IN PARTNERSHIP WITH:
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Université Rennes 1

Activity Report 2017

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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Creation of the Project-Team: 2005 July 04

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1. Personnel

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Olivier Commowick [Inria, Researcher]
Camille Maumet [Inria, Researcher, from Nov 2017]

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Antoine Legouhy [CNRS, granted by ANR and Brittany Region]
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Guillem Gonzalez Vela [Inria, from Feb. 2017 until Jun. 2017]
Amélie Nicolas [Centre hospitalier régional et universitaire de Rennes, Mar. 2017]
Christophe Paya [Univ. Rennes, from Feb. 2017 until Aug. 2017]
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Lorenzo Rota [Inria, Politechnico di Milano, until Mar. 2017]

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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.

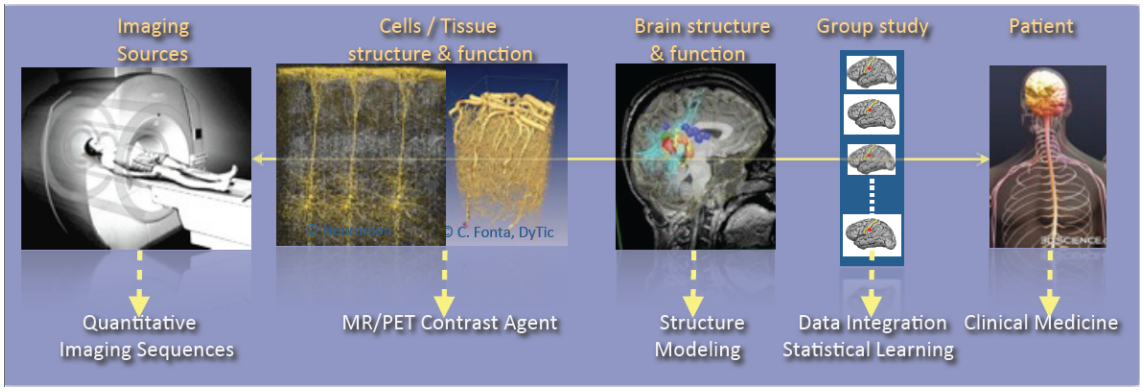

Figure 1. The major overall scientific foundation of the team concerns the integration of data from the Imaging source to the patient at different scales: from the cellular or molecular level describing the structure and function, to the functional and structural level of brain structures and regions, 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 the pathology;
- 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 ...). 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. Recruitment

- Camille Maumet was recruited as Inria Researcher, starting from November 2017.

6. New Software and Platforms

6.1. Anima

KEYWORDS: Registration - Diffusion imaging - Medical imaging - Filtering - 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 and Pierre Maurel
- Contact: Isabelle Corouge
- URL: http://www.irisa.fr/visages/

6.3. MedInria

KEYWORDS: Visualization - DWI - Health - Segmentation - Medical imaging
SCIENTIFIC DESCRIPTION: It 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: Webservices - Soap - C++ - Health - DICOM - Plug-in - Medical imaging - Qt - Shanoir - Nifti
SCIENTIFIC DESCRIPTION: QtShanoir is based on Qt/C++ librairie. 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 structure, manage, archive, visualize and share neuroimaging data with an emphasis on multi-centric collaborative research projects. It provides common features of neuroimaging data management systems along with research-oriented data organization and enhanced accessibility.

Shanoir is a secured J2EE application running on a JBoss server, reachable via graphical interfaces in a browser or by third party programs via web services. It behaves as a repository of neuroimaging files coupled with a relational database hoding meta-data. The data model, based on OntoNeurolog, an ontology devoted to the neuroimaging field, is structured around research studies where of involved patients have examinations which either produce image acquisitions or clinical scores. Each image acquisition is composed of datasets represented by their acquisition parameters and image files. The system only keeps anonymous data.

Image files imports are possible from various sources (DICOM CDs, PACs, image files in NIfTI / Analyze format) using either online wizards, with completions of related meta-data, or commande line tools. Once de-identified during the import phase, DICOM header's customizable feature. Shanoir can also record any executed processing allowing to retrieve workflows applied to a particular dataset along with the intermediate data.

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. A study responsible can thereby define the users allowed to see, download or import data into his study or simply make it public.

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.

Shanoir integrates the enterprise search platform, Apache Solr, to provide the users a vast array of advanced features such as near real-time indexing and queries, full-text search, faceted navigation, autosuggestion and autocomplete.

- 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: PACS - Medical imaging - Neuroimaging - DICOM - Health - Biology - Java - Webservices - 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. Platforms

6.7.1. 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 [1]. 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 overall PIMATGI initiative served for the financing of three distinct, but 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).

[1] http://www.neurinfo.org

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. A 3T Siemens Prisma will be installed early 2018.

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. L2 Similarity Metrics for Diffusion Multi-Compartment Model Images Registration

Participants: Renaud Hédouin, Olivier Commowick, Emmanuel Caruyer, Christian Barillot.

Diffusion multi-compartment models (MCM) allow for a fine and comprehensive study of the white matter microstructure. Non linear registration of MCM images may provide valuable information on the brain for example through population comparison. State-of-the-art MCM registration however relies on pairing-based similarity measures where the one-to-one mapping of MCM compartments is required. This approach leads to non differentiabilties or discontinuities, which may turn into poorer registration. Moreover, these measures are often specific to one MCM compartment model. We proposed [34] two new MCM similarity measures based on the space of square integrable functions, applied to MCM characteristic functions. These measures are pairing-free and agnostic to compartment types. We derived their analytic expressions for multi-tensor models and proposed a spherical approximation for more complex models. Evaluation was performed on synthetic deformations and inter-subject registration, demonstrating the robustness of the proposed measures.

7.1.1.2. Block-Matching Distortion Correction of Echo-Planar Images with Opposite Phase Encoding Directions
Participants: Renaud Hédouin, Olivier Commowick, Élise Bannier, Christian Barillot.

By shortening the acquisition time of MRI, Echo Planar Imaging (EPI) enables the acquisition of a large number of images in a short time, compatible with clinical constraints as required for diffusion or functional MRI. However such images are subject to large, local distortions disrupting their correspondence with the underlying anatomy. The correction of those distortions is an open problem, especially in regions where large deformations occur. We have proposed a new block-matching registration method to perform EPI distortion correction based on the acquisition of two EPI with opposite phase encoding directions (PED). It relies on new transformations between blocks adapted to the EPI distortion model, and on an adapted optimization scheme to ensure an opposite symmetric transformation. We have produced qualitative and quantitative results of the block-matching correction using different metrics on a phantom dataset and on in-vivo data. We have shown the ability of the block-matching to robustly correct EPI distortion even in strongly affected areas. This work has been published in IEEE Transactions on Medical Imaging [21].

7.1.1.3. Diffusion MRI processing for multi-compartment characterization of brain pathology
Participants: Renaud Hédouin, Olivier Commowick, Christian Barillot.

Diffusion weighted imaging (DWI) is a specific type of MRI acquisition based on the direction of diffusion of the brain water molecules. It allows, through several acquisitions, to model the brain microstructure, as white matter, which is significantly smaller than the voxel-resolution. To acquire a large number of images in a clinical setting, very-fast acquisition techniques are required as single-shot imaging. However these acquisitions suffer locally large distortions. We have proposed a block-matching registration method based on the acquisition of images with opposite phase-encoding directions (PED). This technique specially designed for Echo-Planar Images (EPI) robustly correct images and provides a deformation field. This field is applicable to an entire DWI series from only one reversed EPI allowing distortion correction with a minimal acquisition time cost. This registration algorithm has been validated both on phantom and on *in vivo* data and is available in our source medical image processing toolbox Anima. From these diffusion images, we are able to construct multi-compartments models (MCM) which can represent complex brain microstructure. Doing registration, averaging and atlas creation on these MCM images is required to perform studies and statistic analyses. We propose a general method to interpolate MCM as a simplification problem based on spectral clustering. This technique, which is adaptable for any MCM, has been validated on both synthetic and real data. Then, from a registered dataset, we performed a patient to population analysis at a voxel-level computing statistics on MCM parameters. Specifically designed tractography can also be used to make analysis, following tracks, based on individual anisotropic compartments. All these tools are designed and used on real data and contribute to the search of biomakers for brain diseases such as multiple sclerosis.

7.1.1.4. The challenge of mapping the human connectome based on diffusion tractography
Participant: Emmanuel Caruyer.

Tractography based on non-invasive diffusion imaging is central to the study of human brain connectivity. To date, the approach has not been systematically validated in ground truth studies. Based on a simulated human brain data set with ground truth tracts, we organized an open international tractography challenge, which resulted in 96 distinct submissions from 20 research groups. Here, we report the encouraging finding that most state-of-the-art algorithms produce tractograms containing 90 percent of the ground truth bundles (to at least some extent). However, the same tractograms contain many more invalid than valid bundles, and half of these invalid bundles occur systematically across research groups. Taken together, our results demonstrate and confirm fundamental ambiguities inherent in tract reconstruction based on orientation information alone, which need to be considered when interpreting tractography and connectivity results. Our approach provides a novel framework for estimating reliability of tractography and encourages innovation to address its current limitations [26].

7.1.1.5. Comparison of inhomogeneity distortion correction methods in diffusion MRI of the spinal cord
Participants: Haykel Snoussi, Emmanuel Caruyer, Christian Barillot.

Diffusion MRI (dMRI) is a modality that describes the geometry of neural architecture. Diffusion images suffer from various artifacts originating from subject and physiological motion, eddy currents and B0-field inhomogeneity. These can severely affect image quality particularly in the spine region. However, strategies exist to correct these distortions, including co-registration, point spread function, phase field map and reversed gradient polarity method (RGPM). We evalute various correction methods using RGPM which provides best results. More precisely, we compared Voss plus two other recent methods: Topup (FSL) and HySCO (ACID/SPM). This work was presented at the ESMRMB conference [38].

7.1.2. Arterial Spin Labeling:

Our contributions on this topic are illustrated in Fig. 2. Arterial Spin Labeling (ASL) enables measuring cerebral blood flow in MRI without injection of a contrast agent. Perfusion measured by ASL carries relevant information for patients suffering from pathologies associated with singular perfusion patterns.

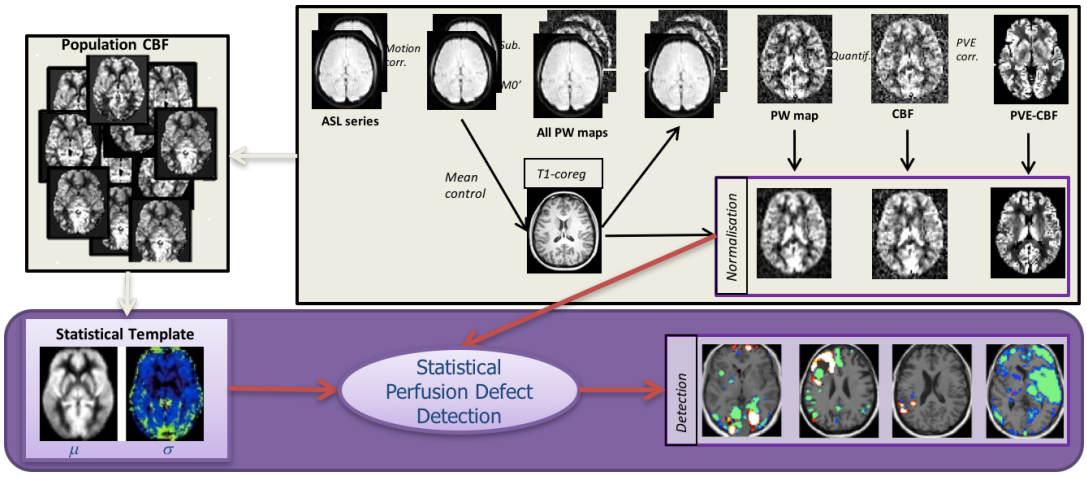

Figure 2. Summary of the image processing workflow that allows the quantification of brain perfusion and detection of potential perfusion defect on patients or populations

However this technique suffers from drawbacks such as low signal to noise ratio and poor resolution.

7.1.2.1. Patch-based super-resolution for arterial spin labeling MRI

Participants: Cédric Meurée, Pierre Maurel, Christian Barillot.

In this context, our contributions focused on a super resolution approach to reduce the influence of Partial Volume Effects (PVE) and obtain images close to the ones that would be acquired at a high resolution, but in a shorter scan duration. PVE are an important limitation of arterial spin labeling (ASL) acquisitions, impacting the validity of quantitative cerebral blood flow (CBF) estimations. This work consists of a super-resolution algorithm, which includes information of high resolution (HR) structural images to reconstruct HR CBF maps from low resolution ASL series, without increasing the acquisition time. Compared with nearest neighbor, trilinear and 3rd order spline interpolations, the proposed algorithm is found to generate a CBF image closer to the one obtained with a reference HR ASL acquisition. CBF calculations can therefore be improved by using this algorithm, which reduces the PVE [36].

7.1.2.2. Resting-state functional ASL

Participants: Corentin Vallée, Isabelle Corouge, Pierre Maurel, Christian Barillot.

We have started to work on resting-state functional ASL (rs-fASL). 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 could lead to significant clinical subject scaled application as CBF can be considered as a biomarker in common neuropathology. As a new topic, we started by building a viable long sequence for rs-fASL. We take advantage of the long duration of the sequence to assess the link between overall quality of rs-fASL and duration of acquisition. To this end, we consider typical functional areas of the brain, and assess their quality compared to gold standards depending on the duration of acquisition. While some more work remain to be done, we tend to show there is an optimal duration of acquistion for rs-fASL. This work was submitted for the next ISMRM Conference.

7.1.2.3. Longitudinal atlas creation and brain development analysis

Participants: Antoine Legouhy, Olivier Commowick, Christian Barillot.

The study of brain development provides insights in the normal trend of brain evolution and enables early detection of abnormalities. We propose a method to quantify growth in three arbitrary orthogonal directions of the brain through linear registration. We introduce a 9 degrees of freedom transformation that gives the opportunity to extract scaling factors describing brain growth along those directions by registering a data base of subjects in a common basis. We apply this framework to create a longitudinal curve of scaling ratios along fixed orthogonal directions from 0 to 16 years highlighting anisotropic brain development. In pediatric image analysis, the study of brain development provides insights in the normal trend of brain evolution and enables early detection of abnormalities. Tools like longitudinal atlases allow to compute statistics on populations, understand brain variability at different ages to highlight changes in growth, shape, structure etc. We experimented different methods to perform longitudinal atlases. This work was submitted for the next ISMRM Conference.

7.1.3. Quantitative relaxation times estimation and processing:

The VisAGeS team has proposed new methodologies to exploit new relaxometry sequences, able to provide direct information on tissue properties (T1, T2, T2* relaxation times) and their alteration in diseases. Such sequences have a great potential in diagnostic and evolution study of patients suffering from various neurological diseases.

7.1.3.1. Gaining Insights Into Multiple Sclerosis Lesion Characteristics from Brain Tissue Microstructure Information: A Multi-Compartment T2 Relaxometry Approach:

Participants: Sudhanya Chatterjee, Olivier Commowick, Christian Barillot.

In addition to raw relaxation times, we have also studied other estimation methods able, from T2 relaxometry sequences, to estimate the fraction of myelin (myelin water fraction) inside each voxel, a quantity that may be largely impacted in neurological diseases. To this end, we have proposed new multi-compartment T2 estimation methods [42] with a new water three-compartment T2 model of tissue bounded water (free water, axons and cells, and myelin), using variable projection to make the estimation faster and more robust. Clinical trends and pathogenetic ways of onset and progression of Multiple Sclerosis (MS) in patients suggest that MS is a highly heterogeneous disease. MS is predominantly a White Matter (WM) disease, which is mainly composed of myelinated axons and neuroglia type cells. Demyelination and axonal loss characterize the condition of MS in a patient. However, they follow varying trends in patients. In this work, we propose a method in which T2 relaxometry data is used to obtain a quantitative brain tissue microstructure information. This information is then studied to check its corroborations with pathogenetic understanding of MS in literature [41].

7.1.3.2. Multi-Compartment T2 Relaxometry Model Using Gamma Distribution Representations: A Framework for Quantitative Estimation of Brain Tissue Microstructures:

Participants: Sudhanya Chatterjee, Olivier Commowick, Christian Barillot.

Advanced MRI techniques (e.g., d-MRI, MT, relaxometry etc.) can provide quantitative information of brain tissues. Image voxels are often heterogeneous in terms of microstructure information due to physical limitations and imaging resolution. Quantitative assessment of the brain tissue microstructure can provide valuable insights into neurodegenerative diseases (e.g., Multiple Sclerosis). In this work, we propose a multicompartment model for T2-Relaxometry to obtain brain microstructure information in a quantitative framework. The proposed method allows simultaneous estimation of the model parameters [42].

7.1.4. Multi-modal EEG and fMRI Source Estimation Using Sparse Constraints:

Participants: Saman Noorzadeh, Pierre Maurel, Christian Barillot.

In this work, a multi-modal approach is presented and validated on real data to estimate the brain neuronal sources based on EEG and fMRI. Combining these two modalities can lead to source estimations with high spatio-temporal resolution. The joint method is based on the idea of linear model already presented in the literature where each of the data modalities are first modeled linearly based on the sources. Afterwards, they are integrated in a joint framework which also considers the sparsity of sources. The sources are then estimated with the proximal algorithm. The results are validated on real data and show the efficiency of the joint model compared to the uni-modal ones. We also provide a calibration solution for the system and demonstrate the effect of the parameter values for uni- and multi-modal estimations on 8 subjects [37].

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

7.2.1. Arterial Spin Labeling:

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

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. In 2017, in the context of the MALTA project, we focused on the application of ASL to activation-fMRI. Functional Arterial Spin Labeling (fASL) has demonstrated its greater specificity as a marker of neuronal activity than the reference BOLD fMRI for motor activation mapping in healthy volunteers. Motor fASL was yet to be investigated in the context of tumors, under the assumption that fASL would be less sensitive to venous contamination induced by the hemodynamics remodeling in the tumor vicinity than BOLD fMRI. As the arterial transit time may be shortened in activation areas, we explored the ability of fASL to map the motor areas at different post-labeling delays (PLD) in healthy subjects and patient with brain tumor. As part of the PhD of Maia Proisy, we have also been working on processing and analyse MR perfusion images using arterial spin labeling in neonates and children for several purposes:

- ASL and TOF-MRA are two totally non-invasive, easy-to-use MRI sequences for children in emergency settings. Hypoperfusion associated with homolateral vasospasm may suggest a diagnosis of migraine with aura (published in Cephalagia and presented in 3 congresses including RSNA)
- Investigation of brain perfusion evolution between 6 month and 15 years using ASL sequence in order to provide reference values in this age range (Measurement of pediatric regional cerebral blood flow from 6 months to 15 years of age article under revision, presented in one national congress)
- Work in Progress: ASL perfusion images in 20 neonates with hypoxic-ischemic encephalopathy that underwent MRI on day-of-life 3 and day-of-life 10.

7.2.2. Hybrid EEG-fMRI Neurofeedback:

Participants: Lorraine Perronnet, Marsel Mano, Élise Bannier, Mathis Fleury, Giulia Lioi, Christian Barillot.

Over the last 4 years, we developed a whole new range of activities around hybrid EEG-MR imaging and neurofeedback for brain rehabilitation. 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. We first performed a thorough state-of-the-art of Neurofeedback (NF) and restorative Brain Computer Interfaces (BCI) under EEG and fMRI modality as well as of EEG-fMRI integration, with a particular focus on applications in depression and motor rehabilitation. This enabled us to design a NF protocol based on motor imagery and compatible with EEG and fMRI. We implemented different types of feedback and compared for the first time the effects of unimodal EEG-NF and fMRI-NF versus bimodal EEG-fMRI-NF by looking both at EEG and fMRI activations. We also introduced a new feedback metaphor for bimodal EEG-fMRI-neurofeedback that integrates both EEG and fMRI signal in a single bi-dimensional feedback (a ball moving in 2D). The participants to this study were able to regulate activity in their motor regions in all NF conditions. Our results also suggest that that EEG-fMRI-neurofeedback could be more specific or more engaging than EEG-NF alone [31].

All the experiments were performed on the Neurinfo platform which is equipped with an EEG MR compatible 64-channel device in 2014 to perform joint EEG and BOLD or ASL fMRI. We developed, installed and successfully tested a hybrid EEG-fMRI platform for bimodal NF experiments. Our system is based on the integration and the synchronization of an MR-compatible EEG and fMRI acquisition subsystems. We developed two real-time pipelines for EEG and fMRI that handle all the necessary signal processing, the joint NF block that calculates and fuses the NF and a visualization block that displays the NF to the subject. The control and the synchronization of both subsystems with each other and with the experimental protocol is handled by the NF Control. Our platform showed very good real-time performance with various pre-processing, filtering, and NF estimation and visualization methods. Its modular architecture is easily adaptable to different experimental environments, and offers high efficiency for optimal real-time NF applications [27].

These developments came as part of the HEMISFER project which is conducted through a very complementary set of competences over the different teams involved (Visages Inserm U1228, HYBRID and PANAMA Teams from Inria/IRISA, EA 4712 team from University of Rennes I and ATHENA team from Inria Sophia-Antipolis). The overall principle of this project is illustrated in Fig. 3.

7.2.3. Multiple sclerosis:

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 presentation at ESMRMB [33]. Based on this work, a second work investigated the sensitivity of magnetization transfer to assess diffuse and focal burden in MS patients [43]. In parallel, methodological developments have addressed spinal cord diffusion data analysis, starting with a comparaison of several distortion correction methods [38].

Finally, we investigated myelin water fraction (MWF) estimation on multiple sclerosis and demonstrated in longitudinal studies [41] how these figures can be related with lesion evolution, paving the way towards myelin oriented MS evaluation of patient future evolution prediction (and thus treatment adaptation) and joint studies between different quantitative imaging modalities (e.g., diffusion).

7.2.4. Recovery imaging:

Participants: Isabelle Bonan, Stephanie Leplaideur, Élise Bannier, Jean-Christophe Ferré, Christian Barillot.

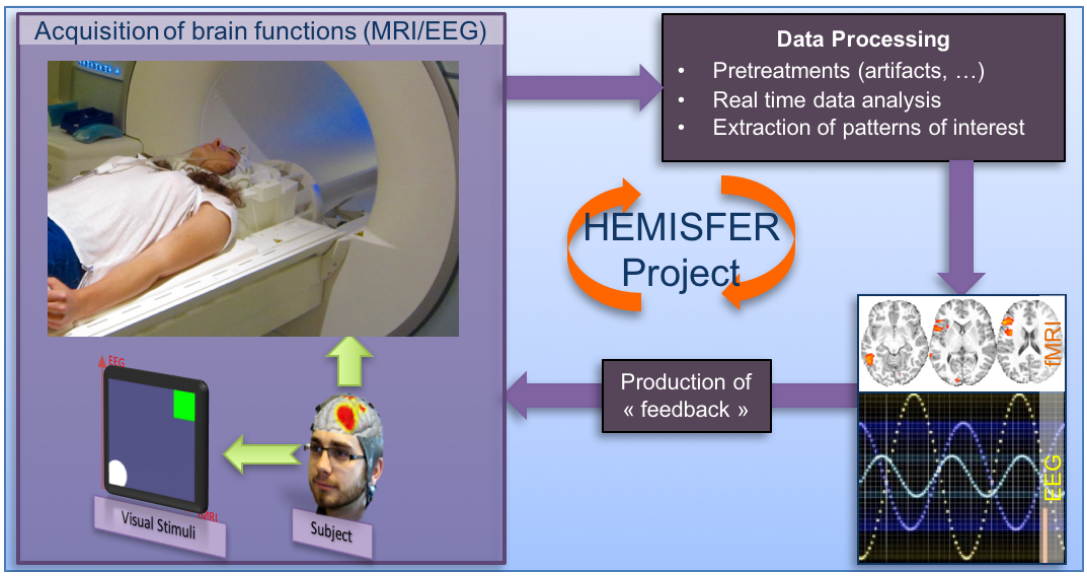

Figure 3. Principle of the Hybrid EEG:fMRI environement set up and used by the HEMISFER project

More common after a right hemispheric brain injury, misperception of body in space, impacting moves and posture is often associated with disturbance of spatial attention (behavioural symptoms of a failure in spontaneously reorienting attention to stimulus information in the left field). While different subjects use different references in their elaboration of spatial representation, body-centered coordinate systems are the most prevalent. As part of an fMRI substudy of a national research study on balance disorder rehabilitation, we investigated differences in activations during body-centered spatial tasks in corporeal and in extracorporeal space. Healthy controls and stroke patients were included in this fMRI sub study comprising 2 egocentric spatial tasks: perception of the midsagittal plane in extracorporeal space (straight-ahead task) and in corporeal space (longitudinal axis task). Results obtained on healthy control data were presented at the SOFMER conference and the journal paper is under review. For both tasks, cerebral activations largely dominated in the right hemisphere and essentially involved the right frontoparietal network. In addition, the straight-ahead task presented specific activations in the temporoparieto-insular cortex and thalamic areas. Patient data processing is ongoing in the context of an MD-PhD. In parallel, a master study investigated the brain structural connections between the cortical areas obtained from the fMRI study using diffusion MRI and the white matter query language.

7.2.5. White matter connectivity analysis in patients suffering from depression:

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

The mood depressive disorder (MDD) is a common chronically psychiatric disorder with an estimated lifetime prevalence reported to range from 10 percent to 15 percent worldwide. This disease is characterized by an intense dysregulation of affect and mood as well as additional abnormalities including cognitive dysfunction, insomnia, fatigue and appetite disturbance. Despite the extensive therapy options available for depression, up to 80 percent of patients will suffer from a relapse [1]. Consequently, exhibiting imaging biomarkers of this disease will support both a better understanding of the neural correlates underlying the depression, and a better diagnosis and treatment of individual depressed patients. Previous studies of structural and functional magnetic resonance imaging have reported several microstructural abnormalities in the prefrontal cortex, anterior cingulate cortex, hippocampus and thalamus [2]. These observations suggest a dysfunction of the

circuits connecting frontal and subcortical brain regions, leading to a "disconnection syndrome" [3]. Given the small sample size used in the past studies, we proposed a more robust analysis using a larger cohort of patients suffering from depression, called LONGIDEP. The latter is a routine care cohort of patients suffering from mood depressive disorder who underwent a clinical evaluation, neuropsychological testing and brain MRI. The population sample consists of 125 patients suffering from depression and 65 healthy age and gender-matched, control subjects. A composite measure of medication load for each patient was assessed using a previously established method [4]. We investigated alterations of white matter integrity using a voxel-based analysis based on fractional anisotropy (FA) and the apparent diffusion coefficient (ADC) in patients with depression. Using graph theory-based analysis, we also examined white matter changes in the organization of networks in patients suffering from depression. 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 MDD pathogenesis. These results are consistent with an overall hypothesis that depression involves a disconnection of prefrontal, striatal, and limbic emotional areas.

7.2.6. Knowing and Remembering: Cognitive and Neural Influences of Familiarity on Recognition Memory in Early Alzheimer's Disease (EPMR-MA):

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

Inclusion of the 20 healthy participants in the "EPMR-MA" study (clinical trials ID NCT02492529) has been achieved, the inclusion phase will be achieved before 30th, december, 2017. Healthy controls data are pre-processed and the first analysis workflow proved promising, it should allow submitting a first paper at the beginning of 2018.

7.2.7. Semantic Dementia Imaging:

Participants: Jean-Christophe Ferré, Isabelle Corouge, Elise Bannier, Christian Barillot.

After demonstrating the relative preservation of fruit and vegetable knowledge in patients with semantic dementia (SD), we sought to identify the neural substrate of this unusual category effect. Nineteen patients with SD performed a semantic sorting task and underwent a morphometric 3T MRI scan. The grey-matter volumes of five regions within the temporal lobe were bilaterally computed, as well as those of two recently described areas (FG1 and FG2) within the posterior fusiform gyrus. In contrast to the other semantic categories we tested, fruit and vegetable scores were only predicted by left FG1 volume. We therefore found a specific relationship between the volume of a subregion within the left posterior fusiform gyrus and performance on fruits and vegetables in SD. We argue that the left FG1 is a convergence zone for the features that might be critical to successfully sort fruits and vegetables. We also discuss evidence for a functional specialization of the fusiform gyrus along two axes (lateral medial and longitudinal), depending on the nature of the concepts and on the level of processing complexity required by the ongoing task [28].

7.3. Research axis 3: Management of Information in Neuroimaging

Participants: Élise Bannier, Christian Barillot, Yao Chi, Isabelle Corouge, Olivier Commowick, Inès Fakhfakh, Michael Kain, Florent Leray, Julien Louis, Aneta Morawin, Mathieu Simon, Arnaud Touboulic.

The major topic that has been reached in the period concerns the sharing of data and processing tools in neuroimaging (through the ANR Neurolog and VIP projects, and more recently the "Programme d'Investissement d'Avenir" project such as OFSEP and FLI-IAM) that led to build a suitable architecture to share images and processing tools). Our overall goal within these projects was to set up a computational infrastructure to facilitate the sharing of neuroimaging data, as well as image processing tools, in a distributed and heterogeneous environment. These consortiums gathered expertises coming from several complementary domains: image processing in neuroimaging, workflows and grid computing, ontology development and ontology-based mediation. Shanoir (SHAring NeurOImaging Resources) is one of the major outcome of these projects. Shanoir uses semantics for concepts organization that are defined by the OntoNeuroLOG ontology. OntoNeuroLOG reuses and extends the OntoNeuroBase ontology. Both were designed using the same methodological framework, based on the use of the foundational ontology DOLCE (Descriptive Ontology for Linguistic and Cognitive

Engineering), and the use of a number of core ontologies, that provide generic, basic and minimal concepts and relations in specific domains such as Artefacts. Shanoir aims at establishing the conditions allowing, through the Internet, to share distributed information sources in neuroimaging, whether these sources are located in various centers of experimentation, clinical departments of neurology, or research centers in cognitive neurosciences or image processing. This enables a large variety of users to diffuse, exchange or reach neuroimaging information with appropriate access means, in order to be able to retrieve information almost as easily as if the data were stored locally by means of the "cloud computing" Storage as a Service (SaaS) concept. The Shanoir environment has been succesfully deployed to the Neurinfo platform were it is routinely used to manage images of the research studies. It is also currently being deployed for two large projets: OFSEP ("*Observatoire Français de la Sclérose en Plaques*") where up to 30000 patients will be acquired on a ten years frame, and the Image Analysis and Management (IAM) node of the France Life Imaging national infrastructure (FLI-IAM). Our team VisAGeS fulfills multiple roles in this nation-wide FLI project. Christian Barillot is the chair of the IAM node, Olivier Commowick is participating in the working group workflow and image processing and Michael Kain is the technical manager of the node. Apart from the team members, software solutions like MedInria and Shanoir are part of the final infrastructure software solutions.

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 was signed in October 2011 for 5 years and renewed in 2016. This contract defines the terms of the collaboration between Siemens, Visages and the Neurinfo platform. From 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).

8.2. Bilateral Grants with Industry

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. Allocation d'Installation Scientifique – Rennes Métropole

Participant: Emmanuel Caruyer.

Diffusion MRI has been a tremendous tool for the diagnosis of a number of brain pathologies such as abnormal development, neuro-degenerative or inflammatory disorders or brain tumors. Typical resolution in diffusion MRI is about 2mm – this suggests that in white matter, any volume element may contain millions of axons. Although currently we can characterize molecular diffusion, recent developments in diffusion MRI have shown the possibility to quantify more specifically some physical tissue parameters in white matter, such as axonal density and diameter: this means that we can retrieve information from a much smaller scale than the typical imaging resolution.

Acquisition time for this kind of measurements remains long and largely incompatible with in vivo application in humans. This projects aims at developing novel signal processing and acquisition methods for the reconstruction of microstructural informations in a reasonable acquisition time. We will study how sparse representations can be applied to the diffusion signal, in order to enable microstructure information reconstruction. In conjunction with this, we will develop acquisition sequences adapted to these sparse representations, in order to reconstruct the diffusion signal from fewer measurements, using results from the compressive sensing theory.

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 and 101 children included. A PhD 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. 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 will work in close collaboration to reach that ambitious goa.

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

9.2.5. 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. The results of this study were presented at the ESMRMB 2017 conference [38].

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. Preliminary results were presented at the ESMRMB and ECTRIMS 2017 conferences [33] [43].

9.2.6. Competitivity Clusters

9.2.6.1. The HEMISFER Project

Participants: Élise Bannier, Jean-Marie Batail, Isabelle Bonan, Isabelle Corouge, Claire Cury, Jean-Christophe Ferré, Jean-Yves Gauvrit, Marsel Mano, Pierre Maurel, Saman Norzade, Lorraine Perronnet, 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" [2]. 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, ...). 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 500keuros will be provided by the CominLabs cluster in the next 3 years to support this project (through experimental designs, PhDs, Post-docs and Expert Engineers).

9.2.6.2. France Life Imaging (FLI)

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

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.

9.2.6.3. 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

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

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. Collaborations in European Programs, Except FP7 & H2020

- **OpenAire-Connect**
  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.
  - Participants: Christian Barillot; Michael Kain; Camille Maumet
  - 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)
- **Health**
  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".
  - Participants: Christian Barillot, Michael Kain
  - Partners: see https://www.eithealth.eu/partners

9.4. International Initiatives

9.4.1. Inria Associate Teams Not Involved in an Inria International Lab

9.4.1.1. BARBANT

Title: Boston and Rennes, a Brain image Analysis Team

International Partner (Institution - Laboratory - Researcher):

Harvard University (United States) - Mathematics Department - Simon K. Warfield

Start year: 2015

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

BARBANT is an Inria associate team shared between Inria VisAGeS research team and the Computational Radiology Laboratory at the Boston Children's hospital (Harvard Medical School). This associate team aims 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, this project will allow 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.

9.4.2. Inria International Partners

9.4.2.1. Informal International Partners

- Collaboration with the Department of Computer Science, University of Verona: Emmanuel Caruyer visited the group of Gloria Menegaz and Alessandro Daducci in the context of the 2017 School on Brain Connectomics (http://brainconnectomics.org/).
- Collaboration with Neuropoly, Polytechnique Montreal: Haykel Snoussi is visiting the group of Julien Cohen-Adad and received an Inria-MITACS fellowship for a 3 months period (Nov. 2017-Jan. 2018). He will be working on the processing of diffusion-weighted images of multiple sclerosis patients' spinal cord in the context of the EMISEP project.
- Collaboration with Department of Mathematics and Statistcis at the Politechnico di Milano, Italy (Simone Vantini, Aymeric Stamm): Lorenzo Rota did visit the team between Oct. 2016 to March 2017 for his Tesi (Master degree) on "Application of shape analysis and functional data analysis tools on fiber bundles analysis".

9.5. International Research Visitors

9.5.1. Visits of International Scientists

- Simon Warfield and Benoit Scherrer, Harvard University, visited the VisAGeS team for the annual seminar on Jun. 2017.

9.5.2. Visits to International Teams

- Sudhanya Chatterjee visited the Computational Radiology Lab, the Boston Children's Hospital, at Harvard University in Nov. 2017. This stay was funded by the international program of University of Rennes 1. Christian Barillot and Olivier Commowick visited the same lab for a 3 days workshop in the context of the Associate Team.

- Haykel Snoussi visited the NeuroPoly Lab for 3 months from Nov. 2017. This stay was funded by the international program of University of Rennes 1.

10. Dissemination

10.1. Promoting Scientific Activities

10.1.1. Scientific Events Organisation

10.1.1.1. Member of the Organizing Committees

- Christian Barillot is member of the Board of Directors of IPMI conference series (Information Processing in Medical Imaging)
- Gilles Edan did organized the 25th anniversary workshop of the "Société Française de Neurologie" in Rennes on Nov. 30th

10.1.2. Scientific Events Selection

10.1.2.1. Member of the Conference Program Committees

- Christian Barillot was area chair of SPIE-MI and ISBI 2017
- Emmanuel Caruyer was Program Committee member of the CDMRI MICCAI workshop.

10.1.2.2. Reviewer

- ISBI (Emmanuel Caruyer, Olivier Commowick), ISMRM (Élise Bannier), MICCAI (Emmanuel Caruyer, Olivier Commowick, Christian Barillot), IPMI (Olivier Commowick, Christian Barillot).

10.1.3. Journal

10.1.3.1. Member of the editorial boards

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

10.1.3.2. Reviewing Activities

- Am J Neuroradiol (Élise Bannier), Comput Biol Med (Christian Barillot), Comput Meth Prog Bio (Christian Barillot), Front Neurosc (Pierre Maurel), Hum Brain Mapp (Emmanuel Caruyer), JMRI (Isabelle Corouge), IEEE TMI (Pierre Maurel, Olivier Commowick), Med Image Anal (Olivier Commowick), Med Phys (Christian Barillot) Neuroimage (Christian Barillot, Isabelle Corouge, Emmanuel Caruyer, Olivier Commowick), Pattern Recog Lett (Christian Barillot).

10.1.4. Leadership within the Scientific Community

- 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 [3] 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

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

10.1.5. Scientific Expertise

- Christian Barillot provided an expertise for the Royal Netherlands Academy of Arts and Sciences (KNAW)
- Christian Barillot provided expertise for the Austrian Science Fund (FWF), the NSERC / CRSNG Canada, the Wellcome Trust (UK)
- Christian Barillot provided an expertise for the KU Leuven, the University of British Columbia, Vancouver, Canada
- Christian Barillot provided expertise for the Idex Université Grenoble Alpes
- Emmanuel Caruyer provided expertise for the Inria Associate Team program.

10.1.6. Invited Talks

- Emmanuel Caruyer gave an invited lecture, "Validating tractography pipelines: the help of simulated phantoms" during the 2017 School on Brain Connectomics, Oct. 9th-13th at the University of Verona, Italy.
- Emmanuel Caruyer gave an invited lecture, "Validating tractography pipelines with the help of simulated phantoms" during the Computational Brain Connectivity Mapping winter school workshop, Nov. 20th-24th in Juan-les-Pins, France.
- Yao Chi and Isabelle Corouge - "Infrastructures pour le traitement et la gestion de données d'imagerie biologique et médicale ", Gen2bio National congress, Nantes, March 2017

10.2. Teaching - Supervision - Juries

10.2.1. Teaching

- Emmanuel Caruyer, Introduction to algorithms (33h), L3 SIF, ENS Rennes, France
- Antoine Legouhy, Introduction to statistical modeling and R language (18h), L2 Biology, Univ. Rennes, France
- Antoine Legouhy, Introduction to numerical analysis and Python language (40h), L1 Biology, Univ. Rennes, France
- Corentin Vallée, Introduction to Machine learning (12h), M1 Fundamental and Applied Microbiology, Univ. Rennes, France
- Corentin Vallée, Machine learning (24h), M1 Molecular and Cellular biology, Univ. Rennes, France
- Corentin Vallée, Machine learning (24h), M1 Bioinformatics, Univ. Rennes, France
- Christian Barillot, Élise Bannier, Emmanuel Caruyer, Olivier Commowick, Isabelle Corouge, Jean-Yves Gauvrit, Master SIBM, University of Angers-Brest-Rennes (26h)
- Christian Barillot is responsible for one semester
- Jean-Yves Gauvrit is the coordinator for the Master
- École Supérieure d'Ingénieur de Rennes (ESIR): Pierre Maurel, General image processing (60h), Algorithmics and complexity (60h), Medical imaging (60h)
- ENS Rennes: Pierre Maurel, Introduction to image processing (24h)
- ISTIC – Université of Rennes 1: Emmanuel Caruyer, Software Engineering (12h)

10.2.2. Supervision

- PhD in progress: Sudhanya Chatterjee, "Image-based Tissue Compartment Characterization of Neural Circuits with in-vivo MRI", Inria, from Nov 2015, Christian Barillot, Olivier Commowick, Jean-Christophe Ferré, Simon Warfield.

- 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 in progress : Antoine Legouhy, "Longitudinal brain altas creation, application to development sudies", CNRS, from Nov 2016, Christian Barillot, François Rousseau, Olivier Commowick.
- 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: Haykel Snoussi, “Diffusion MRI detection of early occurring spine lesions in relapsing-remitting multiple sclerosis with late physical impairment”, from Nov 2015, Christian Barillot, Gilles Edan, Emmanuel Caruyer
- PhD in progress: Pierre-Yves Jonin, “Relationships between context-free and context-rich memory: cognitive and neural subtrates”, Inria/Inserm/CNRS from Oct 2014, Christian Barillot (co-supervisor)
- PhD in progress: Maia Proisy, “Perfusion in neonates and in pediatric diseases”, Univ. Rennes 1/CHRU Rennes, from Oct 2014, Jean-Christophe Ferré (supervisor)
- PhD in progress: Anne Kerbrat, “Quantitative MR imaging in MS for Brain and Spine”, Univ. Rennes 1/CHRU Rennes, from Oct 2014, Gilles Edan (supervisor)
- PhD in progress: Stephanie Leplaideur, “As part of an fMRI substudy of a national research study on balance disorder rehabilitation”, Univ. Rennes 1/CHRU Rennes, from Oct 2017, Isabelle Bonan (supervisor)

10.2.3. Juries

- Olivier Commowick, PhD committee : Renaud Hedouin, Inria, Rennes; June 12th, 2017.
- Christian Barillot, PhD committee: Renaud Hedouin, Inria, Rennes; June 12th, 2017.
- Christian Barillot, PhD committee: Lorraine Perronnet, Inria, Rennes; September 7th, 2017;
- Christian Barillot, PhD committee: Chunfeng LIAN, Rouen, January 27, 2017
- Christian Barillot, PhD review: Mehdi Hadj-Hamou, Nice Sophia Antipolis, January 17, 2017
- Christian Barillot, PhD review: Marco Pizzolato, Nice Sophia Antipolis, March 31, 2017
- Christian Barillot, HDR review: Julien Lefevre, Marseille, March 30, 2017
- Christian Barillot, PhD review: Riccardo Pascuzzo, Mathematics Dept., Politechnico di Milano, Italy, Dec. 2017

10.3. Popularization

10.3.1. My thesis in 180 seconds

- Lorraine Perronnet and Cédric Meurée participated in the 2017 edition of the French edition of the Three Minutes Thesis competition" :
  - Lorraine Perronnet : "Combinaison de l’ElectroEncéphaloGraphie et de l’Imagerie par Résonance Magnétique fonctionnelle pour la réducation du cerveau par Neurofeedback"
  - Cédric Meurée : "Amélioration de la résolution d’images d’IRM de perfusion"

10.3.2. La semaine du cerveau (The Brain Week), from 13/03/2017 to 19/03/2017, Rennes

- Antoine Legouhy et Corentin Vallée : "PhD students processing MRI acquisition"
- Christophe Paya : "Discover brain anatomy with 3D models"
- Isabelle Corouge : "Neurinfo: An MRI dedicated to research"
- Pierre Maurel : "Let’s play to the brain quizz in 3D immersion (using oculus rift)"

- Emmanuel Caruyer : "Medinria: Computer science serving cerebral imaging"

10.3.3. Journées Française de Radiologie 2017, 13-16 Octobre, Paris

- Stand FLI-IAM (Michael Kain, Yao Chi, Aneta Morawin, Mathieu Simon, Ines Fahkfahk, Arnaud Touboulic, Christian Barillot)
- Journée du Réseau d'Entraide en IRM Multicentrique (REMI) co-organisée par Elise Bannier

10.3.4. 50 ans Inria, Paris

- Stand "MedInria" (Olivier Commowick, Pierre Maurel), Nov 7-8, 2017

10.3.5. Journée du Président de la Société Française de Neurologie, Rennes, 7 Décembre 2017

- Organised by Gilles Edan

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