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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 Medicine and Neuro-sciences

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Project-Team VISAGES

Keywords: Medical Images, Image Processing, Imaging Biomarkers, Neuroimaging, Image Guided Intervention

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2. Overall Objectives

2.1. Overall objectives

Since 1970s, medical imaging is a very rapidly growing research domain; the last three decades have shown a rapid evolution of the dimension and quantity of data physicians have to work with. The next decade will follow this evolution by adding not only new spatio-temporal dimensions to the image data produced and used in a clinical environment but also new scales of analysis (nano or micro biological and molecular images to macro medical images). Another evolution will also consist in adding new effectors during image-guided interventional procedures (surgery, interventional radiology...). The classical way of making use of these images, mostly based on human interpretation, becomes less and less feasible. In addition, the societal pressure for a cost effective use of the equipments on the one hand, and a better traceability and quality insurance of the decision making process on the other hand, makes the development of advanced computer-assisted medical imaging systems more and more essential. According to this context, our research team is devoted to the development of new processing algorithms in the context of medical image computing and computer-assisted interventions: image fusion (registration and visualization), image segmentation and analysis, management of image-related information ... In this very large domain, our work is primarily focused on clinical applications and for the most part on head and brain related diseases.

Research activities of the VISAGES team are concerned with the development of new processing algorithms in the field of medical image computing and computer assisted interventions: image fusion (registration and visualization), image segmentation and analysis, management of image related information ... Since this is a very large domain, for seek of efficiency, the application of our work will be primarily focused on clinical aspects and for the most part on head and neck related diseases. Our research efforts mainly concern:

- 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 the 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 labeling based on shape, multimodal and statistical information.
- The field of information management in neuroimaging we aim at enhancing the development of distributed and heterogeneous medical image processing systems

Concerning the application domains, we emphasize our research efforts on the neuroimaging domain with two up-front priorities: Image Guided Neurosurgery and Image Analysis in Multiple Sclerosis, while developing new ones especially in the interventional aspects (per-operative imagery, robotics...).

3. Scientific Foundations

3.1. Introduction

The scientific objectives of our team, concern the development of new medical image computing methods, dealing with image fusion (registration and visualization), image segmentation and analysis, and management of image-related information.

In addition, since these methods are devoted (but not specific) to solve actual medical applications, a constant concern is to build an evaluation framework at each stage of the methodological development process. Therefore, this topic is present as a transversal concern among the generic developments and the applications.

3.2. Registration

Image registration consists in finding a geometrical transformation in order to match n sets of images. Our objective is to work both, on rigid registration methods in order to develop new similarity measures for new imaging modalities, and on deformable registration to address the problem of tissue dissipation.

The registration between two images can be summarized by the expression [59]:

$$\underset{\theta \in \Theta}{arg\,min_{\Psi}} \Delta \left(\Phi_{\theta} \left(\Omega_s \right) - \Omega_t \right)$$

where Ω_s and Ω_t are respectively the two homologous sets of features respectively extracted from the source and the target images. These sets represent the two images in the registration process. They can be very different in nature, and can be deduced from a segmentation process (points, contours, crest lines ...) or directly from the image intensities (e.g. the joint histogram). Φ_{θ} is the transformation, ($\theta \in \Theta$ being the set of parameters for this transformation), Δ is the cost (or similarity) function, and Ψ is the optimization method. $\{\Omega, \Phi, \Delta, \Psi\}$ are the four major decisive factors in a registration procedure, the set Θ being a priori defined. In addition to new evolutions of these factors, a constant concern is to propose a methodology for validating this registration procedure. We already have been largely involved in these aspects in the past and will maintain this effort [64], [69], [66], [67], [63].

In the domain of **rigid registration**, our research is more focused on new problems coming from the applications. For instance, the mono and multimodal registration of ultrasound images is still an open problem. In this context we are working in looking at new similarity measures to better take into account the nature of the echographic signal. Similarly, in the interventional theatre, new matching procedures are required between for instance video, optical or biological images and the pre-operative images (CT, MRI, SPECT/PET, Angiography ...). Some of these problems can be very challenging. For a number of new applications, there are no existing solutions to solve these problems (e.g. fusion of biological images with interventional images and images coming from the planning).

In many contexts, a rigid transformation cannot account for the underlying phenomena. This is for instance true when observing evolving biological and physiological phenomena. Therefore, **deformable registration** methods (also called non-rigid registration) are needed [65]. In this domain, we are working in the following three directions:

- Non-rigid registration algorithms benefit from the incorporation of statistical priors. These statistical priors can be expressed locally (for instance through a statistical analysis of segmented shapes) or globally (by learning statistics about deformation fields directly). Statistical priors (local and global) are useful to capture probable or relevant deformations.
- Non-rigid registration methods can be broadly sorted in two classes: geometric methods that rely on the extraction and matching of sparse anatomical structures and photometric methods that rely on image intensities directly. These two kinds of methods have their advantages and drawbacks. We are working on further cooperative approaches where information of different nature (global, hybrid and local) could be mixed in an elegant mathematical way.
- Finally, our research is focused on a better modeling of the problems, mainly in two directions: firstly the relationship between the observed data (image intensities) and the variables (registration field) should be better understood. This leads to more adapted similarity measures in specific application contexts (for instance when registering ultrasound images or registering two textured reconstructed surfaces from stereovision [68]). Secondly, specific modeling of the deformation field is useful in specific contexts (for instance when matter is disappearing, fluid mechanics models will be more adapted than classical regularized deformation fields).

3.3. Image segmentation and analysis

This topic is very classical in computer vision. For the concern of medical image computing, we are focusing on the development of new tools devoted to the restoration of corrupted images coming from the sources and to the segmentation of anatomical structures based on deformable shape models.

Statistical methods for image restoration: New applications of medical imaging systems are parallel to the development or the evolution of new machinery which come with specific artifacts that are still only partially understood. This is the case for instance with high field MRI, 3D ultrasound imaging or other modalities. With regards to the images to process and analyze, these artifacts translate into geometric or intensity distortions that drastically affect not only the visual interpretation, but also most of the segmentation or registration algorithms, and the quantitative measures that follow. A better comprehension of these artifacts necessitates an increased dialogue between the physicists (who make the images), the computer scientists (who process the images) and the clinicians (who interpret the images). This should lead to define new, specifically-designed algorithms, based on statistical models taking into account the physics of the acquisition.

Segmentation using deformable shapes: We aim at proposing a generic framework to build probabilistic shape models in a 3D$+t$ space applied to biomedical images with a particular emphasis on the problem of modeling anatomical and functional structures in neuroimaging (functional delineations, cortical or deep brain structures). Based on our previous contributions in this domain [57], [58], [60], we work on a methodological framework to segment 3D shapes and to model, in space and time, shape descriptors which can be applied to new extracted shapes; this with the aim of proposing new quantification tools in biomedical imaging.

3.4. Statistical analysis in medical imaging

Nowadays, statistical analysis occupies a central place for the study of brain anatomy and function in medical imaging. It is indeed a question of exploiting huge image data bases, on which we look to reveal the relevant information: measure the anatomical variability to discover better what deviates from it, to measure the noise to discover an activation, etc., in brief, to distinguish what is statistically significant of what is not.

Statistical methods for voxel-based analysis: Statistical analysis tools play a key role in the study of the anatomy and functions of the brain. Typically, statisticians aim at extracting the significant information hidden below the noise and/or the natural variability. Some specific tools exist for the comparison of vector fields or geometrical landmarks. Some others have been developed for the analysis of functional data (PET, fMRI...). Thus, statistics are generally either spatial, or temporal. There is an increasing need for the development of statistics that consider time and space simultaneously. Applications include the follow-up of multiple sclerosis in MR images or the tracking of a deformable structure in an ultrasound image sequence.

Probabilistic atlases: One of the major problems in medical image analysis is to assist the clinician to interpret and exploit the high dimensionality of the images especially when he/she needs to confront his/her interpretation with "classical" cases (previous or reference cases). A solution to deal with this problem is to go through the use of an atlas which can represent a relevant *a priori* knowledge. Probabilistic atlases have been studied to tackle this problem but most of the time they rely on global references which are not always relevant or precise enough, to solve some very complex problems like the interpretation of inter-individual variations of brain anatomy and functions. Based on our previous work proposing a cooperation between global and local references to build such probabilistic atlases [62], [64], we are working to develop a probabilistic atlas capable of labelling highly variable structure (anatomical and functional ones), or for defining relevant indexes for using with data bases systems.

Classification and group analysis: One of the major problems in quantitative image analysis is to be able to perform clustering based on descriptors extracted from images. This can be done either by using supervised or unsupervised algorithms. Our objectives is to develop statistical analysis methods in order to discriminate groups of data for clinical and medical research purposes (e.g. pathologic *vs*. normal feature, male *vs.* female, right-handed *vs.* left-handed, etc.), these data may come from descriptors extracted by using image analysis procedures (e.g. shapes, measurements, volumes, etc.).

3.5. Management of information and knowledge in medical imaging and image-guided neurosurgery

There is a strong need of a better sharing and a broader re-use of medical data and knowledge in the neuroimaging and neurosurgical fields. One of the most difficult problems is to represent this information in such a way that the structure and semantics are shared between the cognitive agents involved (i.e. programs and humans). This issue is not new, but the recent evolution of computer and networking technology (most notably, the Internet) increases information and processing tools sharing possibilities, and therefore makes this issue prevailing. The notion of “semantic web” denotes a major change in the way computer applications will share information semantics in the future, with a great impact on available infrastructures and tools. In coherence with the rest of our research topics, we are focussing on brain imaging and neurosurgery. For brain imaging, this deals with accessing, referring to, and using knowledge in the field of brain imaging, whatever the kind of knowledge - either general knowledge (e.g. models of anatomical structures, “know-how” knowledge such as image processing tools), or related to individuals (such as a database of healthy subjects’ images). This covers both information of a numerical nature (i.e. derived from measurements such as images or 3D surfaces depicting anatomical features), of a symbolic nature (such as salient properties, names - referring to common knowledge - and relationships between entities), as well as processing tools available in a shared environment. Two major aspects are considered: (1) representing anatomical or anatomo-functional data and knowledge and (2) sharing neuroimaging data and processing tools. For neurosurgery, this deals with modeling and understanding the procedural and conceptual knowledge involved in the peri-operative process. This improved understanding and the associated formalization would lead to the development of context aware and intelligent surgical assist systems. Following an ontological approach, models should be defined for describing concepts and associated semantics used by the neurosurgeons when taking a decision or performing an action. Then, methods are required for acquiring/capturing both types of knowledge. Knowledge acquisition could be performed following different elicitation strategies, such as observations, interviews with experts, protocol or discourse analysis. Then we aim at analyzing the acquired data for better understanding of the surgical knowledge and for extracting formal models of surgical knowledge. We will focus on two aspects: 1) the procedural knowledge dedicated to the surgical scenario followed by the surgeon when performing a surgical procedure including main phases and the list of activities and 2) the conceptual knowledge involved in the cognitive processes followed by the surgeon in problem solving.

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.

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. Since MRI has a low specificity for defining in more detail the pathological changes which could discriminate between the different lesion types, but a high sensitivity to detect focal and also widespread, diffuse pathology of the normal appearing white and grey matter, our major objective within this application domain is to define new neuroimaging markers for tracking the evolution of the pathology from high dimensional data (e.g. nD+t MRI). 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.

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 for pre-surgical planning 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 [60], [62], [61], [64], 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.

4.2. Image guided intervention

Image-guided neurosurgical procedures rely on complex preoperative planning and intraoperative environment. This includes various multimodal examinations: anatomical, vascular, functional explorations for brain surgery and an increasing number of computer-assisted systems taking place in the Operating Room (OR). Hereto, using an image-guided surgery system, a rigid fusion between the patient's head and the preoperative data is determined. With an optical tracking system and Light Emitting Diodes (LED), it is possible to track the patient's head, the microscope and the surgical instruments in real time. The preoperative data can then be

merged with the surgical field of view displayed in the microscope. This fusion is called “augmented reality” or “augmented virtuality”.

Unfortunately, it is now fully admitted that this first generation of systems still have a lot of limitations. These limitations explain their relative added value in the surgeon’s decision-making processes. One of the most well known limitations is the issue related to soft tissue surgery. The assumption of a rigid registration between the patient’s head and the preoperative images only holds at the beginning of the procedure. This is because soft tissues tend to deform during the intervention. This is a common problem in many image-guided interventions, the particular case of neurosurgical procedures can be considered as a representative case. Brain shift is one manifestation of this problem but other tissue deformations can occur and must be taken into account for a more realistic predictive work. Other important limitations are related to the interactions between the systems and the surgeon. The information displayed in the operative field of view is not perfectly understood by the surgeon. Display modes have to be developed for better interpretation of the data. Only relevant information should be displayed and when required only. The study of information requirements in image guided surgery is a new and crucial topic for better use of images during surgery. Additionally, image guided surgery should be adapted to the specificities of the surgical procedure. They have to be patient specific, surgical procedure specific and surgeon specific. Minimally invasive therapies in neurosurgery emerged this last decade, such as Deep Brain Stimulation and Transcranial Magnetic Stimulation. Similar issues exist for these new therapies. Images of the patient and surgical knowledge must help the surgeon during planning and performance. Soft tissue has to be taken into account. Solutions have to be specific. Finally, it is crucial to develop and apply strong and rigorous methodologies for validating and evaluating methods and systems in this domain. At its beginning, Computer Assisted Surgery suffered from poor validation and evaluation. Numbers were badly computed. For instance, Fiducial Registration Error (FRE) was used in commercial systems for quantifying accuracy. It is now definitively obvious that FRE is a bad indicator of the error at the surgical target. Within this application domain, we aim at developing methods and systems, which overcome these issues for safer surgery. Intra operative soft tissue deformations will be compensated using surgical guidance tools and real-time imagery in the interventional theatre. This imagery can come from video (using augmented reality procedures), echography or even interventional MRI, biological images or thermal imagery in the future. For optimizing the surgical process and the interactions between the user and the CAS systems, we aim at studying the surgical expertise and the decision-making process involving procedural and conceptual knowledge. These approaches will help developing methods for better planning and performance of minimally invasive therapies for neurosurgery, such as Transcranial Magentic Stimulation (TMS) and Deep Brain Stimulation (DBS). All along this research, frameworks will be developed and applied for validation and evaluation of the developed methods and systems.

Intra-operative imaging in neurosurgery: Our major objective within this application domain is to correct for brain deformations that occur during surgery. Neuronavigation systems make it now possible to superimpose preoperative images with the surgical field under the assumption of a rigid transformation. Nevertheless, non-rigid brain deformations, as well as brain resection, drastically limit the efficiency of such systems. The major objective here is to study and estimate brain deformations using 3D ultrasound and video information.

Modeling of surgical expertise: Research on modeling surgical expertise are divided into two aspects: 1) understanding and modelling the surgical process defined as the list of surgical steps planned or performed by the surgeon, 2) understanding and modelling the surgeon’s information requirements via cognitive analysis of decision-making process and problem solving process. For the first aspect, the main long term objective consists in defining a global methodology for surgical process modelling including description of patient specific surgical process models (SPM) and computation of generic SPM from patient specific SPMs. Complexity of this project requires an international collaborative work involving different surgical disciplines. This conceptual approach has to be used in a clinical context for identifying added values and for publications. Resulting applications may impact surgical planning, surgical performance as well as surgical education. For the second aspect, we study the cognitive processes followed by surgeon during decision and action processes. In surgical expertise, dexterity is not the only involved skill. With the GRESICO laboratory from the University of Bretagne Sud, we will adapt models from cognitive engineering to study differences in cognitive

behaviour between neurosurgeons with different expertise levels as well as information requirements in a decision making or problem solving.

Robotics for 3D echography: This project is conducted jointly with the Lagadic project-team. The goal is to use active vision concepts in order to control the trajectory of a robot based on the contents of echographic images and video frames (taken from the acquisition theatre). Possible applications are the acquisition of echographic data between two remote sites (the patient is away from the referent clinician) or the monitoring of interventional procedure like biopsy or selective catheterisms.

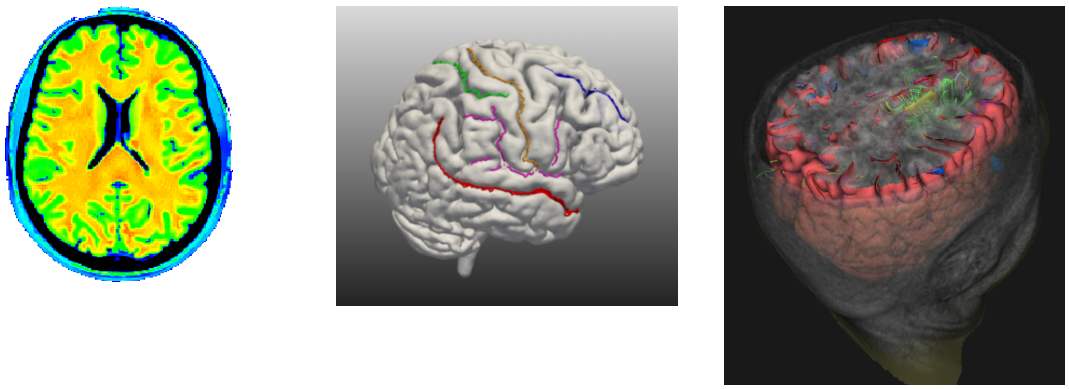
3D free-hand ultrasound: Our major objective within this application domain is to develop efficient and automatic procedures to allow the clinician to use conventional echography to acquire 3D ultrasound and to propose calibrated quantification tools for quantitative analysis and fusion procedures. This will be used to extend the scope of view of an examination.

5. Software

5.1. Vistal

Participant: Alexandre Abadie.

VistaL is a software platform of 3D and 3D+t image analysis allowing the development of generic algorithms used in different contexts (rigid and non-rigid registration, segmentation, statistical modelling, calibration of free-hand 3D ultrasound system and so on, diffusion tensor image processing, tractography). This software platform is composed of generic C++ template classes (Image3D, Image4D, Lattice and so on) and a set of 3D/3D+t image processing libraries. VistaL is a multi-operating system environment (Windows, Linux/Unix...). A web site presenting the project has been developped, precompiled packages and the SDK are now available. VistaL APP registration number is:IDDN.FR.001.200014.S.P.2000.000.21000.
See also the web page http://vistal.gforge.inria.fr.



(a) (b) (c)

Figure 1. Some ViSTAL results screenshots: a) The ViSTAL Logo, b) ViSTAL Brain surface and sulci modelisation, c) The ROI3D Extraction view

- Keywords: medical image processing, image analysis, registration, segmentation, denoising
- Software benefit: New methodological image processing, some GPU based algorithms, easy to use C++ library

- APP: IDDN.FR.001.200014.S.P.2000.000.21000
- License: Licence PropriÃ©taire
- Type of human computer interaction: C++ API and less complete Python API
- OS/Middleware: Windows, Mac et Linux.
- Required library or software: CMake (GPL) - ITK (BSD) - VTK (BSD) - Boost (BSD) - Libxml++ (LGPL) - CppUnit (LGPL)
- Programming language: C/C++, Python
- Documentation: Documentation Doxygen, documentation utilisateur.

5.2. Vistal-Tools

Participant: Alexandre Abadie.

The Vistal-Tools are a set of command line binaries based on the VisTaL library. These programs allow users to perform batch mode processing as well as scripting complex processing workflows. The most popular Vistal-Tools are NLMEANS (perform a NLMEANS filtering of 3D or 4D volumes), Registration (encapsulate the most common rigid registration algorithms), Tractography (track fibers from a DTI volume), etc

5.3. Online applications

Participant: Alexandre Abadie.

Online applications offers a web service for testing the tools developped by the members of the VISAGES team : denoising based on Non Local Mean algorithm (3D and 2D) (NLMEAN), 3D rigid registration, brain symmetry plan estimation. This application support the main formats used in medical imaging data : Nifti-1, Analyze7.5, Mha, GIS. The applications are available at this url http://www.irisa.fr/visages/benchmarks. More than 2000 processes have been benchmarked to date using this service.

5.4. CLARCS: C++ Library for Automated Registration and Comparison of Surfaces

Participants: Alexandre Abadie, Sylvain Prima.

In collaboration with Benoit Combes, within the 3D-MORPHINE ARC project (http://3dmorphine.inria.fr), we conceived and implemented a C++ library (named CLARCS) for the automated analysis and comparison of surfaces. One of the primary goal of this library is to allow the assessment and quantification of morphological differences of free-form surfaces from medical or paleoanthropological data.

- APP: IDDN.FR.001.130002.000.S.P.2011.000.21000
- Programming language: CC++

CLARCS was presented at the MeshMed MICCAI workshop (http://www2.imm.dtu.dk/projects/MeshMed/2011/index.html) [27] and is to be distributed through a dedicated website (http://clarcs.inria.fr).

We also developed a surface viewer (named 'Surface').

- APP: IDDN.FR.001.110019.000.S.P.2011.000.21000
- Programming language: C++, Python

5.5. SUBANA: SUrface-BAsed Neuronavigation on Atlas for TMS

Participant: Sylvain Prima.

In collaboration with Charles Garraud (http://www.syneika.com, Benoit Combes and Pierre Hellier (http://serpico.rennes.inria.fr), we developed a software for i) the automated surface reconstruction of the face and skull cap from sparsely acquired points and ii) the automated nonlinear registration of free-form surfaces. The latter step is implemented using the CLARCS library (http://clarcs.inria.fr). The primary goal of this software is the surface-based neuronavigation for transcranial magnetic stimulation. The method was presented at the MeshMed MICCAI workshop (http://www2.imm.dtu.dk/projects/MeshMed/2011/index.html) [30].

- APP: IDDN.FR.001.440010.000.S.P.2010.000.31230
- Patent: was granted, but the reference number is unknown
- Programming language: C++

5.6. Shanoir

Participants: Guillaume Renard, Alexandre Abadie, Bernard Gibaud, Christian Barillot.

Shanoir (Sharing NeurOImaging Resources) is an open source neuroinformatics platform 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-centres clinical studies on subjects or group of subjects.

Shanoir APP registration number is : IDDN.FR.001.520021.000.S.P.2008.000.31230

See also the web page http://www.shanoir.org

- Keywords: neuroimaging, ontology, sharing neuroimage
- Software benefit: full featured neuroimaging management system with additionnal web services
- APP: IDDN.FR.001.200014.S.P.2000.000.21000
- License: Licence QPL
- Type of human computer interaction: Online web application, web service (SOAP messages based)
- OS/Middelware: Windows, Mac et Linux.
- Required library or software : Java 1.6, JBoss server, JBoss Seam, JSF, JPA Hibernate, EJB, Richfaces, Faceless, Ajax4JSF, Dcmtk, Dcm4chee.
- Programming language: Java
- Documentation : see the website

5.7. QtShanoir

Participants: Alexandre Abadie, Olivier Commowick, Guillaume Renard.

QtShanoir is a C++ Qt based library for querying data from a Shanoir server. For those who don't know what is shanoir, see the shanoir website at http://shanoir.org. QtShanoir uses the soap based webservices provided by a shanoir server to get and display studies, patients, data with their associated metadata. In QtShanoir, you will find a set of Qt widgets (inherited from a QWidget object) that you can embed in your Qt application.

An APP registration is in progress and the library has been release in october under the LGPL license. See http://qtshanoir.gforge.inria.fr.

- Keywords : medical imaging, dicom
- Software benefit: offers a great solution to query a Shanoir server. Can be easily re used in larger Qt applications
- License: no defined licence for the moment
- Type of human computer interaction: C++ library
- OS/Middelware: Linux, Windows and Mac
- Required library or software : Qt
- Programming language: C++
- Documentation : http://qtshanoir.gforge.inria.fr/html

5.8. QtDcm

Participant: Alexandre Abadie.

QtDcm is a C++ library implementing a widget that can be re-used with the Qt development framework. With this new widget, it is now easy to view the content of a Dicom CD-Rom, to manage dicom Query/Retrieve from a PACS and to convert downloaded data in the nifti format (easy to use medical image format). QtDcm APP registration number (2010) is : IDDN.FR.001.490036.000.S.P.2010.000.31230 A new APP registration is in progress and the library has been release in october under the LGPL license. See http://qtdcm.gforge.inria.fr.

See also the web page https://www.irisa.fr/visages/members/aabadie/demos

- Keywords : medical imaging, dicom
- Software benefit: offers a great solution to query medical images storage server (Dicom PACS). Can be easily re used in larger Qt applications
- APP: IDDN.FR.001.490036.000.S.P.2010.000.31230
- License: no defined licence for the moment
- Type of human computer interaction: C++ library
- OS/Middelware: Linux, Windows and Mac
- Required library or software : Qt, Dcmtk, dcm2nii (optional)
- Programming language: C++
- Documentation : http://qtdcm.gforge.inria.fr/html

5.9. AutoMRI

Participant: Camille Maumet.

autoMRI is an SPM-based set of tools to study structural and functional MRI data. This software is currently made up of three modules : autofMRI, autoVBM and autoROI. autofMRI produces statistical maps of activations and deactivations at the group or the subject level based on functional MRI data. It can deal with block or event-related designs and is highly configurable in order to fit to a wide range of needs. autoVBM performs between-group voxel-based morphometric analysis in order to outline regions of grey (or white) matter volume reduction and increase. To further study a morphometric or a functional analysis, regions of interest analysis can be performed with autoROI. This module also provides the user with laterality indexes.

- Keywords : fMRI, MRI, SPM, automation
- Software benefit: Automatic MRI data analysis based on SPM. Once the parameters are set, the analysis can be run without human interaction.
- APP: Coming soon
- License: Ceccil
- Type of human computer interaction: Matlab function (script, no GUI)
- OS/Middleware: Linux/Windows
- Required library or software : Matlab, SPM, SPM toolboxes : Marsbar, LI-toolbox, NS
- Programming language: Matlab
- Documentation : Available

5.10. Medinria

Participants: Alexandre Abadie, Clément Philipot, Olivier Commowick.

Medinria is a national INRIA project shared between 4 INRIA teams (Asclepios, Athena, Parietal and Visages). 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) for two years, starting from late 2010. Th Visages team 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. Medinria is currently being packaged for the main distribution platforms and will be released in the first two weeks of January 2012.

See also the web page http://med.inria.fr

- Keywords: medical imaging, diffusion imaging, registration, filtering, user-friendly interface
- Software benefit: user-friendly interface to cutting-edge research tools for research clinicians. Straightforward to add functionalities through plugins.
- License: core: BSD, plugins: choice of each team.
- Type of human computer interaction: Qt-based GUI
- OS/Middelware: Windows, Mac et Linux.
- Required library or software : Qt, DTK, ITK, VTK.
- Programming language: C++

5.11. EMPROS

Participant: Elise Bannier.

EMPROS stands for "Event Related Emotional Prosody Recognition fMRI Task". This software implements a paradigm, i.e., a sequence of stimuli to be proposed to a subject, in order to study the perception of emotions with functional MRI. The subject hears meaningless but emotionally charged pseudo-words or onomatopes and selects the evoked emotion among 5 emotions (joy, fear, sadness, anger, neutral) by pushing a button. The response of the subject is registered while a BOLD fMRI acquisition images his/her brain. This paradigm aims at detecting the cortical areas involved in emotional perception.

This software will be distributed as open source code.

- APP: IDDN.FR. : APP registration in progress.
- Patent: under application
- Programming language: E-Basic
- Programming software: E-Prime v2.0

5.12. IOGAT

Participant: Elise Bannier.

IOGAT stands for "Iowa Gambling Task for Event Related fMRI". This software implements a paradigm, i.e., a sequence of stimuli to be proposed to a subject, in order to study the decision making process with functional MRI. The subject is presented with 4 decks of cards. Each deck is associated with a gain or a loss of money in a non random way: 2 of them are advantageous to the suject whereas the other 2 are disadvantageous. The subject is asked to pick up cards, choosing freely the deck he/she picks up the card from, so as to maximize his/her gains. While the subject performs this task, his/her brain is imaged with a BOLD fMRI acquisition. This paradigm is designed to localize the cortical areas involved in the decision making process.

This software will be distributed as open source code.

- APP: IDDN.FR. : APP registration in progress.
- License: the software is being licensed to CHU Besancon
- Patent: under application
- Programming language: E-Basic
- Programming software: E-Prime v2.0

6. New Results

6.1. Image Segmentation, Registration and Analysis

6.1.1. Quantitative Analysis of Open Curves in Brain Imaging: Applications to White Matter Fibers and Sulci

Participants: Meena Mani, Christian Barillot.

Shape, scale, orientation and position, the four physical features associated with open curves, have different properties so the usual approach has been to design different metrics and spaces to treat them individually. We took an alternative approach using a comprehensive Riemannian framework where joint feature spaces allow for analysis of combinations of features. We can compare curves by using geodesic distances, which quantify their differences. We validated the metrics we used, demonstrated practical uses and applied the tools to important clinical problems. To begin, specific tract configurations in the corpus callosum are used to showcase clustering results that depend on the Riemannian distance metric used. This nicely argues for the judicious selection of metrics in various applications, a central premise in our work. The framework also provides tools for computing statistical summaries of curves. We represented fiber bundles with a mean and variance, which describes their essential characteristics. This is both a convenient way to work with a large volume of fibers and is a first step towards statistical analysis. Next, we designed and implemented methods to detect morphological changes, which can potentially track progressive white matter disease. With sulci, we addressed the specific problem of labeling. An evaluation of physical features and methods such as clustering leads us to a pattern matching solution in which the sulcal configuration itself is the best feature.

6.1.2. Trimmed-likelihood estimation for focal lesions and tissue segmentation in multisequence MRI for multiple sclerosis

Participants: Sylvain Prima, Christian Barillot.

Following Daniel Garcia-Lorenzo's PhD, we proposed a new automatic method for segmentation of multiple sclerosis (MS) lesions in magnetic resonance images. The method performs tissue classification using a model of intensities of the normal appearing brain tissues. In order to estimate the model, a trimmed likelihood estimator is initialized with a hierarchical random approach in order to be robust to MS lesions and other outliers present in real images. The algorithm was first evaluated with simulated images to assess the importance of the robust estimator in presence of outliers. The method was then validated using clinical data in which MS lesions were delineated manually by several experts. Our method obtains an average Dice similarity coefficient (DSC) of 0.65, which is close to the average DSC obtained by raters (0.66) [15].

6.1.3. Segmentation of Multimodal Brain Images using Spectral Gradient and Graph Cut

Participants: Camille Maumet, Jean-Christophe Ferré, Christian Barillot.

Following Jeremy Lecoeur's PhD, we have introduced a new and original scale-space approach for segmenting normal and pathological tissue from multidimensional images. This method can perform a joint segmentation of three complementary imaging volumes at the same time by embedding a scale-space color invariant edge detector - i.e. the spectral gradient - as the boundary term in a graph cut optimization framework. Finally, we have proposed to extend this new scheme to more than three channels. We focussed the contribution onto the segmentation of tissues or structures of interest from multi-dimensional / multi-sequences brain MRI. This new multidimensional segmentation framework has been validated on simulated data and on clinical data (both pathological and healthy brains). We have exhibited the performances of this new method on various combinations of MRI sequences for the segmentation of normal and pathological tissues and showed how it is able to out perform competitive works. This work is under submission to an international journal.

6.1.4. Adaptive pixon represented segmentation for 3D MR brain images based on mean shift and Markov random fields

Participant: Christian Barillot.

Following Lei Lin and Daniel Garcia Lorenzo's PhDs, we proposed an adaptive pixon represented segmentation (APRS) algorithm for 3D magnetic resonance (MR) brain images. Different from traditional method, an adaptive mean shift algorithm was adopted to adaptively smooth the query image and create a pixon-based image representation. Then K-means algorithm was employed to provide an initial segmentation by classifying the pixons in image into a predefined number of tissue classes. By using this segmentation as initialization, expectation-maximization (EM) iterations composed of bias correction, a priori digital brain atlas information, and Markov random field (MRF) segmentation were processed. Pixons were assigned with final labels when the algorithm converges. The adoption of bias correction and brain atlas made the current method more suitable for brain image segmentation than the previous pixon based segmentation algorithm. The proposed method was validated on both simulated normal brain images from BrainWeb and real brain images from the IBSR public dataset. Compared with some other popular MRI segmentation methods, the proposed method exhibited a higher degree of accuracy in segmenting both simulated and real 3D MRI brain data. The experimental results were numerically assessed using Dice and Tanimoto coefficient [18].

6.1.5. EM-ICP strategies for joint mean shape and correspondences estimation: applications to statistical analysis of shape and of asymmetry

Participant: Sylvain Prima.

In collaboration with B. Combès, we proposed a new approach to compute the mean shape of unstructured, unlabelled point sets with an arbitrary number of points. This approach can be seen as an extension of the EM-ICP algorithm, where the fuzzy correspondences between each point set and the mean shape, the optimal non-linear transformations superposing them, and the mean shape itself, are iteratively estimated. Once the mean shape is computed, one can study the variability around this mean shape (e.g. using PCA) or perform statistical analysis of local anatomical characteristics (e.g. cortical thickness, asymmetry, curvature). To illustrate our method, we performed statistical shape analysis on human osseous labyrinths and statistical analysis of global cortical asymmetry on control subjects and subjects with situs inversus [29]. This work was led within the ARC 3D-MORPHINE (http://3dmorphine.inria.fr).

6.1.6. Surface-based method to evaluate global brain shape asymmetries in human and chimpanzee brains

Participant: Sylvain Prima.

Following Phd and PostDoc works from Benoit Combès and Marc Fournier, in this work we used humans and chimpanzees brain MRI databases to develop methods for evaluating global brain asymmetries. We performed brain segmentation and hemispheric surface extraction on both populations. The human brain segmentation pipeline was adapted to chimpanzees in order to obtain results of good quality. To alleviate the problems due to cortical variability we proposed a mesh processing algorithm to compute the brain global shape. Surface-based global brain asymmetries were computed on chimpanzee and human subjects using individual mid-sagittal plane evaluation and population-level mean shape estimation. Asymmetry results were presented in terms of axis-wise components in order to perform more specific evaluation and comparison between the two populations [35]. This work was led within the ARC 3D-MORPHINE (http://3dmorphine.inria.fr).

6.1.7. Computational techniques for the analysis of endocranial cast and endocranial structures

Participant: Sylvain Prima.

Following Phd and post-doc worlks from Benoit Combès and Marc Fournier, a series of studies were led within the ARC 3D-MORPHINE (http://3dmorphine.inria.fr) and were presented at the 1836th Journées de la Société d'Anthropologie de Paris (January 26-28) and at the 80th annual meeting of the American Association of Physical Anthropologists (April 12-16). These include: a method to assess 3D endocranial asymmetries in extant and fossil species: new insights into paleoneurology [48]; a method to map the distance between the brain and the inner surface of the skull [51], [34]; a method to compare bony labyrinths in humans, chimpanzees and baboons [28]; a method for the analysis of the endocranial shape and its relationship with ectocranial structures [41]; a new reconstruction of the frontal lobe and temporal pole of the Taung (*Australopithecus africanus*) endocast [32].

6.1.8. Evaluation of Registration Methods on Thoracic CT: The EMPIRE10 Challenge

Participant: Olivier Commowick.

We participated, as part of a collaboration with the Asclepios team, to the EMPIRE10 challenge on registration. EMPIRE10 (Evaluation of Methods for Pulmonary Image REgistration 2010) is a public platform for fair and meaningful comparison of registration algorithms which are applied to a database of intra-patient thoracic CT image pairs. Evaluation of non-rigid registration techniques is a non trivial task. This is compounded by the fact that researchers typically test only on their own data, which varies widely. For this reason, reliable assessment and comparison of different registration algorithms has been virtually impossible in the past. In this work we present the results of the launch phase of EMPIRE10, which comprised the comprehensive evaluation and comparison of 20 individual algorithms from leading academic and industrial research groups. All algorithms are applied to the same set of 30 thoracic CT pairs. Algorithm settings and parameters are chosen by researchers expert in the configuration of their own method and the evaluation is independent, using the same criteria for all participants. All results are published on the EMPIRE10 website (http://empire10.isi.uu.nl). The challenge remains ongoing and open to new participants. Full results from 24 algorithms have been published at the time of writing. This article details the organisation of the challenge, the data and evaluation methods and the outcome of the initial launch with 20 algorithms. More details are available in [20].

6.2. Image processing on Diffusion Weighted Magnetic Resonance Imaging

6.2.1. Diffusion Directions Imaging (DDI)

Participants: Aymeric Stamm, Christian Barillot.

Diffusion magnetic resonance imaging (dMRI) is the reference *in vivo* modality to study the connectivity of the brain white matter. Images obtained through dMRI are indeed related to the probability density function (pdf) of displacement of water molecules subject to restricted diffusion in the brain white matter. The knowledge of this diffusion pdf is therefore of primary importance. Several methods have been devised to provide an estimate of it from noisy dMRI signal intensities. They include popular diffusion tensor imaging (DTI) as well as higher-order methods. These approaches suffer from important drawbacks. Standard DTI cannot directly cope with multiple fiber orientations. Higher-order approaches can alleviate these limitations but at the cost of increased acquisition time. We have proposed, in the same vein as DTI, a new parametric model of the diffusion pdf with a reasonably low number of parameters, the estimation of which does not require acquisitions longer than those used in clinics for DTI. This model also accounts for multiple fiber orientations. It is based on the assumption that, in a voxel, diffusing water molecules are divided into compartments. Each compartment is representative of a specific fiber orientation (which defines two opposite directions). In a given compartment, we further assume that water molecules that diffuse along each direction are in equal proportions. We then focus on modeling the pdf of the displacements of water molecules that diffuse only along one of the two directions. Under this model, we derive an analytical relation between the dMRI signal intensities and the parameters of the diffusion pdf. We exploit it to estimate these parameters from noisy signal intensities. We carry out a cone-of-uncertainty analysis to evaluate the accuracy of the estimation of the fiber orientations and we evaluate the angular resolution of our method. Finally, we show promising results on real data and propose a visualization of the diffusion parameters which is very informative to the neurologist. This work was conducted in collaboration with Patrick Perez from Technicolor [56].

6.2.2. Anatomy of the corticospinal tracts: evaluation of a deterministic tractography method

Participants: Romuald Seizeur, Nicolas Wiest-Daesslé, Sylvain Prima, Camille Maumet, Jean-Christophe Ferré, Xavier Morandi.

In this work, anatomical, diffusion-weighted and functional 3T MRI were acquired on 15 right-handed healthy subjects to analyse the portions of the corticospinal tract (CST) dedicated to hand motor and sensory functions. The three MR images were then registered and regions of interest were delineated i) in the mid-brain using 3D T1-weighted MRI, and ii) in the cortex using fMRI using hand motor and sensory tasks. Deterministic tractography was then performed using these two ROIs from diffusion-weighted MRI after the diffusion tensors were computed. The ventrolateral tract fibers of the CST were generally not properly identified, due to fiber crossing in the corona radiata [55].

6.2.3. Tracking of the Hand Motor Fibers within the Corticospinal Tract Using Functional, Anatomical and Diffusion MRI

Participants: Romuald Seizeur, Nicolas Wiest-Daesslé, Olivier Commowick, Sylvain Prima, Aymeric Stamm, Christian Barillot.

In this work, we proposed to compare three diffusion models to track the portion of the corticospinal tract dedicated to the hand motor function (called hand motor fibers hereafter), using diffusion, functional and anatomical MRI. The clinical diffusion data have few gradient directions and low b-values. In this context, we show that a newly introduced model, called diffusion directions imaging (DDI) outperforms both the DTI and the ODF models. This new model allows to capture several diffusion directions within a voxel, with only a low number of parameters. Two important results are that i) the DDI model is the only one allowing consistent tracking from the mesencephalon to the most lateral part of the cortical motor hand area, and that ii) the DDI model is the only model able to show that the number of hand motor fibers in the left hemisphere is larger than in the contralateral hemisphere for right-handed subjects; the DDI model, as the other two models, fails to find such a difference for left-handed subjects. To the best of our knowledge, this is the first time such results are reported, at least on clinical data. [44].

6.2.4. Multifiber Deterministic Streamline Tractography Based on a New Diffusion Model

Participants: Olivier Commowick, Romuald Seizeur, Nicolas Wiest-Daesslé, Sylvain Prima, Aymeric Stamm, Christian Barillot.

In this work, we have built upon a new model, describing the random motion of water molecules in fibrous tissues, to develop a multifiber deterministic tractography algorithm. We apply this algorithm to track the corticospinal tract of the human brain, in both controls and patients with tumors. [31].

6.2.5. Automated detection of white matter fiber bundles

Participant: Olivier Commowick.

This work is part of a collaboration with the Computational Radiology Laboratoy headed by Simon Warfield in Boston, USA. For this topic, we have studied how white matter fiber bundles can be extracted in a reproducible way from diffusion tensor MRI. Usually, white matter (WM) fiber bundles of the brain can be delineated by diffusion tractography utilizing anatomical regions-of-interest (ROI). These ROIs can specify seed regions in which tract generation algorithms are initiated. Interactive identification of such anatomical ROIs enables the detection of the major WM fiber tracts, but suffers from inter-rater and intra-rater variability, and is time consuming. We developed and compared three techniques for automated delineation of ROIs for the detection of two major WM fiber tracts in 12 healthy subjects. Tracts identified automatically were compared quantitatively to reference standard tracts derived from carefully hand-drawn ROIs. Based on comparative performance of the experimental techniques, a multi-template label fusion algorithm was found to generate tracts most consistent with the reference standard. More details on this work are available in [43].

6.3. Management of Information and Semantic Processing

6.3.1. NeuroLOG project: Sharing of data and sharing of processing tools in neuroimaging

Participants: Bernard Gibaud, Bacem Wali.

The NeuroLOG project (ANR ANR-06-TLOG-024) came to its end in december 2010. However, we managed to maintain the NeuroLOG platform in operation, which is important with regards to publication. Several papers are in preparation. A lot of efforts were devoted in 2011 to submit a new proposal to ANR, building on NeuroLOG's achievements. A NeuroLOG2 project was submitted in March to the ANR TECSAN program (health technology). This new project aimed both at going on developing the technology for sharing data and processing tools, while being more involved in neuroimaging applications. Two application fields were proposed, concerning research on Alzheimer Desease, on the one hand, and epilepsy, on the other hand. The consortium was enlarged accordingly, with the integration of new partners such as the EDELWEISS project (INRIA, Sophia), the U642 LTSI (INSERM, Rennes) and U1028 CNRL (INSERM, Lyon). A new submission is envisaged in 2012, taking into account the recommendations of ANR.

6.3.2. Semantic annotation of anatomic images in neuroimaging

Participants: Bernard Gibaud, Tristan Moreau, Xavier Morandi.

This project aims at exploring the feasibility of relying on symbolic knowledge provided by ontologies to assist the annotation of anatomical images. The basic assumption underlying this work is that ontologies not only can provide a reference vocabulary to annotate images, but they can also provide useful prior knowledge that may help the annotation process itself, an assumption supported by the interesting results obtained by Ammar Mechouche in his PhD work. The current study, initiated in 2010 in the context of the Master student work of Elsa Magro (analysis of intra-precentral connections and of the U-fibers connecting the precentral and postcentral gyri) was pursued in 2011 (PhD work of Tristan Moreau). Our most recent works try to establish a parcellation of the grey-matter white matter surface based on the connectivity profiles of individual points of this surface, valid for a population of subjects. This is a prerequisite before identifying the more salient fiber bundles to be modelled in our ontology.

6.3.3. Semantic annotation of models and simulated medical images

Participants: Bernard Gibaud, Germain Forestier.

This project is carried out in the context of the Virtual Imaging Platform (VIP) project, an ANR project aiming at setting up a platform for facilitating the use of image simulation software in medical imaging, and coordinated by Creatis (Lyon). The platform will integrate simulation software to generate image of different modalities (i.e. MR, CT, PET, US). In this project, VISAGES is in charge of coordinating the development of an application ontology to support the annotation of the data shared in this platform (simulated images, anatomical models and physiological models used in simulations), as well as the annotation of simulation software components, in order to facilitate their interoperation within the platform. The work completed in 2011 is a continuation of what was started in 2010. Our major result in 2011 is an ontology allowing to annotate the models used for medical image simulations. Actually models are composed of files containing images (3D voxel maps) or surfaces (meshes). Our ontology includes entities called model layers associated with those files and depicting the model contents in terms of : anatomical structures, pathological structures, foreign bodies, contrast agents etc. Each individual object present in the model is referred to by an object layer part to which physical parameter distributions can be associated, that are used by simulation software. The ontology was modelled as OntoSpec documents (a methodology defined by Gilles Kassel in Amiens), then implemented in OWL. A preliminary version of this model was presented at a workshop organized by EBI in Cambridge in March 2011 (in the context of the VPH/RICORDO project). A more complete version was presented at the CBMS'2011 Conference in Bristol. VIP is a collaborative project, supported by ANR (Agence National de la Recherche), through grant ANR-AA-PPPP-000. The partners with whom we have the tightest relations are: Creatis (Lyon), I3S (Sophia), CEA-LETI (Grenoble).

6.4. Image Guided Intervention

6.4.1. Classification of Surgical Process using Dynamic Time Warping

Participants: Pierre Jannin, Germain Forestier, Florent Lalys, Brivael Trelhu.

Toward the creation of new computer-assisted intervention systems, Surgical Process Models (SPMs) are more and more used as a tool for analyzing and assessing surgical interventions. SPMs represent Surgical Process (SPs) which are defined as symbolic structured descriptions of surgical interventions, using a pre-defined level of granularity and a dedicated terminology. In this context, an important challenge is the creation of new metrics for the comparison and the evaluation of SPs. Thus, correlations between these metrics and pre-operative data allow to classify surgeries and highlight specific information on the surgery itself and on the surgeon, such as its level of expertise. In this study, we explored the automatic classification of a set of SPs based on the Dynamic Time Warping (DTW) algorithm. DTW allows to compute a distance between two SPs that focuses on the different types of activities performed during the surgery and their sequencing, by minimizing the time differences. Indeed, it turns out to be a complementary approach to classical methods focusing only on the time and the number of activities differences. Experiments were carried out on 24 lumbar

disc herniation surgeries to discriminate the level of expertise of surgeons according to prior classification of SPs. Supervised and unsupervised classification experiments have shown that this approach was able to automatically identify groups of surgeons according to their level of expertise (senior and junior), and opens many perspectives for the creation of new metrics for surgeries comparison and evaluation. This work was was performed in collaboration with Dr. Laurent Riffaud, and xas published in the International Journal of Biomedical Informatics [14].

6.4.2. Surgical phases detection from microscope videos by machine learning

Participants: Pierre Jannin, Florent Lalys, Xavier Morandi.

Surgical process analysis and modeling is a recent and important topic aiming at introducing a new generation of computer-assisted surgical systems. Among all of the techniques already in use for extracting data from the Operating Room, the use of image videos allows automating the surgeons' assistance without altering the surgical routine. In collaboration with Carl Zeiss Medical Systems (Oberkochen, Germany), we proposed an application-dependent framework able to automatically extract the phases of the surgery only by using microscope videos as input data and that can be adaptable to different surgical specialties. First, four distinct types of classifiers based on image processing were implemented to extract visual cues from video frames. Each of these classifiers was related to one kind of visual cue: visual cues recognizable through color were detected with a color histogram approach, for shape-oriented visual cues we trained a Haar classifier, for texture-oriented visual cues we used a bag-of-word approach with SIFT descriptors, and for all other visual cues we used a classical image classification approach including a feature extraction, selection, and a supervised classification. The extraction of this semantic vector for each video frame then permitted to classify time series using either Hidden Markov Model or Dynamic Time Warping algorithms. The framework was validated on cataract surgeries, obtaining accuracies of 95%. This work was performed in collaboration with Laurent Riffaud and was published at the ORASIS and MICCAI conferences.

6.4.3. Surgical tools recognition and pupil segmentation for cataract surgery modeling

Participants: Pierre Jannin, Florent Lalys.

In the above project work performed through the MS intership of David Bouget, we focus on developping an application-dependant framework able to extract surgical phases from microscope videos. The aim of this study was to enhance results of this framework by adding new visual cues extraction modules. We studied two modules: one to segment the pupil and one to extract and recognize surgical tools. Validation studies, performed with cataract surgery videos, show an increase of the framework accuracy to detect eight surgical phases. This work has been accepted at the MMVR 2012 international conference.

6.4.4. Automatic computation of electrode trajectories for Deep Brain Stimulation: a hybrid symbolic and numerical approach

Participants: Pierre Jannin, Florent Lalys, Camille Maumet, Claire Haegelen.

The optimal electrode trajectory is needed to assist surgeons in planning Deep Brain Stimulation (DBS). We developed and tested a method for image-based trajectory planning. Rules governing the DBS surgical procedure were defined with geometric constraints. A formal geometric solver using multimodal brain images and a template built from 15 brain MRI scans were used to identify a space of possible solutions and select the optimal one. For validation, a retrospective study of 30 DBS electrode implantations from 18 patients was performed. A trajectory was computed in each case and compared with the trajectories of the electrodes that were actually implanted. Computed trajectories had an average difference of 6.45 degrees compared with reference trajectories and achieved a better overall score based on satisfaction of geometric constraints. Trajectories were computed in 2min for each case. We demonstrated that a rule-based solver using pre-operative MR brain images can automatically compute relevant and accurate patient-specific DBS electrode trajectories. This work was published in the International Journal of Computer Assisted Radiology and Surgery.

6.4.5. Analysis of electrodes' placement and deformation in deep brain stimulation from medical images

Participants: Pierre Jannin, Florent Lalys, Alexandre Abadie, Xavier Morandi, Claire Haegelen.

This work was performed during the intership of Maroua Mehri. Deep brain stimulation (DBS) is used to reduce the motor symptoms such as rigidity or bradykinesia, in patients with Parkinson's disease (PD). The Subthalamic Nucleus (STN) has emerged as prime target of DBS in idiopathic PD. However, DBS surgery is a difficult procedure requiring the exact positioning of electrodes in the pre-operative selected targets. This positioning is usually planned using patients' pre-operative images, along with digital atlases, assuming that electrode's trajectory is linear. However, it has been demonstrated that anatomical brain deformations induce electrode's deformations resulting in errors in the intra-operative targeting stage. In order to meet the need of a higher degree of placement accuracy and to help constructing a computer-aided-placement tool, we studied the electrodes' deformation in regards to patients' clinical data (i.e., sex, mean PD duration and brain atrophy index). Firstly, we presented an automatic algorithm for the segmentation of electrode's axis from post-operative CT images, which aims to localize the electrodes' stimulated contacts. To assess our method, we applied our algorithm on 25 patients who had undergone bilateral STNDBS. We found a placement error of 0.91+/-0.38 mm. Then, from the segmented axis, we quantitatively analyzed the electrodes' curvature and correlated it with patients' clinical data. We found a positive significant correlation between mean curvature index of the electrode and brain atrophy index for male patients and between mean curvature index of the electrode and mean PD duration for female patients. These results help understanding DBS electrode' deformations and would help ensuring better anticipation of electrodes' placement. This work has been accepted at the SPIE Medical Imaging 2012 conference.

6.5. Medical Image Computing in Brain Pathologies

6.5.1. Detection of cortical abnormalities in drug resistant epilepsy

Participants: Elise Bannier, Camille Maumet, Jean-Christophe Ferré, Jean-Yves Gauvrit, Christian Barillot.

Focal cortical dysplasia and heterotopias are a recognized cause of epilepsy. Indication for drug resistant epilepsy surgery relies on precise localization and delineation of the epileptogenic zone and lesion identification is an important issue. Visual detection and delineation of small or occult focal cortical dysplasia and heterotopias on MR images are sometimes difficult. The Double Inversion Recovery (DIR) imaging, by nulling white matter and cerebrospinal fluid signal, seems particularly appropriate to detect intracortical lesions in MS and Epilepsy. In this work we evaluated at 3T and using voxel-based morphometry (VBM) the ability of a 9-minute 3D DIR sequence to detect cortical and juxtacortical lesions in drug resistant epileptic patients. Results on 21 patients and 20 healthy volunteers show the potential of 3D DIR VBM to detect cortical abnormalities. Further work will investigate the use of alternate registration frameworks (e.g. DARTEL), improved intensity normalization of 3D DIR images and joint 3D T1-w/DIR analysis to improve detection sensitivity and specificity.

6.5.2. Multi-modal NMR cartography of USPIO positive and negative tissues in MS human models

Participants: Olivier Luong, Olivier Commowick, Christian Barillot.

The main objective of this work was to build an input object for an MRI simulator. Each voxel of the object is defined by its three physical entities which are T_1, T_2 and ρ MR relaxation parameters. In our case, this object comes from Multiple Sclerosis brains. We initially defined a simplified model with respect to pathological regions, based on a combination of the Brainweb template and the lesion manually delineated from pathological images. From this, we allocated relaxation parameters for each voxels of these ROI based on fixed values of T_1, T_2 and ρ (initialized from in vivo relaxometry acquisitions). This model model does not allow to obtain a fine description of the pathological regions, as potentially defned by differential contrats between USPIO and Gd enhanced images. In order to obtain this finer description, we used an MRI simulator based on the Bloch's equations, in order to estimated the T_1, T_2 and ρ parameters on each voxel from initial conditions coming from in-vivo images acquired in Rennes by using the USPIO-6 protocol.

This work is part of the VIP collaborative project, supported by ANR (Agence National de la Recherche), through grant ANR-AA-PPPP-000. The partners with whom we have the tightest relations are: Creatis (Lyon), I3S (Sophia), CEA-LETI (Grenoble).

6.6. Vascular Imaging and Arterial Spin Labelling

6.6.1. Arterial spin labeling for motor activation mapping at 3T

Participants: Jan Petr, Aymeric Stamm, Elise Bannier, Jean-Christophe Ferré, Jean-Yves Gauvrit, Christian Barillot.

Functional arterial spin labeling (fASL) is an innovative biomarker of neuronal activation that allows direct and absolute quantification of activation-related CBF and is less sensitive to venous contamination than BOLD fMRI. This study evaluated fASL for motor activation mapping in comparison with BOLD fMRI in terms of involved anatomical area localization, intra-individual reproducibility of location, quantification of neuronal activation, and spatial accuracy. Imaging was performed at 3T with a 32-channel coil and dedicated post-processing tools were used. Twelve healthy right-handed subjects underwent fASL and BOLD fMRI while performing a right hand motor activation task. Three sessions were performed 7days apart in similar physiological conditions. Our results showed an activation in the left primary hand motor area for all 36 sessions in both fASL and BOLD fMRI. The individual functional maps for fASL demonstrated activation in ipsilateral secondary motor areas more often than the BOLD fMRI maps. This finding was corroborated by the group maps. In terms of activation location, fASL reproducibility was comparable to BOLD fMRI, with a distance between activated volumes of 2.1mm and an overlap ratio for activated volumes of 0.76, over the 3 sessions. In terms of activation quantification, fASL reproducibility was higher, although not significantly, with a CVintra of 11.6% and an ICC value of 0.75. Functional ASL detected smaller activation volumes than BOLD fMRI but the areas had a high degree of co-localization. In terms of spatial accuracy in detecting activation in the hand motor area, fASL had a higher specificity (43.5%) and a higher positive predictive value (69.8%) than BOLD fMRI while maintaining high sensitivity (90.7%). The high intra-individual reproducibility and spatial accuracy of fASL revealed in the present study will subsequently be applied to pathological subjects [25].

6.6.2. Construction and evaluation of a quantitative ASL brain perfusion template at 3T

Participants: Jan Petr, Elise Bannier, Jean-Christophe Ferré, Jean-Yves Gauvrit, Christian Barillot.

Arterial spin labeling (ASL) allows non-invasive imaging and quantification of brain perfusion by magnetically labeling blood in the brain-feeding arteries. ASL has been used to study cerebrovascular diseases, brain tumors and neurodegenerative disorders as well as for functional imaging. The use of a perfusion template could be of great interest to study inter-subject regional variation of perfusion and to perform automatic detection of individual perfusion abnormalities. However, low spatial resolution and partial volume effects (PVE) issues inherent to ASL acquisitions remain to be solved. The purpose of this study is to enhance the template quality by using DARTEL non-rigid registration and by correcting for PVE. PICORE-Q2TIPS ASL datasets were acquired on 25 healthy volunteers at 3T. Four methods of creating the template were evaluated using leave-one-out cross correlation. Subsequently, these methods were applied to hyper-perfusion detection on functional ASL data of 8 healthy volunteers and compared with the standard generalized linear model (GLM) activation detection [40].

6.6.3. Evaluation of functional arterial spin labeling data using a perfusion template

Participants: Jan Petr, Elise Bannier, Jean-Christophe Ferré, Jean-Yves Gauvrit, Christian Barillot.

ASL allows non-invasive imaging and quantification of brain perfusion by magnetically labeling blood in the brain-feeding arteries. In this study, a template created from perfusion images of 25 resting healthy subjects was used to automatically detect hyper perfusion patterns of 8 other subjects. DARTEL registration was used to improve the precision of the template and partial volume correction to prevent interpolation artifacts. This study showed that a perfusion template can be used to assess task-related activation zones in functional ASL data while using only activated phase. Two assumptions can be made to explain why standard functional analysis yields slightly larger activation regions. First, the use of FWHM 6mm Gaussian kernel possibly enlarges the detected zones. Second, the data analyzed using SPM contains both resting and activated phases whereas only the activated phase was compared to the template. Future work will focus on detection of hyperperfusion in different neurodegenerative diseases taking into account registration issues of pathological T1 images. [24].

6.6.4. A contrario detection of focal brain perfusion abnormalities based on an ASL template

Participants: Camille Maumet, Elise Bannier, Jean-Christophe Ferré, Pierre Maurel, Christian Barillot.

Arterial Spin Labeling (ASL) is a recent MRI perfusion technique which enables quantification of cerebral blood flow (CBF). The presence of regions with atypical CBF can characterize a pathology. In brain tumors for instance, perfusion increase can be directly related to the grading of the malignant tissues. It is therefore of great interest to identify these regions in order to provide the patients with the most appropriate therapy. In this work, we proposed to detect abnormal brain perfusion by using an a contrario framework and an ASL template as a model of normal perfusion. Validation was undertaken by qualitative comparison with CBF extracted from dynamic susceptibility weighted contrast enhanced (DSC) sequence. We experimented this framework on four patients presenting brain tumors. Results show that high perfusion regions found in DSC CBF maps are correctly identified as hyperperfusions with a contrario detection. Automatic detection has clear advantages over manual delineation since it is less time-consuming, does not depend on medical expertise and allows quantification of perfusion abnormalites within the detected regions.

6.6.5. Peripheral angiography using non-contrast enhanced imaging

Participants: Elise Bannier, Isabelle Corouge, Nicolas Wiest-Daesslé.

Arteriography, CT and MR angiography are routinely performed in patients presenting peripheral arteriopathy. Yet, contrast agent injection is contraindicated in patients with renal insufficiency and the underlying risk of developing nephrogenic systemic fibrosis further encourages research on non-contrast enhanced MR angiography techniques (NCE MRA). In this context, we evaluated at 3T the ability of a 2 NCE MRA new sequences to reliably detect peripheral vascular abnormalities from the abdominal aorta to the calf in comparison with CE MRA.

A first study including 20 healthy volunteers and 4 patients evaluated the NCE ECG-gated T2 TSE NATIVE SPACE MRI sequence. It demonstrated its potential in noninvasively imaging peripheral vasculature, from the abdominal aorta to the calf, within a clinically acceptable acquisition duration. Although signal inhomogeneity and peristalsis artifacts were sometimes observed in the abdominal aortic station, very good image quality was obtained on all subjects on lower stations, with no venous contamination.

A second study evaluated the NCE ECG-gated Quiescent Interval Single Shot (QISS) MRA sequence. Preliminary results obtained on 11 patients show that several lesions were not detected with QISS MRA especially on the thigh station. Ongoing patient inclusions are required to confirm these results. Finally, a concomitant NCE and CE MRA reading will be performed to compare stenosis grading, stenosis-thrombosis mismatch and lesions not detected with NCE MRA.

6.7. Abnormal functional lateralization and activity of language brain areas in developmental dysphasia

Participants: Clément De Guibert, Camille Maumet, Jean-Christophe Ferré, Pierre Jannin, Christian Barillot.

Atypical functional lateralization and specialization for language have been proposed to account for developmental language disorders, yet results from functional neuroimaging studies are sparse and inconsistent. This functional magnetic resonance imaging study compared children with a specific subtype of specific language impairment affecting structural language, to a matched group of typically developing children using a panel of four language tasks neither requiring reading nor metalinguistic skills, including two auditory lexico-semantic tasks (category fluency and responsive naming) and two visual phonological tasks based on picture naming. Data processing involved normalizing the data with respect to a matched pairs paediatric template, groups and between-groups analysis, and laterality indices assessment within regions of interest using single and combined task analysis. Children with specific language impairment exhibited a significant lack of left lateralization in all core language regions (inferior frontal gyrus-opercularis, inferior frontal gyrus-triangularis, supramarginal gyrus and superior temporal gyrus), across single or combined task analysis, but no difference of lateralization for the rest of the brain. Between-group comparisons revealed a left hypoactivation of Wernicke's area at the posterior superior temporal/supramarginal junction during the responsive naming task, and a right hyperactivation encompassing the anterior insula with adjacent inferior frontal gyrus and the head of the caudate nucleus during the first phonological task. This study thus provides evidence that this subtype of specific language impairment is associated with atypical lateralization and functioning of core language areas [12].

7. Contracts and Grants with Industry

7.1. Contracts with Industry

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

In the context of the Neurinfo imaging platform, a partnership between Siemens SAS - Healthcare and University of Rennes 1 was signed in October 2011 for 5 years. This contract defines the terms of the collaboration between Siemens and the Neurinfo platform. The Neurinfo platform is now granted access to source code and/or object code of selected MRI sequences. This a major advance in the collaboration since it will enable the development of MRI sequences on site. Besides, the Arterial Spin Labeling (ASL) was grounded as a key research activity by both parties and will be the object of a strong collaboration, particularly on the sequence development side.

8. Partnerships and Cooperations

8.1. Regional Initiatives

8.1.1. TransIRMf project

Participants: Christian Barillot, Jean-Yves Gauvrit, Jean-Christophe Ferré, Elise Bannier, Camille Maumet, Isabelle Corouge.

duration : 18 months, from 01/10/2010

The objective of this project is to set up and validate acquisition and data processing pipelines for metabolic and functional MRI. Acquition techniques comprise innovative block design and event related paradigms based on various stimuli (visual, auditive) and use various MRI sequences (BOLD, ASL). Paradigms were selected to cover a large scope of potential applications. The protocol imaging namely includes a BOLD fMRI resting state paradigm, an n-back working memory paradigm for BOLD fMRI, as well as and for the first time, for functional ASL. An emotional prosody recognition task was implemented, also for the first time, in an event related BOLD fRMI context. Data were acquired on 30 healthy subjects. Processing of these data is in progress based on inhouse pipelines (e.g., template construction using DARTEL, PVE correction for ASL data). This grant was awarded in collaboration with Biotrial within the CRITT-Santé Bretagne program.

8.1.2. CPER 2007-2013, NeurInfo Platform

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

duration : 7 years, from 01/01/2007

Visages is the founding actor of a new experimental research platform which has just been installed 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 concerns the in-vivo human imaging for clinical research and neuroinformatics especially in the context of CNS pathologies. A new research 3T MRI system has been acquired in summer 2009 in order to develop the clinical research in the domain of morphological, functional, structural and cellular in-vivo imaging. 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 the next three years, additional equipments will arrive among them are two PET labs for experimentation of new ligands for molecular imaging, an in vivo confocal microscope for interventional imaging in neurosurgery and large computing facilites for storage and processing of large collection of data. This new platform has been supported under the “Contrat de Projets Etat-Région“ (C. Barillot is the PI) and have received a total amount of 5.1 Meuros for the period of 2007–2013. A specific technical staff to conduct this platform is under recruitment in order to make this new environment open to a large scientific and clinical community.

8.1.3. COREC projects

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

COREC is the "COmité de REcherche Clinique" of the University Hospital of Rennes. This comity proposes an annual project funding in the limit of 30keuros per project. In 2011, the Neurinfo platform as an incitative action for clinical research project emergence accompanied the COREC call by financially supporting the imaging part of the projects up to 50 MRI hours, ie 30keuros. Two projects were selected by the COREC in this context.

8.1.4. Emotional prosody recognition in fMRI and vulnerability to suicide

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

This project, initiated by the Psychiatry Department of the University Hospital of Rennes, is a clinical research study looking for correlations between cerebral activity observed with fMRI during an emotional prosody recognition task in a cohort of depressed patients and at risk for suicide. This study will include 3 groups of 20 patients : i) depressed patients with recent attempted suicide, ii) depressed with attempted suicide history, iii) depressed with no attempted suicide history. fMRI data will be acquired at the Neurinfo platform, their processing and interpretation will be performed in close collaboration between the Psychiatry Department and the VisAGeS team.

8.1.5. DIMITRI: Evaluation of the test object DIMITRI to measure diffusion restriction in full body MRI in bone infiltration

Participant: Elise Bannier.

Initiated by the Radiology Department of the University Hospital of Rennes, this clinical research study will evaluate the reproductibility of the diffusion restriction quantification methods. The experimental framework will rely on the test object DIMITRI and will consider inter-raters variability (fiability), intra-MRI sanner variability (repeatability) and inter-MRI scanners variability. Clinical applications of this work concern the use of diffusion restriction as a biomarker for myeloma diagnosis and follow-up.

8.2. National Initiatives

8.2.1. Cardiac imaging project

Participants: Jean-Yves Gauvrit, Christian Barillot, Elise Bannier.

duration : from 04/10/2011

A proposal led by the Cardiology Department of the University Hospital of Rennes in collaboration with the Radiology Department, the University of Rennes 1 and the Neurinfo platform was granted by the Fédération FranÃ§aise de Cardiologie in order to acquire an advanced MRI software specific to cardiac imaging ("Advanced Cardiac #3T"). This software, installed in October 2011, will enable the development of local cardiac imaging projects in close collaboration with cardiologists and cardio-radiologists. It will also increase the capacity of the Neurinfo platform to take part into external clinical reseach studies involving cardiac imaging.

8.2.2. Apathy in depression: neural basis from perfusion and functional MR

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

duration : 18 months from 01/07/2011

Depression is becoming a major cause of handicap due to its relapses and chronicity. The main risk factors for relapse are residual symptoms like apathy. Apathy is defined as a decrease in motivation and expresses itself on the behavorial, cognitive and emotional levels. However, the neural basis of apathy remain unknown. This project proposes 1) to use Arterial Spin Labeling to characterize the neural basis of apathy in the major depressive index episode (MDIE), 2) to use an fMRI emotional recognition task (the Variable Attention Affective Task) to characterize apathy involved brain structures dysfunction in the MDIE. 45 subjects will be recruited : i) 15 apathetic subjects with MDIE, ii) 15 non apathetic subjects with MDIE, iii) 15 healthy subjects. This research program was initiatied by the Psychiatry Department of the University Hospital of Rennes and is built on a collaborations between the Psychiatry and Neuroradiology Departments of the University Hospital of Rennes, the URU425 Research Unit and the VisAGeS team. It is funded by the "Fondation de l'Avenir pour la Recherche Médicale Appliquée".

8.3. European Initiatives

8.3.1. Collaborations in European Programs, except FP7

Program: COST

Project acronym: AID (oc-2010-2-8615)

Project title: Arterial spin labelling Initiative in Dementia

Acceptation date: 18/05/2011

Coordinator: X. Golay, UCL, London, UK

Other partners: Ghent University (BE), Liege University (BE), Hospital Cantonal de Geneve (CH), Fraunhofer MEVIS (D), Freiburg University (D), Max Planck Institute for Human Cognitive & Brain Sciences (D), Glostrup Hospital (DK), Hospital Santa Creu I Sant Pau (ES), Universidad Rey Juan Carlos (ES), University of Narvarra (ES), INSERM U836 Grenoble (FR), University of Rennes I (FR), Centro San Giovanni di Dio - Fatebenefratelli (IT), Fondazione Instituto Neurologico Besta (IT), Leiden University Medical Center (NL), UMC Utrecht (NL), VU University Medical Centre (NL), Instituto Superior Técnico (PT), University of Porto (PT), Lund University Hospital (SE), Uppsala University Hospital (SE), Skane University Hospital (SE), Bogazici University (TR), King's College London (UK), University College London (UK), University of Nottingham (UK), University of Oxford (UK)

Abstract: Dementia is a major clinical challenge with care costs approaching 1% of global GDP. Recent estimates suggest that delaying disease onset by 5 years would halve its prevalence. As new disease-modifying treatments will be specific to causative diseases, expensive and bear significant side effects, early diagnosis of dementia will be essential. Current diagnostic criteria include the use of image-based biomarkers using radiotracers. The AID Action aims at coordinating the development of an alternative and cost-effective tool based on an MRI technique, Arterial Spin Labelling (ASL), to obtain reproducible brain perfusion measurements in dementia patients by

bringing together scientists and clinicians from across Europe through the flexibility of the COST mechanism. The scientific program is centered around four work packages and three workgroups aiming at developing standards, improving the reliability of the technique and as establishing it as a possible clinical trial outcome measure. Development of MRI methods, post-processing tools, protocols of cross-validation, statistical analyses and launch of clinical and comparative studies will be undertaken. The main benefit of this Action will be to provide a cost-effective alternative to radiotracer-based biomarkers, and help care providers throughout Europe balancing the need for early diagnosis of dementia with the necessary healthcare cost containment.

8.3.2. Major European Organizations with which Visages has followed Collaborations

Institution: European Insitute for Biomedical Imaging Research (EIBIR)

Role: Participation to the steering committee of the EIBIR's Biomedical Image Analysis Platform: Through training, collaborative projects, and drafting a roadmap towards improved interoperability of and access to biomedical image analysis tools, EIBIR's Biomedical Image Analysis Platform is taking an active role in shaping the future of biomedical imaging research.

8.4. International Initiatives

8.4.1. INRIA Associate Teams

8.4.1.1. NEUROMIME

Title: Objective Medical Image Methods Evaluation for Neurological and Neurosurgical Procedures

INRIA principal investigator: Christian Barillot

International Partner:

Institution: McGill University (Canada)

Laboratory: Montreal Neurological Institute

Duration: 2006 - 2011

See also: https://www.irisa.fr/visages/collaborations/neuromime

The goal of this INRIA associated team is to combine the respective research efforts we have recently conducted between the VisAGeS and IPL teams, and thus benefit from the resulting cross-fertilization in order to prolong the efforts which just start to give significant deliverables. We aim at addressing specific aspects of medical image processing for the purpose of neurological disease analysis and their treatment through surgery. Both teams have now significant experience in developing together research tools or experimental framework aiming at:

- improving neurosurgical practice through pre-operative planning, intra-operative guidance and imaging of brain deformations through the establishment of image processing workflows and validation benchmarks;
- improving neurological exploitation of the spatio-temporal and multiparametric MRI data produced in the context of multiple sclerosis and more specifically focal MS-lesions.

8.4.2. Visits of International Scientists

- Prof. Charles Guttmann, Director of the Center for Neurological Imaging at Brigham and Women's Hospital and Assistant Professor in Radiology at Harvard Medical School. Dec. 15-16, 2011.
- Dr. Alexander Hammers, Chair of Excellence in Functional Neuroimaging at the Neurodis Foundation in Lyon, France, Visiting/Honorary Reader at Imperial College London and at the Institute of Neurology, UCL, London. Oct 19-20, 2011.

- Dr. Xiaojun Chen, Laureate of the France Talent Innovation, Associate Professor, Shanghai Jiao Tong University, China. Aug 28th, 2011.
- Prof. Daniel RUECKERT, Professor of Visual Information Processing and head of the Biomedical Image Analysis group, Department of Computing, Imperial College London, UK. Jan 31st, 2011.
- Dr. Bertrand Thirion, Head of the Parietal project Team, Inria Saclay, Neurospin/CEA. Jan 31st, 2011.

8.5. National initiatives

8.5.1. ANR USComp

Participants: Jan Petr, Christian Barillot.

We participate in the US comp project, headed by Lagadic project. UScomp aims at developing methods to compensate in real-time the soft tissue motion. Organs are imaged with an ultrasound probe held by a robotic arm. Within the project, we have contributed to develop a real-time ultrasound processing thanks to a GPU implementation of an adapted NL-means approach, the implementation of a graph cut segmentation method being developed through the post doc position of Jan Petr.

8.5.2. ANR "Neurological and Psychiatric diseases" NUCLEIPARK

Participants: Christian Barillot, Sylvain Prima, Olivier Commowick.

This three-year project, led by CEA/NEUROSPIN (Cyril Poupon) in Saclay, will start in fall 2009. It involves a collaboration with Visages and Odyssee INRIA project-teams and INSERM La Pitié-Salpétrière, Paris. Its goal is to study high field MR imaging (7T and 3T) of the brainstem, the deep nuclei and their connections in the parkinsonian symdromes, with applications to prognosis, pathophysiology and improvement of therapeutic strategies methodological solutions. Our contribution in this project is on processing of diffusion imaging and on study of cortical differences between the different populations.

8.5.3. ANR Cosinus VIP

Participants: Bernard Gibaud, Olivier Luong, Germain Forestier, Christian Barillot.

VIP is collaborative project supported by ANR "Conception and Simulation"; it was accepted in 2009 (around 1 million euros). VIP aims at building a computing environment enabling multi-modality, multi-organ and dynamic (4D) medical image simulation, using GRID infrastructure. The goal is to integrate proven simulation software of the four main imaging modalities (MRI, US, PET and X-Ray/CT), and to cope interoperability challenges among simulators. The partners are CREATIS in Lyon (maain contractor, Principal Investigator: Tristan Glatard), UNS-I3S in Nice, CEA-LETI in Grenoble and MAAT-G Maat G, a spanish company. The role of VISAGES in this project concerns primarily Task 1.1 and Task 3.3, focusing respectively on ontologies development and application to multiple sclerosis images simulation. This grant serves as support for the positions of Olivier Luong (PhD student) and Germain Forestier (post-doc).

9. Dissemination

9.1. Animation of the scientific community

9.1.1. Editorial board of journals

- C. Barillot is Associate Editor of IEEE Transactions on Medical Imaging (IEEE-TMI).
- C. Barillot is Associate Editor of Medical Image Analysis (MedIA).
- C. Barillot is Associate Editor of ISRN Signal Processing.
- C. Barillot is Associate Editor of Current Medical Imaging Reviews.

- C. Barillot serves in the peer review committee of the Journal of Computer Assisted Tomography.
- C. Barillot serves in the peer review committee of Neuroimage.
- P. Jannin is Deputy Editor of the International Journal of Computer Assisted Radiology and Surgery.

9.1.2. Workshop/Symposium Organization

- C. Barillot was co-chairman of the MICCAI workshop on Mesh Processing in Medical Image Analysis (MeshMed 2011), Toronto, ON, Sept. 18th, 2011 (http://www2.imm.dtu.dk/projects/MeshMed/)

9.1.3. Peer Reviews of journals

- Reviewing process for IEEE TMI (PH, SP, PJ, BG), IEEE TIP (SP, CB), IEEE TBE (SP), IEEE TITB 5SP), Medical Image Analysis (CB, SP), NeuroImage (CB, IC), Academic Radiology (PJ), Artificial Intelligence in Medicine (CB), Computer Methods and Programs in Biomedicine (CB), International Journal of Computer Assisted Radiology and Surgery (PJ, SP), Machine Vision and Applications (SP). Pattern recognition letters (SP), American Journal of Physical Anthropology (SP), Journal of Anatomy (SP)

9.1.4. Technical Program Committees (TPC) of conferences

- C. Barillot was area chair for SPIE Medical Imaging 2011, Miccai 2011, IPMI 2011, TPC member for MICCAI workshops HPDC 2011, MBIA 2011, IAHBD 2011, MESHâMED 2011, and TPC member for IEEE CBMS 2011, ESMRMb 2001, ECR/imaGine 2011,
- B. Gibaud was TPC member for CARS 2011
- P. Jannin was area chair and TPC member for SPIE Medical Imaging 2011 and CARS 2011 and TPC member for MICCAI 2011
- O. Commowick was TPC member MICCAI 2011, IEEE ISBI 2011
- S. Prima was TPC member of MICCAI 2011, IEEE ISBI 2011

9.1.5. Scientific societies

- P. Jannin is General Secretary of ISCAS
- B. Gibaud is member of the AIM
- B. Gibaud is member of the Board of Directors of EuroPACS
- C. Barillot is member of the Board of Directors of IPMI (Information Processing in Medical Imaging)
- C. Barillot and P. Jannin are members of IEEE EMBS
- C. Barillot is senior member of IEEE
- C. Barillot,O. Commowick, S. Prima, P. Jannin are members of the MICCAI society
- P. Jannin is member of SPIE

9.2. Teaching

Teaching on 3D Medical Imaging (visualization, segmentation, fusion, management, normalization) and Image Guided Surgery in the following tracks:

- Master 2 SIBM, University of Angers-Brest-Rennes : 26h (*C. Barillot, O. Commowick, S. Prima, B. Gibaud, P. Jannin, X. Morandi, I. Corouge, E. Bannier, JY Gauvrit*)
- C. Barillot, B. Gibaud and P. Jannin are responsible for three different semesters
- .J-Y. Gauvrit is the coordinator for the Master.

- Master 1 SIBM, University of Rennes : 24h (*S. Prima, B. Gibaud, P. Jannin*), P. Jannin is responsible for one semester.
- Master "Rayonnements ionisants et application ", Univ. de Nantes: 4h (*C. Barillot*)
- Master "Méthodes de traitement de l'information biomédicale et hospitalière", University of Rennes I : 9h (*B. Gibaud*)
- Master "Equipements biomédicaux", UTC Compiègne: 3h (*B. Gibaud*)
- Master " Signaux et Images en Médecine ", University Paris XII Val de Marne: 3h (*B. Gibaud*)
- European School for Medical Physics:3h (*B. Gibaud, P. Jannin*)

9.3. Participation to seminars, scientific evaluations, awards

- C. Barillot was elected in 2011 as a Miccai Fellow by the Medical Image Computing and Computer Assisted Intervention http://www.miccai.org/FellowList
- C. Barillot served as external reviewer for the recruitment commission of University of Caen
- C. Barillot served in the panel committee of ANR Blanc program (SIMI3 panel)
- B. Gibaud served as expert for ANR ('Blanc' Program)
- C. Barillot served as expert for the APHP-DHU program 2011
- C. Barillot is elected-member of the Scientific Board of CNRS-INS2I
- C. Barillot is permanent member of the Administrative Council of the pôle de compétitivité "Images & Réseaux"
- Sylvain Prima is a member of the CUMIR committee (Commission des Utilisateurs des Moyens Informatiques pour la Recherche) and of the working group "voyages".
- C. Barillot is member of the CRBSP (Comité Recherche Biomédicale et santé publique), CHU Rennes
- E. Bannier: Atelier SFNR Club des Techniques Avancées (CluTAV) sur l'IRM de perfusion "ARM sans produit de contraste a 3T, Techniques et perspectives", CHU Rennes, 19/05/2011
- E. Bannier: Seminar "Imagerie fonctionnelle et psychiatrie", Centre Hospitalier Guillaume Régnier, Rennes, 16/06/2011

9.4. Dissemination toward non specialists

- The VisAGeS team was chosen to represent INRIA at the annual Festival des Sciences 2011 in Pont-Péan and Rennes (14-15-16 October). Sylvain Prima was responsible for the organisation of the event, assisted by Isabelle Corouge and Elise Bannier for the organisation, and by most people of the team for the event itself.
- "Le gros cerveau de Cro-Magnon", Sciences Ouest Magazine, no286, March 2011 (http://www.espace-sciences.org/node/41161)
- "Une maladie suivie en images", Sciences Ouest Magazine, no286, March 2011 (http://www.espace-sciences.org/node/41170)
- "Neurinfo, une plateforme de recherche equipée pour la clinique", Sciences Ouest Magazine, no286, March 2011 (http://www.espace-sciences.org/node/41170)

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Major publications by the team in recent years

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