. In a case report, we tested the feasibility of applying bimodal EEG-MRI NF on two stroke patients. [54]

This work was done in collaboration with Anatole Lecuyer from the Inria/IRISA HYBRID team.

7.2.2. Refining understanding of working memory buffers through the construct of binding: Evidence from a single case informs theory and clinical practise

Participants: Pierre-Yves Jonin, Quentin Duché.

Binding operations carried out in working memory enable the integration of information from different sources during online performance. While available evidence suggests that working memory may involve distinct binding functions, whether or not they all involve the episodic buffer as a cognitive substrate remains unclear. Similarly, knowledge about the neural underpinnings of working memory buffers is limited, more specifically regarding the involvement of medial temporal lobe structures. In the present study, we report on the case of patient KA, with developmental amnesia and selective damage to the whole hippocampal system. We found that KA was unable to hold shape-colours associations (relational binding) in working memory. In contrast, he could hold integrated coloured shapes (conjunctive binding) in two different tasks. Otherwise, and as expected, KA was impaired on three relational memory tasks thought to depend on the hippocampus that are widely used in the early detection of Alzheimer's disease. Our results emphasized a dissociation between two binding processes within working memory, suggesting that the visuo-spatial sketchpad could support conjunctive binding, and may rely upon a large cortical network including sub-hippocampal structures. By contrast, we found evidence for a selective impairment of relational binding in working memory when the hippocampal system is compromised, suggesting that the long-term memory deficit observed in amnesic patients may be related to impaired short-term relational binding at encoding. Finally, these findings may inform research on the early detection of Alzheimer's disease as the preservation of conjunctive binding in KA is in sharp contrast with the impaired performance demonstrated very early in this disease [15].

This work was done in collaboration with Mario Alfredo Parra and Clara Calia, from Herriot Wyatt University, Edinburgh, UK; with Emmanuel Barbeau and Sophie Muratot from the CNRS 5549 CerCo unit in Toulouse, France; and with Serge Belliard, from CHU de Rennes, Service de Neurologie, Rennes, France.

7.2.3. Superior explicit memory despite severe developmental amnesia: In-depth case study and neural correlates

Participants: Pierre-Yves Jonin, Christian Barillot.

The acquisition of new semantic memories is sometimes preserved in patients with hippocampal amnesia. Robust evidence for this comes from case reports of developmental amnesia suggesting that low-to-normal levels of semantic knowledge can be achieved despite compromised epi-sodic learning. However, it is unclear whether this relative preservation of semantic memory results from normal acquisition and retrieval or from residual episodic memory, combined with effortful repetition. Furthermore, lesion studies have mainly focused on the hippocampus itself, and have seldom reported the state of structures in the extended hippocampal system. Preserved components of this system may therefore mediate residual episodic abilities, contributing to the apparent semantic preservation. We recently reported an in-depth study of Patient KA, a 27-year-old man who had severe hypoxia at birth, in which we carefully explored his residual episodic learning abilities. We used novel speeded recognition paradigms to assess whether KA could explicitly acquire and retrieve new context-free memories. Despite a pattern of very severe amnesia, with a 44-point discrepancy between his intelligence and memory quotients, KA exhibited normal-to-superior levels of knowledge, even under strict time constraints. He also exhibited normal-to-superior recognition memory for new material, again under strict time constraints. Multimodal neuroimaging revealed an unusual pattern of selective atrophy within each component of the extended hippocampal system, contrasting with the preservation of anterior subhippocampal cortices. A cortical thickness analysis yielded a pattern of thinner but also thicker regional cortices, pointing toward specific temporal lobe reorganization following early injury. We thus report the first case of superior explicit learning and memory in a severe case of amnesia, raising important questions about how such knowledge can be acquired [14].

This work was done in collaboration with Emmanuel Barbeau and Gabriel Besson from the CNRS 5549 CerCo unit in Toulouse, France; with Renaud La Joie; with Jérémie Pariente from the Inserm UMR 1214 Tonic unit in Toulouse, France; and with Serge Belliard, from CHU de Rennes, Service de Neurologie, Rennes, France.

7.2.4. Retrieval practice based on recognition memory: testing the retrieval effort hypothesis

Participants: Pierre-Yves Jonin, Christian Barillot.

We tested a core prediction of the retrieval effort hypothesis as an account for the testing effect (TE). Retrieval effort predicts that automatic, effortful retrieval should not lead to TE. Experiment 1 (N=76) showed that despite an encoding duration of three times less, object pictures retention is better after repeated testing under Old/New recognition conditions, than following repeated study. Experiment 2 (N=30) used a speeded and accuracy boosting procedure to rule out the contribution of recollection to retrieval. Retention of object pictures at 25 minutes and 6 months was similar after repeated testing or after repeated studying. These results call for a revision of the retrieval effort hypothesis as a mechanistic account of TE [53].

This work was done in collaboration with Audrey Noël, from Université de Rennes 2, Rennes, France; with Gabriel Besson from the CNRS 5549 CerCo unit in Toulouse, France; with Emmanuel Barbeau and Sophie Muratot from the CNRS 5549 CerCo unit in Toulouse, France; and with Serge Belliard, from CHU de Rennes, Service de Neurologie, Rennes, France.

7.2.5. Voxel-wise Comparison with a-contrario Analysis for Automated Segmentation of Multiple Sclerosis Lesions from Multimodal MRI

Participants: Francesca Galassi, Olivier Commowick, Christian Barillot.

We have introduced a new framework for the automated and un-supervised segmentation of Multiple Sclerosis lesions from multimodal Magnetic Resonance images. It relies on a voxel-wise approach to detect local white matter abnormalities, with an a-contrario analysis, which takes into account local information. First, a voxel-wise comparison of multimodal patient images to a set of controls is performed. Then, region-based probabilities are estimated using an a-contrario approach. Finally, correction for multiple testing is performed. Validation was undertaken on a multi-site clinical dataset of 53 MS patients with various number and volume of lesions. We showed that the proposed framework outperforms the widely used FDR-correction for this type of analysis, particularly for low lesion loads [37].

This work was done in collaboration with Emmanuel Vallée from Orange Labs, Lannion, France.

7.2.6. Integration of Probabilistic Atlas and Graph Cuts for Automated Segmentation of Multiple Sclerosis lesions

Participants: Francesca Galassi, Olivier Commowick, Christian Barillot.

We have proposed a framework for automated segmentation of Multiple Sclerosis (MS) lesions from MR brain images. It integrates a priori tissues and MS lesions information into a Graph-Cuts algorithm for improved segmentation results. [36].

7.2.7. Multiple sclerosis

7.2.7.1. Spinal Cord

Participants: Anne Kerbrat, Gilles Edan, Jean-Christophe Ferré, Benoit Combès, Olivier Commowick, Élise Bannier, Sudhanya Chatterjee, Haykel Snoussi, Emmanuel Caruyer, Christian Barillot.

The VisAGeS research team has a strong focus on applying the developed methodologies (illustrated in research axis 1) to multiple sclerosis (MS) understanding and the prediction of its evolution. Related to the EMISEP project on spinal cord injury evolution in MS, a first work investigated the magnetization transfer reproducibility across centers in the spinal cord and was accepted for publication [6]. Based on this work, a second work investigated the sensitivity of magnetization transfer to assess diffuse and focal burden in MS patients and was published in Multiple Sclerosis [5].

7.2.7.2. Reproducibility and Evolution of Diffusion MRI measurements within the Cervical Spinal Cord in Multiple Scleros

Participants: Haykel Snoussi, Anne Kerbrat, Benoit Combès, Olivier Commowick, Élise Bannier, Emmanuel Caruyer, Christian Barillot.

In Multiple Sclerosis (MS), there is a large discrepancy between the clinical observations and how the pathology is exhibited on brain images, this is known as the clinical-radiological paradox (CRP). One of the hypotheses is that the clinical deficit may be more related to the spinal cord damage than the number or location of lesions in the brain. Therefore, investigating how the spinal cord is damaged becomes an acute challenge to better understand and overcome the CRP. Diffusion MRI is known to provide quantitative

figures of neuronal degeneration and axonal loss, in the brain as well as in the spinal cord. In this work, we have proposed to investigate how diffusion MRI metrics vary in the different cervical regions with the progression of the disease. We first study the reproducibility of diffusion MRI on healthy volunteers with a test-retest procedure using both standard diffusion tensor imaging (DTI) and multi-compartment Ball-and-Stick models. Then, based on the test re-test quantitative calibration, we provided quantitative figures of pathology evolution between M0 and M12 in the cervical spine on a set of 31 MS patients, exhibiting how the pathology damage spans in the cervical spinal cord.

7.2.8. Epilepsy

Participants: Élise Bannier, Jean-Christophe Ferré.

Accurate localization of the thalamic subregions is of paramount importance for Deep Brain Stimulation (DBS) planning. Current MRI protocols use T2 and Gadolinium-enhanced T1 images, to visualize both the basal ganglia and the vessels, in order to define the electrode trajectory and target. A study showing the usefulness of Fluid and White Matter Suppression, i.e. FLAWS imaging, in eleven drug-resistant epileptic patients for preoperative Deep Brain Stimulation planning and anterior thalamic nucleus targeting was presented as a Power Pitch at the ISMRM Meeeting in Paris [27].

This work was done in collaboration with Giulio Gambarota, Anca Nica and Claire Haegelen from the LTSI and Tobias Kober from Lausanne.

7.2.9. Arterial Spin Labeling in pediatric populations

Participants: Élise Bannier, Christian Barillot, Olivier Commowick, Isabelle Corouge, Jean-Christophe Ferré, Antoine Legouhy, Maia Proisy.

Arterial Spin Labeling is an attractive perfusion MRI technique due to its complete non-invasiveness. However it still remains confidential in clinical practice. Over the years, we have developed several applications to evaluate its potential in different contexts. As part of the PhD of Maia Proisy, we have been working on processing and analysing MR perfusion images using arterial spin labeling in neonates and children for several purposes:

- Investigation of brain perfusion evolution between 6 month and 15 years using ASL sequence in order to provide reference values in this age range [4],
- Evaluation of the evolution of the cerebral blood flow changes betwren day-of-life 3 and day-of-life 10 in a population of neonates with hypoxic-ischemic encephalopathy [45], [*"Changes in brain perfusion in successive arterial spin labelling MRI scans in neonates with hypoxic-ischaemic encephalopathy"*, article in revision in Neuroimage: Clinical].

7.2.10. Diffusion MRI in depression

7.2.10.1. Diffusion MRI as an imaging marker of depression from a large and homogenous population study

Participants: Julie Coloigner, Jean-Marie Batail, Isabelle Corouge, Jean-Christophe Ferre, Christian Barillot.

Despite the extensive therapy options available for depression, up to 80% of patients will suffer from a relapse. Consequently, understanding the neural correlates underlying the depression will optimize the diagnosis and treatment of individual depressed patients. In an experimental study, we investigated alterations of white matter integrity in a large cohort of patients suffering from depression using diffusion tensor imaging. Our findings provide robust evidence that the reduction of white-matter integrity in the interhemispheric connections and fronto-limbic neuronal circuits may play an important role in depression pathogenesis. [34].

This work was done in collaboration with Dominique Drapier from Academic Psychiatry Department, Centre Hospitalier Guillaume Régnier, Rennes, France, EA 4712 Behavior and Basal Ganglia, CHU Rennes, Rennes 1 University, Rennes, France.

7.2.10.2. Diffusion MRI as a descriptive imaging marker of the pathogenesis of treatment-resistant depression
Participants: Julie Coloigner, Jean-Marie Batail, Isabelle Corouge, Jean-Christophe Ferre, Christian Barillot.

Despite the extensive therapy options available for depression, treatment-resistant depression (TRD) occurs in 20-30% of depressed patients. Consequently, identification of neural changes in TRD could support to better understand the mechanism of resistance and to improve the treatment of individual depressed patients. We aimed to investigate the white-matter microstructure in a sample of depressed patients in which response to treatment was subsequently evaluated 6 months after. Our findings suggest the abnormalities of the white-matter integrity in multiple white matter tracts, such as anterior limb of internal capsule and genu of corpus may play a role in the pathogenesis of treatment-resistant depression [33].

Depressive disorder is characterized by a profound dysregulation of affect and mood as well as additional abnormalities including cognitive dysfunction, insomnia, fatigue and appetite disturbance. This disease is the most prevalent mental illness, with an estimated lifetime prevalence reported to range from 10% to 15% worldwide. Despite the extensive therapy options available for depression, up to 80% of patients will suffer from a relapse. Consequently, understanding the neural correlates underlying the depression is critical for improving the specificity and efficacy of diagnostic and treatment strategies.Previous studies of structural and functional magnetic resonance imaging have reported several microstructural abnormalities in the prefrontal cortex, anterior cingulate cortex, hippocampus and thalamus. These observations suggest a dysfunction of the circuits connecting frontal and subcortical brain regions, leading to a "disconnection syndrome". Using graph theory-based analysis, we examined white matter changes in the organization of networks in patients suffering from depression. Our diffusion imaging data showed white matter alteration in patients suffering from depression is occurring in the anterior thalamic radiation and in the cingulate bundle. Our findings suggest decreased fiber density in circuits connecting subcortical brain regions with the frontal and parietal cortex, supporting the theory of limbic-frontal circuit dysfunction [50]. *We were awarded for this workby the French Institute of Psychiatry for our communication at its annual Forum.*

This work was done in collaboration with Dominique Drapier from Academic Psychiatry Department, Centre Hospitalier Guillaume Régnier, Rennes, France, EA 4712 Behavior and Basal Ganglia, CHU Rennes, Rennes 1 University, Rennes, France.

7.3. Research axis 3: Management of Information in Neuroimaging

7.3.1. Large-scale data analyses

7.3.1.1. Objective Evaluation of Multiple Sclerosis Lesion Segmentation using a Data Management and Processing Infrastructure
Participants: O. Commowick, M. Kain, F. Leray, M. Simon, J.-C. Ferré, A. Kerbrat, G. Edan, C. Barillot.

In collaboration with OFSEP and France Life Imaging, we have proposed a study of multiple sclerosis segmentation algorithms conducted at the international MICCAI 2016 challenge. This challenge was operated using France Life Imaging (FLI-IAM), a new open-science computing infrastructure. This allowed for the automatic and independent evaluation of a large range of algorithms in a fair and completely automatic manner. This computing infrastructure was used to evaluate thirteen methods of MS lesions segmentation, exploring a broad range of state-of-the-art algorithms, against a high-quality database of 53 MS cases coming from four centers following a common definition of the acquisition protocol. Each case was annotated manually by an unprecedented number of seven different experts. Results of the challenge highlighted that automatic algorithms, including the recent machine learning methods (random forests, deep learning,...), are still trailing human expertise on both detection and delineation criteria. In addition, we demonstrated that computing a statistically robust consensus of the algorithms performs closer to human expertise on one score (segmentation) although still trailing on detection scores [7]

This work was done in collaboration with A. Istace, B. Laurent, S. C. Pop, P. Girard, R. Ameli, T. Tourdias, F. Cervenansky, T. Glatard, J. Beaumont, S. Doyle, F. Forbes, J. Knight, A. Khademi, A. Mahbod, C. Wang, R. Mckinley, F. Wagner, J. Muschelli, E. Sweeney, E. Roura, X. Lladó, M. M. Santos, W. P. Santos, A. G. Silva-Filho, X. Tomas-Fernandez, H. Urien, I. Bloch, S. Valverde, M. Cabezas, F. J. Vera-Olmos, N. Malpica, C. R. G. Guttmann, S. Vukusic, M. Dojat, M. Styner, S. K. Warfield and F. Cotton.

7.3.1.2. Same Data - Different Software - Different Results? Analytic Variability of Group fMRI Results
Participant: Camille Maumet.

A wealth of analysis tools are available to fMRI researchers in order to extract patterns of task variation and, ultimately, understand cognitive function. However, this 'methodological plurality' comes with a drawback. While conceptually similar, two different analysis pipelines applied on the same dataset may not produce the same scientific results. Differences in methods, implementations across software packages, and even operating systems or software versions all contribute to this variability. Consequently, attention in the field has recently been directed to reproducibility and data sharing. Neuroimaging is currently experiencing a surge in initiatives to improve research practices and ensure that all conclusions inferred from an fMRI study are replicable. In this work, our goal was to understand how choice of software package impacts on analysis results. We used publically shared data from three published task fMRI neuroimaging studies, reanalyzing each study using the three main neuroimaging software packages, AFNI, FSL and SPM, using parametric and nonparametric inference. We obtained all information on how to process, analyze, and model each dataset from the publications. We made quantitative and qualitative comparisons between our replications to gauge the scale of variability in our results and assess the fundamental differences between each software package. While qualitatively we found broad similarities between packages, we also discovered marked differences, such as Dice similarity coefficients ranging from 0.000-0.743 in comparisons of thresholded statistic maps between software [28], [48].

This work was done in collaboration with Alexander Bowring and Prof. Thomas Nichols from the Oxford Big Data Institute in the UK.

7.3.1.3. Detecting and Interpreting Heterogeneity and Publication Bias in Image-Based Meta-Analyses
Participant: Camille Maumet.

With the increase of data sharing, meta-analyses are becoming increasingly important in the neuroimaging community. They provide a quantitative summary of published results and heightened confidence due to higher statistical power. The gold standard approach to combine results from neuroimaging studies is an Image-Based Meta-Analysis (IBMA) [1] in which group-level maps from different studies are combined. Recently, we have introduced the IBMA toolbox, an extension for SPM that provides methods for combining image maps from multiple studies [2]. However, the current toolbox lacks diagnostic tools used to assess critical assumptions of meta-analysis, in particular whether there is inter-study variation requiring random-effects IBMA, and whether publication bias is present. We have proposed two new tools added to the IBMA toolbox to detect heterogeneity and to assess evidence of publication bias [40].

This work was done in collaboration with Thomas Maullin-Saper and Prof. Thomas Nichols from the Oxford Big Data Institute in the UK.

7.3.2. Infrastructures

7.3.2.1. Open Science for the Neuroinformatics community
Participants: Camille Maumet, Xavier Rolland, Michael Kain, Christian Barillot.

The Neuroinformatics community in OpenAire-Connect is represented by members of the France Life Imaging (FLI) collaboration. In this context, we aim at leveraging OpenAire-Connect services and give our community members the possibility to easily publish and exchange research artefacts from FLI platforms, such as VIP and Shanoir. This will enable open and reproducible science, since literature, data, and methods can be linked, retrieved, and replayed by all the members of the community [30].

This work was done in collaboration with Sorina Pop, Axel Bonnet and Tristan Glatard.

7.3.3. Standardisation and interoperability

7.3.3.1. Interoperability with Boutiques and CARMIN

Participants: Camille Maumet, Michael Kain, Christian Barillot.

A growing number of platforms and tools have lately been developed to meet the needs of various scientific communities. Most of these solutions are optimized to specific requirements from different user groups, leading to technological fragmentation and lack of interoperability. In our quest of open and reproducible science, we proposed two complementary tools, Boutiques and CARMIN, providing cross-platform interoperability for scientific applications, data sharing and processing [29].

This work was done in collaboration with Sorina Pop, Axel Bonnet and Tristan Glatard.

7.3.3.2. A standardised representation for non-parametric fMRI results

Participant: Camille Maumet.

Reuse of data collected and analysed at another site is becoming more prevalent in the neuroimaging community but this process usually relies on intensive data and metadata curation. Given the ever-increasing number of research datasets produced and shared, it is desirable to rely on standards that will enable automatic data and metadata retrieval for large-scale analyses. We recently introduced NIDM-Results, a data model to represent and publish data and metadata created as part of a mass univariate neuroimaging study (typically functional magnetic resonance imaging). In this work, we have proposed to extend this model to allow for the representation of non-parametric analyses and we introduce a JSON API that will facilitate export into NIDM-Results [25].

This work was done as part of an international collaboration with Guillaume Flandin, Martin Perez-Guevara, Jean-Baptiste Poline, Justin Rajendra, Richard Reynolds, Betrand Thirion, Thomas Maullin-Sapey and Thomas Nichols.

7.3.3.3. Development of an Ontology for the INCF Neuroimaging Data Model (NIDM)

Participant: C. Maumet.

The successful reuse of shared data relies on the existence of easily-available well-described metadata. The metadata, as a rich description of the data, must capture information on how the data was acquired, processed and analyzed. The terms used to describe the data should be chosen with a logical, consistent framework in mind and include definitions to avoid ambiguity. In addition, a lexicon or ontology should reuse terms from existing efforts as much as possible [38].

This work was done as part of an international collaboration with K.G. Helmer, K.B. Keator, T. Auer, S. Ghosh, T.E. Nichols, P. Smruti and J.B. Poline.

8. Bilateral Contracts and Grants with Industry

8.1. Bilateral Contracts with Industry

8.1.1. Siemens

In the context of the Neurinfo imaging platform, a master research agreement between Siemens SAS - Healthcare and University of Rennes 1 defines the terms of the collaboration between Siemens, Visages and the Neurinfo platform. Relying on this research agreement contract, Neurinfo has received work in progress (WIP) sequences from Siemens in the form of object code for evaluation in the context of clinical research. The Neurinfo platform has also received source code of selected MRI sequences. As an example, the diffusion sequence code was modified to load arbitrary diffusion gradient waveforms for the FastMicroDiff project led by E. Caruyer. This is crucial in the collaboration since it enables the development of MRI sequences on site. Siemens currently provides research resources through the funding of a PhD student (Cédric Meurée: CIFRE Inria / Siemens grant). The MR Diffusion pulse sequence source code was modified in collaboration with our Siemens clinical scientist as part of our Master Research Agreement, Marc Lapert, in order to play arbitrary gradient waveforms. This was done on the Syngo VB17 software version and again on VE11C (nearly finished).

The PhD of Cédric Meurée is funded by Siemens Healthineers under a CIFRE grant.

9. Partnerships and Cooperations

9.1. Regional Initiatives

9.1.1. INCR: MUltiple Sclerosis Imaging Check-out (MUSIC)

Participants: Gilles Edan, Francesca Galassi, Olivier Commowick, Christian Barillot, Anne Kerbrat, Jean-Christophe Ferre.

The objective of this project is to investigate algorithms aimed at detecting, segmenting and following overtime the MS lesions, robustly enough to work on a multi-site clinical database. Methods are being evaluated on an amount of training and testing MS images with high quality segmentations from radiographers. The goal is to integrate the developed framework into a production workflow that will be employed by the clinical health network MUltiple Sclerosis Imaging Check-out (MUSIC), covering the western part of France.

9.1.2. ARED VARANASI

Participants: Christian Barillot, Camille Maumet, Xavier Rolland.

Thanks to the development of open science practices, more and more public datasets are available to the research community. In the field of brain imaging, these data, combined, bring a critical increase in sample size, necessary to build robust models of the typical and atypical brain. But, in order to build valid inferences on these data, we need to take into account their heterogeneity. Variability can arise due to multiple factors such as: differences in imaging instruments, in acquisitions protocols and even, in post-processing pipelines. In particular, the expansion of open source machine learning workflows creates a multitude of possible outputs out of the same dataset. The variations induced by this methodological plurality can be referred to as 'analytic variability' which will be the focus of the thesis funded in half by this ARED. The thesis will address two challenges: 1) How to combine neuroimaging data generated by different analysis pipelines? 2) How to publish neuroimages with an adequate level of metadata to enable their reuse? Methodological developments will combine machine learning techniques with methods from knowledge representation.

9.2. National Initiatives

9.2.1. Projet Fondation de France: PERINE

Participants: Élise Bannier, Isabelle Corouge, Julie Coloigner, Maia Proisy, Jean-Christophe Ferré, Christian Barillot.

This study evaluates the effect of prenatal exposure to neurotoxicants on the developing brain. Following previous studies in the PELAGIE cohort this MRI study involves ASL, Diffusion and working memory as well as motor inhibition BOLD fMRI together with neuropsychological tests in children. Inclusions have started in November 2014 and lasted for 2 years. The MRI acquisitions of the PERINE projects have all been performed with a total of 101 children participating to the project. A collaboration with an external PhD student started in January 2017 to process the functional MRI data of this project and Julie Coloigner was hired as a post-doc to work on the Diffusion and ASL data.

9.2.2. Projet Fondation de France: EPMR-MA

Participants: Pierre-Yves Jonin, Élise Bannier, Christian Barillot, Quentin Duché.

This project evaluates memory effects in healthy adults and in patients presenting cognitive impairments using BOLD fMRI and diffusion MRI. The inclusions of patients started in 2016 and all inclusions will be over by the end of 2017. Quentin Duché was hired to process the functional MRI and diffusion data end of 2016 and his contract was extended until May 2018.

9.2.3. Projet Fondation de France: Connectivity of the amygdala in depression

Participants: Christian Barillot, Jean-Marie Batail, Emmanuel Caruyer, Julie Coloigner, Gabriel Robert.

The onset of depression in teenagers and young adults increases the risk to develop a drug-resistant depression in the adulthood. This project aims at evaluating the role of early changes in the microstructure and connectivity of the amygdala. Using a cohort of drug-resistant patients (N=30), non drug-resistant patients (N=30) and controls (N=30), we will identify imaging biomarkers of the pathology. We will compute the same biomarkers in a group of young adults (N=180) and compare these with emotional and cognitive phenotypes in this population, searching for early differences in the development of the amygdala connectivity.

9.2.4. ANR "MAIA", 2015 generic projects program

Participants: Maia Proisy, Pierre Maurel, Antoine Legouhy, Olivier Commowick, Isabelle Corouge, Jean-Christophe Ferré, Christian Barillot.

Each year in France, 55 000 children are born prematurely, i.e., before the 37th week of gestation. Long-term studies of the outcome of prematurely born infants have clearly documented that the majority of such infants may have significant motor, cognitive, and behavioral deficits.

However, there is a limited understanding of the nature of the cerebral abnormality underlying these adverse neurologic outcomes. In this context, the emergence of new modalities of 3D functional MRI, e.g., Arterial Spin Labeling (ASL), or optical imaging technologies, e.g., Near InfraRed Spectroscopy (NIRS), brings new perspectives for extracting cognitive information, via metabolic activity measures. Other classical techniques devoted to cerebral signal measurement, such as ElectroEncephaloGraphy (EEG), provide cognitive information at the cortical level. Each of these various non-invasive imaging technologies brings substantial and specific information for the understanding of newborn brain development.

This project aims at developing innovative approaches for multi-image / multi-signal analysis, in order to improve neurodevelopment understanding methods. From a fundamental point of view, mathematics and computer science have to be considered in association with imaging physics and medicine, to deal with open issues of signal and image analysis from heterogeneous data (image, signal), considered in the multiphysics contexts related to data acquisition (magnetic, optic, electric signals) and biophysics modeling of the newborn brain. A sustained synergy between all these scientific domains is then necessary.

Finally, the sine qua non condition to reach a better understanding of the coupled morphological- cognitive development of premature newborns, is the development of effective software tools, and their distribution to the whole medical community. The very target of this project will be the design of such software tools for medical image / signal analysis, actually operational in clinical routine, and freely available. Academic researchers and industrial partners are working in close collaboration to reach that ambitious goal.

9.2.5. Fondation pour la recherche médicale (FRM) - Project "Hybrid EEG/IRM Neurofeedback for rehabilitation of brain pathologies

Participants: Élise Bannier, Jean-Marie Batail, Isabelle Bonan, Isabelle Corouge, Jean-Christophe Ferré, Jean-Yves Gauvrit, Pierre Maurel, Mathis Fleury, Giulia Lioi, Christian Barillot.

The goal of this project is to make full use of neurofeedback (NF) paradigm in the context of brain rehabilitation. The major breakthrough will come from the coupling associating functional and metabolic information from Magnetic Resonance Imaging (fMRI) to Electro-encephalography (EEG) to “optimize” the neurofeedback protocol. We propose to combine advanced instrumental devices (Hybrid EEG and MRI platforms), with new hybrid Brain computer interface (BCI) paradigms and new computational models to provide novel therapeutic and neuro-rehabilitation paradigms in some of the major mental and neurological disorders of the developmental and the aging brain (stroke, language disorders, Mood Depressive Disorder (MDD), ...). Though the concept of using neurofeedback paradigms for brain therapy has somehow been experimented recently (mostly through case studies), performing neurofeedback through simultaneous fMRI and EEG has almost never been done before so far (two teams in the world including us within the HEMISFER CominLabs project). This project will be conducted through a very complementary set of competences over

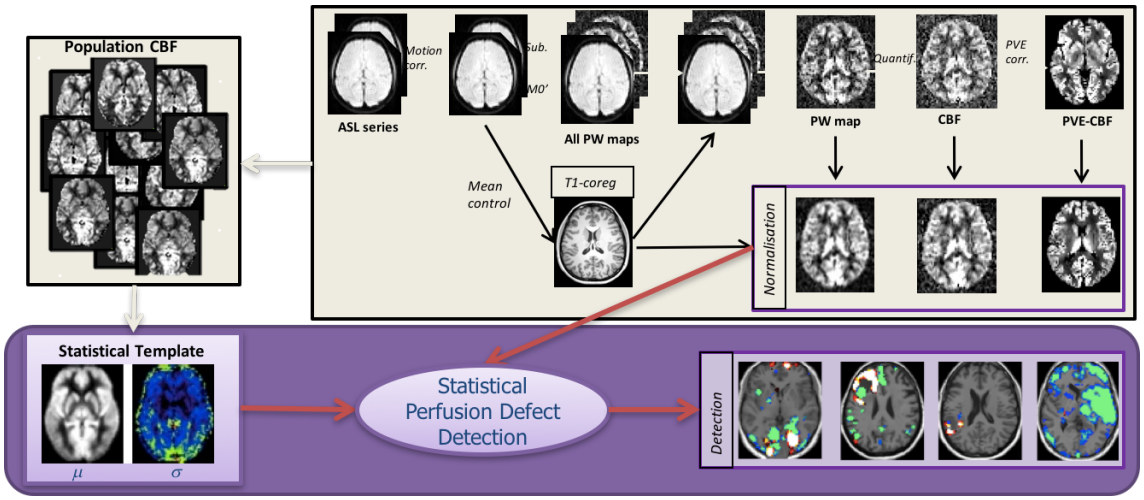

Figure 2. Processing workflow for quantification of Arterial Spin Labelling Cerebral Blood Flow with detection of abnormal perfusion

the different involved teams: VISAGES U1228, HYBRID and PANAMA Teams from Inria/Irisa Rennes and EA 4712 team from U. of Rennes I.

9.2.6. PHRC EMISEP: Evaluation of early spinal cord injury and late physical disability in Relapsing Remitting Multiple Sclerosis

Participants: Élise Bannier, Christian Barillot, Emmanuel Caruyer, Benoit Combès, Olivier Commowick, Gilles Edan, Jean-Christophe Ferré, Anne Kerbrat, Haykel Snoussi.

Multiple Sclerosis (MS) is the most frequent acquired neurological disease affecting young adults (1/1000 inhabitants in France) and leading to impairment. Early and well adapted treatment is essential in patients presenting aggressive forms of MS. This PHRC project focusses on physical impairment and especially on the ability to walk. Several studies, whether epidemiologic or based on brain MRI, have shown that several factors were likely to announce aggressive development of the disease, such as age, number of focal lesions on baseline MRI, clinical activity. However, these factors only partially explain physical impairment progression, preventing their use at the individual level. Spinal cord is often affected in MS, as demonstrated in postmortem or imaging studies. Yet, early radiological depiction of spinal cord lesions is not always correlated with clinical symptoms. Preliminary data, on reduced number of patients, and only investigating the cervical spinal cord have shown that diffuse spinal cord injury, observed via diffusion or magnetisation transfer imaging, would be correlated with physical impairment as evaluated by the EDSS score. Besides, the role of early spinal cord affection (first two years) in the evolution of physical impairment remains unknown.

In this project, we propose to address these different issues and perform a longitudinal study on Relapsing Remitting Multiple Sclerosis (RRMS) patients, recruited in the first year of the disease. Our goal is to show that diffuse and focal lesions detected spinal cord MRI in the first 2 years can be used to predict disease evolution and physical impairment at 5 years. Twelve centers are involved in the study to include 80 patients.

To date, all subjects have been included. H. Snoussi is working in the scope of his PhD thesis on diffusion imaging in the spinal cord starting with distortion correction.

B. Combès started as a post-doc in November 2016 to process the EMISEP imaging data, starting with morphological data processing (registration, segmentation) and magnetization transfer data processing.

9.2.7. Competitivity Clusters

9.2.7.1. The HEMISFER Project

Participants: Élise Bannier, Jean-Marie Batail, Isabelle Bonan, Isabelle Corouge, Claire Cury, Jean-Christophe Ferré, Jean-Yves Gauvrit, Pierre Maurel, Christian Barillot.

The HEMISFER project ("Hybrid Eeg-MrI and Simultaneous neuro-FEedback for brain Rehabilitation") will be conducted at Inria Rennes with the support of the Cluster of Excellence "CominLabs" [1]. The goal of HEMISFER is to make full use of the neurofeedback paradigm in the context of rehabilitation and psychiatric disorders. The major breakthrough will come from the use of a coupling model associating functional and metabolic information from Magnetic Resonance Imaging (fMRI) to Electro-encephalography (EEG) to "enhance" the neurofeedback protocol. We propose to combine advanced instrumental devices (Hybrid EEG and MRI platforms), with new man-machine interface paradigms (Brain computer interface and serious gaming) and new computational models (source separation, sparse representations and machine learning) to provide novel therapeutic and neuro-rehabilitation paradigms in some of the major neurological and psychiatric disorders of the developmental and the aging brain (stroke, attention-deficit disorder, language disorders, treatment-resistant mood disorders, etc.). This project will be conducted with the HYBRID and PANAMA Teams from Inria Rennes, the EA 4712 team from University of Rennes I and the ATHENA team from Inria Sophia-Antipolis. This work will benefit from the research 3T MRI and MRI-compatible EEG systems provided by the NeurInfo in-vivo neuroimaging platform on which these new research protocols will be set up. A budget of 500K€ provided by the CominLabs cluster to support this project (through experimental designs, PhDs, post-docs and expert engineers).

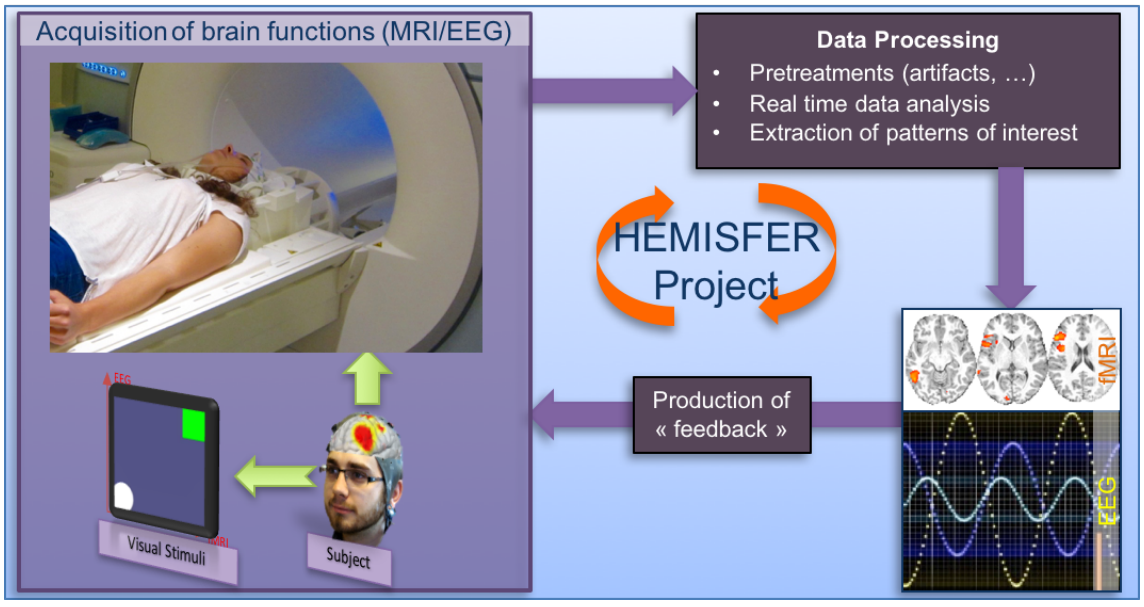

Figure 3. Principle of the Hemisfer project.

9.2.7.2. France Life Imaging (FLI)

Participants: Christian Barillot, Olivier Commowick, Michael Kain, Florent Leray, Julien Louis, Aneta Morawin, Mathieu Simon, Yao Chi.

[1] https://iww.inria.fr/cominlabs-newsletter/april-2013-four-projects-selected/#hemisfer

France Life Imaging (FLI) is a proposed large-scale research infrastructure project aimed at establishing a coordinated and harmonized network of biomedical imaging in France. This project was recently selected by the call "Investissements d'Avenir - Infrastructure en Biologie et Santé". One node of this project is the node Information Analysis and Management (IAM), a transversal node build by a consortium of teams that will contribute to the construction of a network for data storage and information processing. Instead of building yet other dedicated facilities, the IAM node will use already existing data storage and information processing facilities (LaTIM Brest; CREATIS Lyon; CIC-IT Nancy; VisAGeS U1228 Inria Rennes; CATI CEA Saclay; LSIIT/ICube Strasbourg) that will increase their capacities for the FLI infrastructure. Inter-connections and access to services will be achieved through a dedicated software platform that will be developed based on the expertise gained through successful existing developments. The IAM node has several goals. It aims first at building a versatile facility for data management that will inter-connect the data production sites and data processing for which state-of-the-art solutions, hardware and software, will be available to infrastructure users. Modular solutions are preferred to accommodate the large variety of modalities acquisitions, scientific problems, data size, and adapted for future challenges. Second, it aims at offering the latest development that will be made available to image processing research teams. The team VisAGeS fulfills multiple roles in this nation-wide project. Christian Barillot is the chair of the node IAM, Olivier Commowick is participating in the working group workflow and image processing and Michael Kain the technical manager. Apart from the team members, software solutions like MedInria and Shanoir will be part of the final software platform.

9.2.7.3. OFSEP

Participants: Élise Bannier, Christian Barillot, Olivier Commowick, Gilles Edan, Jean-Christophe Ferré, Michael Kain, Inès Fakhfakh.

The French Observatory of Multiple Sclerosis (OFSEP) is one of 10 projects selected in January 2011 in response to the call for proposal in the "Investissements d'Avenir - Cohorts 2010" program launched by the French Government. It allows support from the National Agency for Research (ANR) of approximately € 10 million for 10 years. It is coordinated by the Department of Neurology at the Neurological Hospital Pierre Wertheimer in Lyon (Professor Christian Confavreux), and it is supported by the EDMUS Foundation against multiple sclerosis, the University Claude Bernard Lyon 1 and the Hospices Civils de Lyon. OFSEP is based on a network of neurologists and radiologists distributed throughout the French territory and linked to 61 centers. OFSEP national cohort includes more than 50,000 people with Multiple Sclerosis, approximately half of the patients residing in France. The generalization of longitudinal monitoring and systematic association of clinical data and neuroimaging data is one of the objectives of OFSEP in order to improve the quality, efficiency and safety of care and promote clinical, basic and translational research in MS. For the concern of data management, the Shanoir platform of Inria has been retained to manage the imaging data of the National OFSEP cohort in multiple sclerosis.

9.3. European Initiatives

9.3.1. FP7 & H2020 Projects

9.3.1.1. OpenAire-Connect

Participants: Christian Barillot, Michael Kain, Camille Maumet, Xavier Rolland.

Project title: **OpenAire-Connect**

Partners: PI: CNR, Italy; Athena Research And Innovation Center In Information Communication & Knowledge Technologies, Greece; Uniwersytet Warszawski, Poland; JISC LBG, UK; Universitaet Bremen, Germany; Universidade Do Minho, Portugal; CNRS (Visages, Creatis), France; Universita Di Firenze, Italy; Institut De Recherche Pour Le Developpement (IRD), France; European Organization For Nuclear Research (CERN), Switzerland; International Center For Research On The Environment And The Economy, Greece

Budget: 2M € (120k€ for CNRS)

Abstract: The OpenAire-Connect H2020 project will introduce and implement the concept of Open Science as a Service (OSaaS) on top of the existing OpenAIRE infrastructure, delivering out-of-the-box, on-demand deployable tools. OpenAIRE-Connect will adopt an end-user driven approach (via the involvement of 5 prominent research communities), and enrich the portfolio of OpenAIRE infrastructure production services with a Research Community Dashboard Service and a Catch-All Notification Broker Service. The first will offer publishing, interlinking, packaging functionalities to enable them to share and re-use their research artifacts (introducing methods, e.g., data, software, protocols). This effort, supported by the harvesting and mining "intelligence" of the OpenAIRE infrastructure, will provide communities with the content and tools they need to effectively evaluate and reproduce science. OpenAIRE-Connect will combine dissemination and training with OpenAIRE's powerful NOAD network engaging research communities and content providers in adopting such services. These combined actions will bring immediate and long-term benefits to scholarly communication stakeholders by affecting the way research results are disseminated, exchanged, evaluated, and re-used. In this project VisAGeS is acting, through CNRS, as the French coordinator to develop the link with the Neuroimaging research community. This will be performed in the context of the FLI-IAM national infrastructure.

9.3.1.2. EIT-Health

Participants: Christian Barillot, Michael Kain.

Abstract: EIT Health aims to promote entrepreneurship and develop innovations in healthy living and active ageing, providing Europe with new opportunities and resources. EIT Health will enable citizens to lead healthier and more productive lives by delivering products, services and concepts that will improve quality of life and contribute to the sustainability of healthcare across Europe. EIT Health is a strong, diverse and balanced partnership of best-in-class organisations in education, research, technology, business creation and corporate and social innovation. EIT Health intends to foster cooperation and unlock Europe's innovation and growth potential – developing and retaining the best talents, creating high-quality jobs and boosting the global competitiveness of European industry. VisAGeS is involved in this project through the Inserm and Inria institutions. Christian Barillot is representing Inria as one expert in the dedicated WG "Healthy Brain". VisAGeS is also concerned by the WG "big data"..

9.4. International Initiatives

9.4.1. Inria International Partners

9.4.1.1. BARBANT

Title: Boston and Rennes, a Brain image Analysis Team

International Partner (Institution - Laboratory - Researcher):

Harvard University (United States) - Medical School - Simon K. Warfield

See also: https://team.inria.fr/barbant/

Between 2012 and 2017, BARBANT was an Inria associate team shared between Inria VisAGeS research team and the Computational Radiology Laboratory at the Boston Children's hospital (Harvard Medical School). The collaboration continued in 2018 aiming at better understanding the behavior of normal and pathological Central Nervous System (CNS) organs and systems. Pathologies of particular interest to us are multiple sclerosis, psychiatric, and pediatric diseases such as pediatric multiple sclerosis or tuberous sclerosis. A major challenge is to characterize the future course of the pathological processes in each patient as early as possible in order to predict the progression of the disease and/or adverse neurological outcomes, and to develop better techniques for both monitoring response to therapy and for altering therapy (duration, dose and nature) in response to patient-specific changes in imaging characteristics. At term, the goal is to introduce objective figures to correlate qualitative and quantitative phenotypic markers coming from the clinic and image analysis, mostly at the early stage of the pathologies. This will allow for the selection or adaptation of the treatment for patients at an early stage of the disease. Sudhanya Chatterjee's PhD was performed in 2018 under this collaboration.

9.4.1.2. Informal International Partners

- Collaboration with Neuropoly, Polytechnique Montreal: Haykel Snoussi visited the group of Julien Cohen-Adad and received an Inria-MITACS fellowship for a 3 months period (Nov. 2017-Jan. 2018). He worked on the processing of diffusion-weighted images of multiple sclerosis patients' spinal cord in the context of the EMISEP project. We also collaborate with Neuropoly, Polytechnique Montreal through the EMISEP project: Spinal cord data from the EMISEP study was shared with the group in Montreal for manual lesion segmentation and topological analysis of the presence of lesions, in the brain and spinal cord. This work resulted in a common publication [12].
- Camille Maumet collaborates with Prof. Thomas Nichols and his group, NISOx at the Oxford Big Data Institute and with international members of the INCF on neuroimaging data sharing.
- In the context of a project at Neurinfo, Elise Bannier and Jean-Christophe Ferré collaborated with Tobias Kober from Lausanne, to evaluate a sequence named FLAWS, allowing Fluid and White Matter supression for anterior thalamic nucleus visualization.

9.5. International Research Visitors

9.5.1. Visits of International Scientists

- Jean-Baptiste Poline, Associate Professor at McGill University, Montreal, Canada will visit the team on Dec 18-19 and give a talk on reproducibility in neuroimaging.
- Alice Bates, Postdoctoral research fellow at Australian National University, Canberra, visited the team from Oct 8 to Oct 26. She gave a talk on signal sampling and processing for spherical data, and collaborated with the team on a project related to multidimensional diffusion MRI.

9.5.2. Visits to International Teams

9.5.2.1. Research Stays Abroad

- Haykel Snoussi visited NeuroPoly, Polytechnique Montréal, Canada, from Oct 30th 2017 to Jan 26 2018; he was awarded a MITACS-Inria Globalink research award.

10. Dissemination

10.1. Promoting Scientific Activities

10.1.1. Scientific Events Organisation

10.1.1.1. General Chair, Scientific Chair

- MS workshop: https://project.inria.fr/msworkshop2018/, Jan 30-31, London, UK (Claire Cury).
- Brainhack Global Rennes 2018: https://brainhack.irisa.fr, May 25-26, Rennes, France (Camille Maumet).
- Christian Barillot is member of the Board of Directors of IPMI conference series (Information Processing in Medical Imaging)

10.1.1.2. Member of the Organizing Committees

- Brainhack Global Rennes 2018: https://brainhack.irisa.fr, May 25-26, Rennes, France (Julie Coloigner, Olivier Commowick, Claire Cury, Mathis Fleury, Armelle Mozziconacci, Édith Blin).
- MS workshop: https://project.inria.fr/msworkshop2018/, Jan 30-31, London, UK (Christian Barillot).
- ARSEP workshop on multiple sclerosis, Feb 2, ICM (Elise Bannier, Anne Kerbrat).
- Official launching ceremony of Neurinfo new MR scanner, Nov 27, CCP, Rennes (Elise Bannier, Isabelle Corouge in collaboration with Inria and University of Rennes 1).

- Jean-Luc Anton, Elise Bannier, Marie Chupin, Gabriela Hossu, Irène Tropres created in 2016 an academic network for multicenter mutual aid in MRI called REMI. The network gathers over 150 members from nearly 80 different research and clinical sites. Pluri-annual meetings are organised and a website (https://remi.network/) allows members to share expertise, observations and questions. Different themes are discussed : Quality Assurance, Devices, Sequences, Good clinical practices, Data preprocessing, Data management and a preclinical theme was added this year. This initiative is supported by France Life Imaging. An issue of the french magazine for MR tech dedidated to research was published in September 2018 and also describes the REMI among other initiatives : http://new.afppe.com/le-n278-de-septembre-est-en-ligne-sur-la-mediatheque. REMI meetings, March 27 and Oct 9, ICM, Paris (Elise Bannier).

10.1.1.3. Program Participant

- Organizer of the project "A deep learning playground", Brainhack Global Rennes 2018: https://brainhack.irisa.fr, May 25-26, Rennes, France (Francesca Galassi).
- Session moderator "3T versus 7T", SFNR, March 21, Paris, France (Elise Bannier).

10.1.2. Scientific Events Selection

10.1.2.1. Member of the Conference Program Committees

- Christian Barillot was area chair of IEEE-ISBI 2018 and SPIE Medical Imaging 2018
- Scientific commitee of SFRMBM 2019, bi-annual congress that will be help in Strasbourg in March 2019 https://sfrmbm2019.sciencesconf.org/ (Elise Bannier).
- Neuroinformatics 2019: http://neuroinformatics2019.org/, Sept. 1-2, Warsaw, Poland (Camille Maumet).

10.1.2.2. Reviewer

- International Symposium on Medical Information Processing and Analysis: ISBI (Julie Coloigner, Olivier Commowick, Pierre Maurel, Emmanuel Caruyer)
- International Symposium on Medical Information Processing and Analysis: SIPAIM (Julie Coloigner)
- MICCAI (Olivier Commowick, Francesca Galassi)
- Annual congress of the Organisation of Human Brain Mapping (Camille Maumet)
- African Conference on Research in Computer Science and Applied Mathematics (CARI) (Pierre Maurel)

10.1.3. Journal

10.1.3.1. Member of the Editorial Boards

- Christian Barillot is Editor-in-Chief of Frontiers in ICT: Computer Image Analysis.
- Christian Barillot is member of Editorial Boards of Medical Image Analysis, Current Medical Imaging Reviews, ISRN Signal Processing
- Camille Maumet is member of Editorial Boards of Neuroinformatics

10.1.3.2. Reviewer - Reviewing Activities

- Journal of Alzheimer's disease (Claire Cury)
- NeuroImage (Olivier Commowick, Pierre Maurel, Camille Maumet, Christian Barillot)
- NeuroImage: Clinical (Julie Coloigner, Christian Barillot)
- IEEE TMI (Olivier Commowick)
- IEEE Biomedical Engineering (Christian Barillot)
- Med Image Anal (Olivier Commowick, Emmanuel Caruyer, Christian Barillot)
- Magn Reson Med (Emmanuel Caruyer)

- Med Phys (Emmanuel Caruyer)
- Nature Scientific Data (Christian Barillot)

10.1.4. Invited Talks

- Barillot, C., "Defining and evaluating imaging markers for multiple sclerosis". Workshop on Machine Learning in Radiology (MLRad 2018). CHUV - Siemens, Lausanne.
- Barillot, C., "Nouveaux enjeux, nouvelles techniques d'imagerie pour analyser le système nerveux", École Recherche Translationnelle en Neurosciences. ITMO NNP - AVIESAN, Bordeaux.
- Barillot, C., "Medical image analysis and integration". Workshop on "Artificial Intelligence in Health Grand Challenge". AI Singapore, Singapore.
- C. Barillot and O.Commowick. "Objective Evaluation of Multiple Sclerosis Lesion Segmentation using a Data Management and Processing Infrastructure" - Journées françaises de radiologie (JFR 2018) - Paris (Oct 2018) [19]
- Christian Barillot, Michel Dojat, Michael Kain. "France Life Imaging and the transversal node for Information Analysis and Management (IAM)". Journées françaises de radiologie (JFR 2018) - Paris (Oct 2018) [18]
- Michael Kain. "Solutions de gestion des données d'imagerie : exemples avec Shanoir, Archimed et Cati-DB". Journées françaises de radiologie (JFR 2018) - Paris (Oct 2018) [20]
- O. Commowick. "OFSEP and FLI infrastructure for the organisation of the international challenge on MS lesions segmentation". MS workshop, London (January 2018)
- O. Commowick. "Objective Evaluation of Multiple Sclerosis Lesion Segmentation using a Data Management and Processing Infrastructure". France Life Imaging workshop - Orsay (March 2018)
- O. Commowick "Towards Multiple Sclerosis Lesions Segmentation Transfer to the Clinics: Methods and Evaluation". Gdr ISIS - Paris (March 2018)
- In the context of the EMISEP project on MS and spinal cord imaging and in order to discuss further collaboration, Anne Kerbrat, Benoit Combès and Elise Bannier visited the CEMEREM in Marseille on Monday and gave a talk " Characterisation of spinal cord involvement in early RRMS patients using MRI" (October 22st)
- C. Maumet "Tools and standards to make neuroimaging derived data reusable", Keynote at Neuroinformatics 2018, Montreal, Canada, August 2018 [21].
- Yao Chi and Christian Barillot "Infrastructures pour le traitement et la gestion de données d'imagerie biologique et médicale", 6ème Forum de l'Institut de Psychiatrie, Amiens, September 2018.

10.1.5. Leadership within the Scientific Community

- Chair-elect of the international OHBM Open Science Special Interest Group (Camille Maumet)
- Member of the international working group on data sharing in neuroimaging of the International Neuroinformatics Coordinating Facility (Camille Maumet)
- Member (by invitation) of Aperture, an international new online publishing plateform for the OHBM community, in the "workflow working group" led by Peter Bandettini (Camille Maumet).
- Member (by selection) of the "comité de la science ouverte", a national initiative to foster open science in France, in the "open and free software working group" led by Roberto Di Cosmo (Camille Maumet).
- Mentor (by selection) of the international training "Mozilla Open leaders" led by Abigail Cabunoc Mayes (Camille Maumet).
- Member (by selection) of the "Bio Imaging and Signal Processing" (BISP) Technical Committee of the IEEE Signal Processing Society (Emmanuel Caruyer).
- Gilles Edan was elected Fellow of the European Academy of Neurologie. Member of the EAN teaching committee in 2015

- Christian Barillot is member of the Scientific Council of the INS2I [2] Institute of CNRS since 2011 and is Chairman of the Board since 2015
- Christian Barillot is member of the C3N committee (CNRS)
- Christian Barillot is member of the scientific board of “GIS France Grilles”
- Christian Barillot is member of the scientific board of the Neuroscience and psychiatry institute of AVIESAN

10.1.6. Scientific Expertise

- Expertise as a reviewer for “Agence Nationale de la Recherche” (ANR) (Emmanuel Caruyer)
- Expertise as a reviewer for the Comité Français d’Évaluation de la Coopération Scientifique et Universitaire avec le Brésil (Christian Barillot)
- Expertise as a reviewer for the Israel Science Foundation (Christian Barillot)
- Expertise as a reviewer for the Research Council KU Leuven (Christian Barillot)
- Expertise as a reviewer for the Swiss National Science Foundation (Christian Barillot)
- Expertise as a reviewer for the "European Research Council" for the starting grant call (Christian Barillot)

10.2. Teaching - Supervision - Juries

10.2.1. Teaching

ESIR: Cédric Meurée, Algorithms and Complexity, 28h, M1, École Supérieure d’Ingénieur de Rennes (ESIR), France

ESIR: Benoit Combès, Statistiques, 12h, M1, École Supérieure d’Ingénieur de Rennes (ESIR), France

Master Molecular and Cellular biology/Master Bioinformatics/Master Fundamental and Applied Microbiology: Corentin Vallée, Machine Learning, 64h, M1, Univ. Rennes, France

L2 informatique: Raphaël Truffet, Génie Logiciel, 24h, L2, ISTIC, France

ESIR: Pierre Maurel, General image processing (60h), Algorithmics and complexity (60h), Medical imaging (60h), École Supérieure d’Ingénieur de Rennes (ESIR).

ENS Rennes: Pierre Maurel, Introduction to image processing (24h)

Licence SIF: Emmanuel Caruyer, Algorithms, 30h, L3, ENS Rennes, France.

Master 2 "Troubles de la Cognition et du Langage": Pierre-Yves Jonin, Introduction aux méthodes de neuroimagerie pour la recherche en neuropsychologie (3h) Master 2. Université de Poitiers, France.

Master 2 "Troubles de la Cognition et du Langage": Pierre-Yves Jonin, Evaluation neuropsychologique à visée diagnostique. Le cas des syndromes démentiels. Master 2 (2 x 6h) Université de Poitiers, France.

Medicine (4th & 5th year) UE Psychologie et Neurobiologie: Pierre-Yves Jonin,L’exploration neuropsychologique des maladies neurologiques et psychiatriques. 4ème & 5ème année de médecine (4h), Université de Brest, France.

Master 2 Neurosciences Cliniques: Pierre-Yves Jonin, Neurosciences cognitives de la mémoire humaine. Master 2. 3 heures. Université de Rennes 1, France.

Licence 3 de Psychologie: Pierre-Yves Jonin, Les syndromes neuropsychologiques. L3, (16h) Université de Rennes 2, France

Licence 3 de Psychologie: Pierre-Yves Jonin, L’approche neuropsychologique du handicap chez les patients cérébro-lésés. Licence 3. Université de Rennes 2.

[2] http://csins2i.irisa.fr

Master 2 "Handicap et troubles du développement": Pierre-Yves Jonin, Evaluation neuropsychologique à visée diagnostique. Le cas des syndromes démentiels. Master 2. 2 x 6 heures. Université de Rennes 2.

Master 2 "Handicap et troubles du développement".: Pierre-Yves Jonin, Méthodologie de la recherche clinique. Master 2. 3 heures. Université de Rennes 2.

Master 2 "Psychologie, mention Neuropsychologie": Pierre-Yves Jonin, Méthodologie clinique et principes de l'évaluation neuropsychologique à visée diagnostique. Master 2. 3h30. Université de Savoie.

L2 biologie: Antoine Legouhy, Bio-statistques 34h, L2, Univ. Rennes 1, France.

M1 mathématiques: Antoine Legouhy, Optimisation 12h, M1, Univ. Rennes 1, France.

IUT GEA: Mathis Fleury, Mathématiques; 64h (3 months); Licence; IUT Saint-Malo, France.

L1 INF1: Francesca Galassi, Programming in Java (TD : 20h, TP : 20h), L1, ISTIC University of Rennes 1, France.

L2 PO: Francesca Galassi, Object Oriented Programming in Java (TP : 20h), L2, ISTIC University of Rennes 1.

Master SISEA: Benoit Combès, Méthodes statistiques pour l'image 10h, M2, Univ. Rennes 1, France.

Master SIBM, M2, University of Angers-Brest-Rennes, France.

- Christian Barillot (Plenary: 12h), responsible for one semester.
- Jean-Yves Gauvrit, Coordinator for the Master
- Olivier Commowick (Plenary: 6h).
- Quentin Duché, "Traitements des données d'IRM fonctionnelle" (Plenary: 1h).
- Isabelle Corouge, "Bio-marqueurs d'imagerie et IRM metabolique et fonctionnelle" (Plenary: 3h).
- Camille Maumet, "Imaging processing pipelines" (Plenary: 3h).
- Élise Bannier, "IRM fonctionnelle BOLD" (Plenary: 3h).
- Emmanuel Caruyer, "Introduction to diffusion MRI" (Plenary: 3h).
- Benoit Combès, "Méthodes statistiques pour le traitement d'image" (Plenary: 3h).

10.2.2. Supervision

10.2.2.1. PhD & HdR

PhD in progress : Antoine Legouhy, "Longitudinal brain altas creation, application to development studies", CNRS, from Nov 2016, Christian Barillot, François Rousseau, Olivier Commowick.

PhD in progress: Cédric Meurée, "Quantitative Analysis Of Arterial Spin Labeling MRI For Robust Parametric Information Of Perfusion Maps", Inria / Siemens, from Mar 2014, Christian Barillot, Pierre Maurel.

PhD: Sudhanya Chatterjee, "Gaining insights into brain tissues using multi-compartment T2 relaxometry models", Inria, defended on Dec 5, 2018, Christian Barillot, Olivier Commowick, Jean-Christophe Ferré, Simon Warfield.

PhD in progress : Corentin Vallée, "Joint estimation of neuronal activation, resting-state and basal metabolism from Arterial Spin Labeling", Univ. Rennes, from Nov 2016, Christian Barillot, Isabelle Corouge, Pierre Maurel.

PhD in progress : Anne-Claire Binter, "Étude des effets possibles des expositions prénatales à des neurotoxiques (solvants organiques et insecticides organophosphorés) sur le fonctionnement du cerveau de l'enfant évalués par imagerie cérébrale (Cohorte Pélagie)", Univ. Rennes, from Janv 2017, Fabienne Pelé, Cécile Chevrier, Elise Bannier.

PhD in progress : Xavier Rolland, “Modeling analytic variability in brain imaging”, CNRS, from Oct 2018, Christian Barillot, Camille Maumet.

PhD in progress : Raphaël Truffet, “Compressed sensing for microstructure-enabled diffusion MRI”, Univ. Rennes / ENS Rennes, from Oct 2018, Christian Barillot, Emmanuel Caruyer.

PhD: Maia Proisy, “Étude de la perfusion cérébrale par Arterial Spin Labeling en IRM à 1.5T chez le nouveau-né et l’enfant”, Univ. Rennes/CHRU Rennes, defended on Dec 12, 2018, Jean-Christophe Ferré.

PhD: Anne Kerbrat Univ. Rennes/CHRU Rennes, defended on Oct 24, 2018, Gilles Edan

10.2.2.2. Other supervisions

Master student: Solene Tarride, “Deep learning for segmentation of MS lesions from multimodal MRI”, Apr-Oct 2018, Francesca Galassi.

10.2.3. Juries

- Gilles Edan, Jean-Christophe Ferre, Christian Barillot. PhD committee: Anne Kerbrat, Univ. Rennes, Rennes; October 24, 2018.
- Jean-Christophe Ferre, Christian Barillot. PhD committee: Maia Proisy, Univ. Rennes, Rennes; December 12, 2018.
- Jean-Christophe Ferre, Christian Barillot. PhD committee: Jean-Marie Batail, Univ. Rennes, Rennes; December 15, 2018.
- Olivier Commowick, Christian Barillot. PhD committee: Sudhanya Chatterjee, Inria, Rennes; December 5, 2018.
- Isabelle Corouge, PhD thesis in medicine committee: Christophe Paya, Univ. Rennes, Rennes; June 25, 2018.
- Isabelle Corouge, PhD mid-term committee (CSI) : Cédric Meurée, Rennes; May 2018.
- Élise Bannier, PhD mid-term committee (CSI) : Haykel Snoussi, Rennes; May 2018.
- Élise Bannier, PhD mid-term committee (CSI) : Louis Marage, Rennes; July 2018.
- Emmanuel Caruyer, PhD mid-term committee (CSI) : Sudhanya Chatterjee, Rennes; June 2018.
- Christian Barillot, PhD committee: Gaetan Galisot, Tours Université Tours, March 21, 2018
- Christian Barillot, PhD review: Pauline Bezivin-Frere, Orsay Université Paris X, July 4, 2018
- Christian Barillot, Chairman PhD committee: Mayela Toledo, Rennes Université Rennes 1, May 23, 2018

10.3. Popularization

10.3.1. Press

- Isabelle Bonan and Christian Barillot did present the activity of Neurofeedback in Visages during a press conference in Paris on November 14th, 2018 organized by Inria. Press reports have been issued from this conference : France Inter morning news, Usbek et Rica (https://usbeketrica.com/article/le-xxieme-siecle-sera-celui-du-cerveau), and Egora (https://www.egora.fr/actus-medicales/neurologie/43575-l-interface-cerveau-ordinateur-efficace-dans-le-traitement-de).
- Article in "Sciences Ouest" on "*Un miroir intelligent pour entraîner son cerveau*" https://www.espace-sciences.org/sciences-ouest/366/dossier/un-miroir-intelligent-pour-entrainer-son-cerveau, Nov. 2018

10.3.2. Film

A film presenting the Neurinfo imaging facility was recorded by Inria for the official launching ceremony of the new 3T Prisma scanner and further use for general communication about Neurinfo. Reports on local press: Ouest-france (https://www.ouest-france.fr/bretagne/rennes-35000/video-une-irm-ultra-puissante-pour-faire-avancer-la-recherche-rennes-6095044) and TV-Rennes (https://www.tvr.bzh/programmes/tvr-soir-1543339500).

10.3.3. Articles and contents

- Camille Maumet: Blog post "Open science working group on scientific software" http://blog.camillemaumet.com/posts/12, November, personal website.
- Elise Bannier: Blog post "Village des sciences 2018" https://team.inria.fr/visages/village-des-sciences-2018/, October, VisAGeS blog.
- Camille Maumet: Blog post "Extending BIDS to fMRI analyses" http://blog.camillemaumet.com/posts/11, October, personal website.
- Olivier Commowick: Blog post: "Anima scripts release" https://team.inria.fr/visages/anima-scripts-release/, September, VisAGeS blog.
- Camille Maumet: Blog post "Collaborative AFNI projects at DC code convergence" http://blog.camillemaumet.com/posts/10, September, personal website.
- Camille Maumet: Blog post "Meeting Montreal neuroinformatics community at the INCF congress and hackathon" http://blog.camillemaumet.com/posts/9, August, personal website.
- Camille Maumet: Blog post "Mentoring for Mozilla Open Leaders" http://blog.camillemaumet.com/posts/8, August, personal website.
- Camille Maumet with Claire Cury: Blog post "Interview: Let's organise a Brainhack!" https://team.inria.fr/visages/interview-lets-organise-a-brainhack/, July, VisAGeS blog.
- Camille Maumet with Elise Bannier: Blog post "Interview: Participating in my first hackathon at Brainhack Rennes 2018" https://team.inria.fr/visages/participating-in-my-first-hackathon-at-brainhack-rennes-2018/, July, VisAGeS blog.
- Camille Maumet: Blog post "OHBM 2018: first remotely-attended conference" http://blog.camillemaumet.com/posts/7, June, personal website.
- Camille Maumet: Blog post "Sprinting with bio-imagers and how I learnt about NEUBIAS, EuBI, Elixir and tried out myBinder!" http://blog.camillemaumet.com/posts/6, May, personal website.
- Olivier Commowick: Blog post "Anima v3.0 release" https://team.inria.fr/visages/anima-v3-0-release/, March, VisAGeS blog.
- Claire Cury: Blog post "Workshop Multiple Sclerosis 2018 (UCL, Inria)" https://team.inria.fr/visages/workshop-multiple-sclerosis-2018-ucl-inria/, April, VisAGeS blog.
- Olivier Commowick: Blog post "Brainhack Rennes 2018 (April 25-26)" https://team.inria.fr/visages/brainhack-rennes-2018-april-25-26/, March, VisAGeS blog.
- Olivier Commowick: Blog post "medInria 3.0 available" https://team.inria.fr/visages/medinria-3-0-available/, March, VisAGeS blog.

10.3.4. Education

- L codent L créent - An outreach program to send PhD students to teach Python to middle school students in 8 sessions of 45 minutes. Tassadit Bouadi (Univ. Rennes 1), Camille Maumet (VisAGeS) and Anne-Cecile Orgerie (Myriads) are coordinating the local version of this program, initiated in Lille. The first session in Rennes is planned for April 2019. The program is currently supported by: Fondation Blaise Pascal, ED MathSTIC, Inria and Fondation Rennes 1.

10.3.5. Interventions

10.3.5.1. National brain week: "Semaine du Cerveau"

- Giulia Lioi: Talk "Lire dans son cerveau grâce au neurofeedback EEG, c'est mieux bouger", March 14, Warpzone, Rennes, France.
- Mathis Fleury: Bar en (neuro) sciences; May 14-16; Presentation of the Neurofeedback and demonstration of a EEG based Neurofeedback with a motor imagery paradigm.

10.3.5.2. National science week: "Village des sciences"

Visages took part in the Village des Sciences 2018, opening the Neurinfo platform to 45 middle school students (Oct 5) and 120 visitors from the general public (Oct 6-7), Oct 5-7, Rennes, France. https://www.univ-rennes1.fr/evenements/20072018/village-des-sciences-2018-visites-guidees-de-laboratoires-pour-les-scolaires, https://team.inria.fr/visages/members-area/projects/village-des-science-2018/. The event was coordinated by Julien Le Bonheur from the University of Rennes, and Elise Bannier coordinated the contribution of Neurinfo/Visages. We covered 4 themes:

- Giulia Lioi, Mathis Fleury, Simon Butet, Pauline Rolland: Neurofeedback EEG
- Pierre Maurel, Charlélie Erhart, Antoine Legouhy, Corentin Vallée, Francesca Galassi, Julie Coloigner: Image processing with MedInria
- Isabelle Corouge, Catherine Guillemot, Emmanuel Caruyer, Elise Bannier, Benjamin Parat: Brain and MRI
- Quentin Duché, Florian Chapelain, Virginie Dardier: Functional MRI

10.3.5.3. Other interventions

- Pierre-Yves Jonin: Series of 6 talks on neuropsychology, Universités du Temps Libre de Bretagne, Jan-Dec, Rennes, France.
- Pierre-Yves Jonin: Talk "La mémoire humaine, comment la conserver, quand s'inquiéter", Bien Vieillir en Ille-et-Vilaine, June, Rennes, France.
- Mathis Fleury: Talk "Qu'est ce qu'un doctorant ?"Journée des métiers IUT rennes - , Nov 16, IUT Rennes, France.
- Camille Maumet: Talk to middle school students (around 100) "La neuroinformatique", PRNB, April, Rennes, France.
- Olivier Commowick: Presentation of research done in VisAGeS on medical image processing and of the MedInria software, Journée LOGIN, Nov 27, Grenoble, France.

10.3.6. Creation of media or tools for science outreach

- Launching of a Twitter account for the VisAGeS team (Camille Maumet) and setup on the VisAGeS website (Olivier Commowick) http://twitter.com/visages_inria. Tweets by lab members (Quentin Duché, Christian Barillot)
- Development of the VisAGeS blog and writing of blog posts (Camille Maumet, Olivier Commowick, Claire Cury, Elise Bannier).

11. Bibliography

Publications of the year

Doctoral Dissertations and Habilitation Theses

[1] S. CHATTERJEE. *Gaining insights into brain tissues using multi-compartment T2 relaxometry models*, Universite Rennes 1, December 2018, https://hal.archives-ouvertes.fr/tel-01949963

Articles in International Peer-Reviewed Journals

[2] R. BOURCIER, D. ABED, M. PIOTIN, H. REDJEM, J. FERRÉ, F. EUGÈNE, H. RAOULT, M. MIRZA, R. CHAPOT, H. DESAL, H. NORDMEYER. *Multicenter initial experience with the EmboTrap device in acute anterior ischemic stroke*, in "American Journal of Neuroradiology", July 2018, vol. 45, n^{o} 4, pp. 230-235, https://hal.archives-ouvertes.fr/hal-01939638

[3] R. BOURCIER, P.-L. ALEXANDRE, F. EUGÈNE, B. DELASALLE-GUYOMARCH, B. GUILLON, B. KERLEROUX, S. SALEME, G. MARNAT, S. BOUCEBCI, M. MIRZA, J.-C. FERRÉ, C. PAPAGIANNAKI, H. DESAL. *Is bridging therapy still required in stroke due to carotid artery terminus occlusions?*, in "Journal of Neurointerventional Surgery", June 2018, vol. 10, n^{o} 7, pp. 625 - 628 [*DOI :* 10.1136/NEURINTSURG-2017-013398], https://www.hal.inserm.fr/inserm-01935345

[4] A. CARSIN-VU, I. COROUGE, O. COMMOWICK, G. BOUZILLÉ, C. BARILLOT, J.-C. FERRÉ, M. PROISY. *Measurement of pediatric regional cerebral blood flow from 6 months to 15 years of age in a clinical population*, in "European Journal of Radiology", April 2018, vol. 101, pp. 38-44 [*DOI :* 10.1016/J.EJRAD.2018.02.003], https://www.hal.inserm.fr/inserm-01708945

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