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Project-Team VisAGeS

Vision Action et Gestion d'informations en Santé

Rennes - Bretagne-Atlantique

Theme : Computational Medicine and Neurosciences

Activity Report

2009

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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 [49]:

$$\underset{\theta \in \Theta}{arg\,min_{\Psi}} \Delta \left(\Phi_{\theta}\left(\Omega_{s}\right) - \Omega_{t}\right)$$

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 [54], [61], [56], [57], [53].

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 [55]. 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 [60]). 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 [47], [48], [50], 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 [52], [54], 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 [50], [52], [51], [54],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 surgeonÕs 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 surgeonÕs 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 Universit de 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

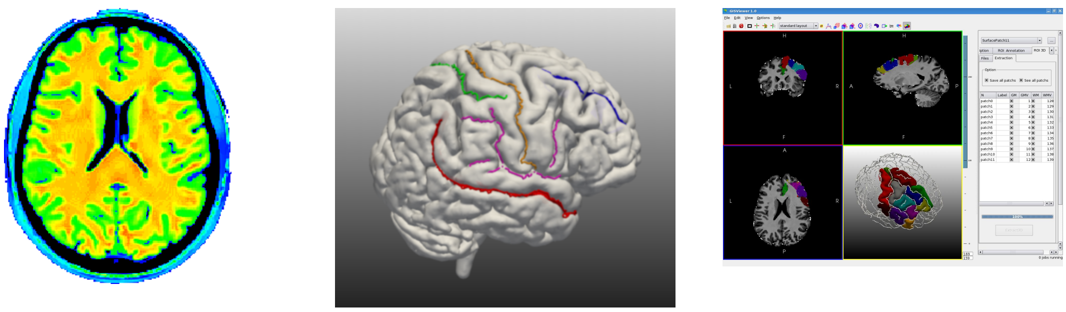
5.1. Introduction

Our objectives concerning the software development and dissemination are directed to the set-up of a software platform at the University Hospital in order to deploy new research advances and to validate them in the clinical context with our local partners, and especillay for the near future in close link with the new in-vivo imaging ressearch platform "‘NeurInfo"’. We intend to disseminate our results via a free software distribution (source code or web-based applications). Complying with both objectives requires software engineering resources, which was partially covered in the short term by the PRIR "PlogICI" project continued today with the InriaNeuroTK and VIGNES INRIA supported action.

5.2. VistaL

Participants: Alexandre Abadie, Pierre Hellier, Sylvain Prima, Bernard Gibaud, Pierre Jannin, Christian Barillot.

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).



(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

This software library is composed of generic C++ template classes (Image3D, Image4D, Lattice and so on) and a set of 3D/3D+t image processing filters. VistaL is a multi-operating system environment (Windows, Linux/Unix...). A web site presenting the project has been opened at this url http://vistal.gforge.inria.fr, precompiled packages and the SDK are now available. VistaL APP registration number is:IDDN.FR.001.200014.S.P.2000.000.21000.

5.3. 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

5.4. Online applications

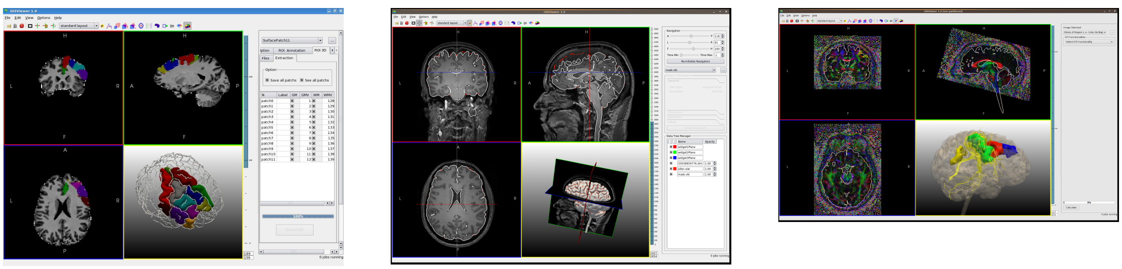
Participant: Alexandre Abadie.

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. Almost 1500 processes have been benchmarked in 2009.

5.5. GISViewer

Participants: Alexandre Abadie, Pierre Hellier, Sylvain Prima, Bernard Gibaud, Pierre Jannin, Christian Barillot.

The GISViewer is a graphical user interface for the visualization of medical image data. Some basic processing method can be applied : windowing, reformating, thresholding, erosion, dilatation, surface extraction. More complex processing methods are also available as plug-ins : sulcal traces extraction, diffusion tensor imaging methods, patch extraction for atlas computing, GraphCut segmentation method. The GISViewer is designed to be multi-platform because it's based on Qt library.



(a) (b) (c)

Figure 2. Some GISViewer screenshots: a) The ROI3D extraction functionnality, b) The Sulci traces extraction functionnality, c) The DTI tractography functionnality

5.6. Monade

Participants: Alexandre Abadie, Pierre Hellier, Sylvain Prima, Christian Barillot.

Monade is en efficient filter based on the NL-means approach for $3D$ images. Considerable speedup compared to the traditional method was achieved thanks to multithreading, blockwise approach and adaptive dictionnaries Monade is registered at APP (Agence pour la Protection des Programmes, IDDN.FR.001.070033.000.S.P.2007.000.21000).

5.7. Dbsurg

Participant: Pierre Jannin.

DBSurg is a software for recording descriptions of surgical procedures based on a previously defined ontology [58], [59]. DBSURG allows prospective and retrospective descriptions of planned and/or performed surgical procedures. Queries capabilities provide the neurosurgeon with tools to browse the database and to analyse occurrences of dedicated surgical characteristics. The last version that we developed is used for different projects following French or English language interface. DBSurg is based on php and PostGreSQL.

5.8. CLASH

Participant: Pierre Hellier.

Tulipe : **T**hree dimensional **UL**trasound reconstruction **I**ncorporating Prob**E** trajectory was developed using Vistal and is a registered at APP under IDDN.FR.001.120034.S.A.2006.000.21000. This 3D freehand ultrasound reconstruction technique is based on the acquisition of B-scans, which can be parallel or not, whose position in 3D space is known by a 3D localizer (optic or magnetic) attached to the probe.

5.9. TULIPE

Participants: Pierre Hellier, Christian Barillot.

Clash (Correction of Local Acoustic SHadows) was developed to detect acoustic shadows on ultrasound images. Clash was registered at APP under IDDN.FR.001.270019.000.S.P.2007.000.21000.

5.10. TMSInria

Participants: Vincent Gratsac, Pierre Hellier.

TMSInria has been developed as a neuronavigation system for transcranial magnetic stimulation.

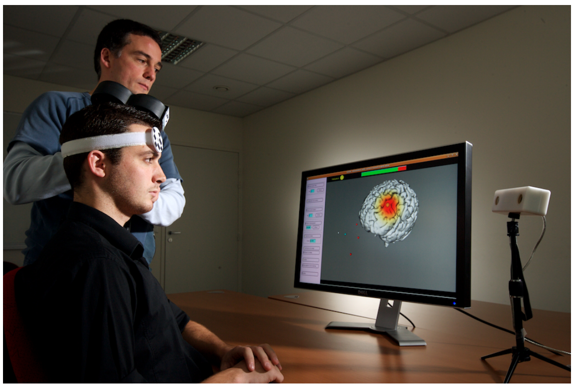


Figure 3. TMS Inria system in action.

The software enables to track the patient and the stimulation probe, as well as to perform image to patient registration.

5.11. Shanoir

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

Shanoir is the new name of InriaNeuroTK. Shanoir (Sharing NeurOImaging Ressources) aims at providing the VisAGeS team a software for managing neuroimaging data. This project is able to manage multimodal data (MR, CT) by extracting their metadata. The metadata can come from the original DICOM format but also from external sources. This system offers a better exploitation and marking of neuroimaging data. Shanoir is fully developped in Java language and is based on the JBoss SEAM framework. Currently, a set a web service has been developped to query the image base from client softwares. Shanoir is also deployed in a production environment with the Neurinfo experimental platform (http://neurinfo.org). This software is registered at APP and licensed under the terms of the QPL (see http://shanoir.gforge.inria.fr).

5.12. IGNS

Participants: Romain Carpentier, Alexandre Abadie, Pierre Hellier, Pierre Jannin, Xavier Morandi.

This development project provides two separate softwares aimed at being used during the preoperative planning and during the operation procedure. The main goal of the preoperative application is to help the surgeons in the preparation of their surgical interventions by offering the maximum information from multimodal data (T1, T2, DTI, IRMf). The intraoperative application uses the results of the planning coupled with US data acquired during the operation.

5.13. FUID

Participants: Fernanda Palhano, Pierre Hellier, Guillermo Andrade.

We have developped a real-time speckle filtering method designed for ultrasound images based on a Bayeasian adaptation of the NL-means filter. Thanks to the GPU computing capabilities, real-time filtering (20 ms for standard images) was achieved. FUID (Fast Ultrasound Image Denoising) is registered at APP (Agence pour la Protection des Programmes, IDDN.FR.001.310018.000.S.P.2009.000.21000).

5.14. CLARCS

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

Participants: Ronan Le Tiec, Mathieu Biston, Alexandre Abadie, Benoit Combes, Sylvain Prima.

Within the 3D-MORPHINE ARC project (http://3dmorphine.inria.fr), we began the conception and implementation of a C++ library (named CLARCS) for the automated analysis and comparison of surfaces. To make these tools widely available to paleoanthropologists, we developed a viewer/application based on this library, VTK and Qt. One of the primary goals of this application (work under progress) is to allow the assessment and quantification of morphological differences of endocranial surfaces within and between species.

6. New Results

6.1. Image Segmentation, Registration and Analysis

6.1.1. Non Local Means-based Speckle Filtering for Ultrasound Images

Participants: Pierrick Coupé, Pierre Hellier, Christian Barillot.

In ultrasound (US) imaging, preprocessing is expected to improve the performance of quantitative image analysis techniques. In this work [15], an adaptation of the Non Local (NL) means filter is proposed to denoise ultrasound images. Originally developed for additive white Gaussian noise, we propose a Bayesian framework to design an NL-means filter adapted to a relevant ultrasound noise model. 2D and 3D experiments were carried out on synthetic and real images. Quantitative results on synthetic images with various noise models demonstrate that the proposed method outperforms state-of-the-art methods for speckle reduction. Results on real images show that the proposed method is very efficient in terms of edge preservation and noise removal. Finally, we introduced a new registration-based evaluation framework and we show that the NL-means-based speckle filter is very competitive to accurately register real images, compared to other denoising methods.

6.1.2. Prior affinity measures on matches for ICP-like nonlinear registration of free-form surfaces

Participants: Benoît Combès, Sylvain Prima.

In this work, we showed that several well-known nonlinear surface registration algorithms can be put in an ICP-like framework, and thus boil down to the successive estimation of point-to-point correspondences and of a transformation between the two surfaces. We proposed to enrich the ICP-like criterion with additional constraints and showed that it is possible to minimise it in the same way as the original formulation, with only minor modifications in the update formulas and the same convergence properties. These constraints help the algorithm to converge to a more realistic solution and can be encoded in an affinity term between the points of the surfaces to register. This term is able to encode both a priori knowledge and higher order geometrical information in a unified manner. We illustrated the high added value of this new term on synthetic and real data [35].

6.1.3. Setting priors and enforcing constraints on matches for nonlinear registration of meshes

Participants: Benoît Combès, Sylvain Prima.

In this work, we showed that a simple probabilistic modelling of the registration problem for surfaces allows to solve it by using standard clustering techniques. In this framework, point-to-point correspondences are hypothesized between the two free-form surfaces, and we showed how to specify priors and to enforce global constraints on these matches with only minor changes in the optimisation algorithm. The purpose of these two modifications is to increase its capture range and to obtain more realistic geometrical transformations between the surfaces. We performed some validation experiments and showed some results on synthetic and real data [36].

6.1.4. A modified ICP algorithm for normal-guided surface registration

Participants: Daniel Münch, Benoît Combès, Sylvain Prima.

The ICP is probably the most popular algorithm for registration of surfaces. However, ICP-related registration methods suffer from the fact that they only consider the distance between the surfaces to register in the criterion to minimize, and thus are highly dependent on how the surfaces are aligned in the first place. This explains why these methods are likely to be trapped in local minima and to lead to erroneous solutions. A solution to partly alleviate this problem would consist in adding higher order information in the criterion to minimize (e.g. normals, curvatures, etc.), but previous works along these research tracks have led to computationally intractable minimization schemes. In this work, we proposed a new way to include the point normals in addition to the point coordinates to derive an ICP-like scheme for non-linear registration of surfaces and showed how to keep the properties of the original ICP algorithm with adequate implementation choices (most notably the use of a local, continuous, parametrization of the surfaces and a locally affine deformation model). We experimentally showed the strong added value of using the normals in a series of controlled experiments [37].

6.1.5. Optimized supervised segmentation with Graph Cuts from multispectral MRIs

Participants: Jérémy Lecoeur, Christian Barillot.

We have proposed an optimized supervised segmentation method from multispectral MRIs. As MR images do not behave as natural images, using a spectral gradient based on a psycho-visual paradigm is sub-optimal. Therefore, we propose to create an optimized spectral gradient using multi-modalities MRIs. To that purpose, the algorithm learns the optimized parameters of the spectral gradient based on ground truth which are either phantoms or manual delineations of an expert. Using Dice Similarity Coefficient as a cost function for an optimization algorithm, we were able to compute an optimized gradient and to utilize it in order to segment MRIs with the same kind of modalities. Results show that the optimized gradient matrices perform significantly better segmentations and that the supervised learning of an optimized matrix is a good way to enhance the segmentation method. This has been applied to segment MS lesions with objective improved performances.

6.1.6. Supervised segmentation with Graph Cuts from multispectral images and atlas priors

Participants: Jérémy Lecoeur, Ryan Datteri, Christian Barillot.

The atlas based registration method uses both spatial and textural information, often resulting in a good segmentation. However, the search space is much too large to be comprehensively searched and, thus, some segmentations may have errors. The graph cut algorithm on the other hand is quick to compute and is able to use information from three separate image modalities, but it does not use any spatial information and can often be confused by organs that have a similar appearance. Also, the graph cut algorithm has the limitation of being semi-automatic. Therefore, the goal of this work was to combine both of these methods, creating better segmentations. A registration algorithm (affine or non-linear) is used to automate and initialize the graph cut algorithm as well as to add needed spatial information. Thanks to the multispectral implementation of the Graph Cut, the atlas prior is used as a complementary spatial information to multimodal observations in order to drive the segmentation to the most probable contours (from the observed images and from the probable location). Preliminary results on the segmentation of the Thalami shows better accordance than when using adapted atlas-based non-linear registration alone.

6.1.7. MAP Segmentation of 3D MR Images Based on Mean Shift and Markov Random Fields

Participants: Lei Lin, Christian Barillot.

In this work, we propose to combine mean-shift annealing, prior distribution coming from a probablistic atlas and Markov Random Field (MRF) to jointly estimate intensity inhomogeneities (to correct for bias field) and posterior maps of brain tissues. We employed the mean-shift algorithm to get a pixon-based image representation, and then the Markov random field (MRF) model was used to partition the image into a predefined number of tissue classes. The prior map coming from the SPM probabilistic template is then used to initialize the contribution of each tissue in individual pixon and a Bayesian framework is used to iterativelly estimate the global intensity inhomogeneity map plus the maximum a posteriori disctribution of each brain tissue class. The new method was validated on the simulated normal brain images from BrainWeb and on real brain images coming from IBSR. Compare with alternative MRI segmentation methods, the new method exhibited a higher degree of accuracy in segmenting real 3D MRI brain data.

6.2. Image processing on Diffusion Weighted Magnetic Resonance Imaging

6.2.1. Clustering and classification ofwhite matter fibers from Diffusion Tensor Imaging (DTI)

Participants: Meena Mani, Christian Barillot.

This project can be broken down into three major aspects:

- Spectral clustering of DTI fibers using different distance metrics. Two distance metrics, a mean closest point (MCP) and a barymetric distance were found to give the best clustering results on data sets such as the corpus callosum.
- Spectral clustering using the Nystrom approximation to handle large data sets. This included an investigation of the error involved when the Nystrom approximation is used.

- Clustering and statistical quantitative analysis of DTI fibers using a comprehensive Riemannian framework that allows for a joint analysis of features in a consistent manner. This work was done with Professor Anuj Srivastava at Florida State University. A paper based on this work was submitted to the ISBI 2010 conference.

6.3. Management of Information and Semantic Processing

Participants: Bacem Wali, Daniel Garcia-Lorenzo, Franck Michel, Franck Michel, Farooq Ahmad, Bernard Gibaud, Christian Barillot.

6.3.1. Introduction

A better sharing of resources (by "resources" we denote both data and image processing tools) is one of the keys for the success of future research in the medical imaging domain. Especially, the discovery and the validation of new imaging biomarkers for the diagnosis of neurological diseases and the monitoring of their evolution and treatment highly depends on collaborative work associating expert centers with similar or complementary skills. Suitable information infrastructures must be provided to support such collaborative work, enabling an easy sharing of images and associated data and a flexible sharing and re-use of processing tools available at the different sites. Tradionnally, sharing can be envisaged according to two different models, a "centralized" one and a "federated" one. Our assumption is that the latter is much more suited to the biomedical research field, especially due to the legitimate wish of involved organisations to define and control how their data should be organized and shared. One of the most critical aspects of the design of such federated systems is the definition of common semantics of shared information. Ontologies and semantic web technologies can provide powerful solutions to this problem. Ontologies provide both a reference vocabulary and explicit definitions (using formal semantics) of entities, which can be used to reason about real world entities, classify them, and retrieve them from data repositories. One of our basic assumptions is that such technologies should be used in the neuroimaging domain to make explicit the nature and content of the images and relate them to other kinds of data : biological data, clinical data, neuropsychological data, genomic data, etc.

6.3.2. Neurolog project: Sharing of data and sharing of processing tools in neuroimaging

Our participation in Neurolog concerned primarily three workpackages : WP1 "data distribution", WP2 "ontologies and semantic processing" and WP5 "applicative testbests". Regarding the first, our major achievement was the implementation of a middleware (called Neurolog server) to share the data as well as the processing tools. The specific contribution of Visages concerned more specifically the design of the "data manager" and "metadata manager". Concerning the second, two major results were obtained. A first version of the OntoNeurolog ontology was delivered, covering entities such as: Study, Center, Examination, Subject, Dataset Acquisition, Datasets, Dataset expression, Files, Data Processing etc. This first version was made available for use by the other work packages, especially WP1 (development of the Metadata Manager), WP5 (development of the Neurolog Client) and for the development of the InriaNeuroTk software (a toolkit to populate local image databases). This first version of the ontology was also communicated to our colleagues of the BIRN project in the USA (Dr Jessica Turner, University of California, Irvine). A second version was issued in september 2009, including an ontology of "Instruments" (neuropsychological tests, behavioural tests, neuroclinical scales, as well as the various scores resulting of their use). This is very important since most neuroimaging studies aim at correlating observations made on images (based on image processing) with (quite) objective clinical observations made by healthcare professionals using such instruments. Important work was also done about modeling MR protocols and sequences, but still not delivered. The second significant result is the implementation of a semantic query software, based on the METAMORPHOSES and CORESE software packages. This software is currently being deployed according to a client-server architecture (semantic module implemented in the Neurolog server and accessed through web services). Finally, we participated in the functional specification and to the development of the GUI of the NeuroLOG client application. In particular, a "browse metadata" GUI tab allows users to browse through metadata of the federated database along a predefined (though customizable) browsing tree, using different search criteria. Ultimately, the browsing allows to collect datasets into the user cart, that may be used to: (1) explore details of each dataset object, (2) download data files from a specific dataset expression (i.e. format, such as DICOM or NifTi) and pass them to the image viewer (developed by Visioscopy), (3) use dataset expressions as inputs for processing tools invocation.

Neurolog is a collaborative project, supported by ANR (Agence National de la Recherche), through grant ANR-06-TLOG-024. The partners with whom we have the tightest relations are: I3S (Sophia) and Business Objects, for WP1; MIS (Amiens), GIN (Grenoble) and Piti-Salptrire (Paris) for WP2; GIN (Grenoble) and Piti-Salptrire (Paris) for WP5.

6.4. Image Guided Intervention

6.4.1. Automatic geometrical and statistical detection of acoustic shadows

Participants: Pierre Hellier, Xavier Morandi.

In ultrasound images, acoustic shadows appear as regions of low signal intensity linked to boundaries with very high acoustic impedance differences. Acoustic shadows can be viewed either as informative features to detect lesions or calcifications, or as damageable artifacts for image processing tasks such as segmentation, registration or 3D reconstruction. In both cases, the detection of these acoustic shadows is useful. We have designed a new method [20] to detect these shadows that combines a geometrical approach to estimate the B-scans shape, followed by a statistical test based on a dedicated modeling of ultrasound image statistics. Results demonstrate that this detection improves the reconstruction and registration of tracked intraoperative brain ultrasound images.

6.4.2. Automatic steps recognition in neurosurgical procedures by microscope video analysis

Participants: Florent Lalys, Xavier Morandi, Laurent Riffaud, Pierre Jannin.

Analysis of surgical procedures is a recent field allowing the creation of complex patient-specific and generic surgical process models. With the increased number of technological tools incorporate in the Operating Room (OR), the need for new computer-assisted system has emerged. By extracting different signals (at different levels of granularity) from the OR, it's possible to extract helpful information such as the surgical workflow followed by the surgeons. Our project, in collaboration with Carl Zeiss Medical Systems (Oberkochen, Germany) is based on the extraction of information from digital microscope videos. We decided in a first step to use static information, without taking into account the motion, by extracting image features from videos and by training models with machine learning techniques. Image data-bases have been constructed for different types of neurosurgical procedures. The problem is thus reduced to an image classification problem which allow us to automatically detect the different steps of a procedure but also to recognize other helpful information. We evaluated the approach with a database of 18 videos of transsphenoidal pituitary surgeries. 400 images were extracted and we obtained for the step segmentation a correct classification rate of 82 percent.

6.4.3. Comparison of classification methods for modeling neurosurgical process

Participants: Brivael Trelhu, Laurent Riffaud, Xavier Morandi, Pierre Jannin, Florent Lalys.

We performed a study for the analysis of neurosurgical procedures with the aim to improve their comprehension and optimize the surgery. We first used a XML Database included 157 tumors surgeries descriptions. 85 variables were identified and classified into predictive variables (i.e., known before operation) and into variables to be predicted (i.e., pertaining for the surgical gestures). We investigated a six classify methods comparison to determine the mostly adapted method for classifying and predicting neurosurgical procedures steps. Five criteria (correct rate (CR), sensitivity (SEN), specificity (SPC), positive predictive value (PPV) and negative predictive value (NPV)) were used to compare the methods against. Results were studied and interpreted by an expert neurosurgeon to estimate and to validate medical applications.

6.4.4. Cognitive analysis of surgical planning and information requirements in image guided neurosurgery

Participants: Pierre Jannin, Xavier Morandi.

With the GRESICO (Groupe de REcherche en Sciences de l'Information et de la COgnition) laboratory (Thierry Morineau, Nadege Le Moellic) from the Université de Bretagne Sud in Vannes (France), we have defined a methodology for identifying differences in cognitive behaviour between neurosurgeons with different expertise levels. 9 neurosurgeons were interviewed. First results indicate a clear distinction between surgeons and provide a basis for further analysis. We also developed a method for analysis the surgical work domain and used it for assessing information provided by image guided surgery systems for surgical planning. We are currently applying the results in a study comparing different display modes (2-D vs. 3-D display) with different users (engineers, medical students, and surgeons).

6.4.5. Post operative assessment of Deep Brain Stimulation (DBS) based on multimodal images

Participants: Pierre Jannin, Florent Lalys, Claire Haegelen, Jean-Christophe Ferré, Xavier Morandi, Jean-Yves Gauvrit.

Deep Brain Stimulation (DBS) is a surgical procedure used from about 20 years mainly for functional neurosurgery of Parkinson disease. It consists of inserting and stimulating an electrode within deep brain structures such as the sub thalamic nucleus (STN). For patients suffering of movement disorders, medical therapy could be not effective. In that case high frequency electrical stimulation via the electrode will considerably reduce the functional pathology. The targeting of the STN is based on anatomic, imaging and stastistical data obtained on anatomic and clinical studies. By using pre and post operative multimodal images and clinical scores, we developed an approach for post operative assessment of DBS. It includes the automatic segmentation of the electrode from post operative CT, and the development of a registration workflow in order to express the coordinates of the electrodes and the stimulated electrode contacts in a common coordinates system for different patients. We built a 3T MR mono subject template in order to make easier comparison between different subjects which serves as the common coordinate system. This template allow visualisation of spatially complex structures as well as increased contrast. We also showed that it greatly improved the accuracy of template based registration. The registration workflow between pre and post operative images and the anatomical MR template was validated on clinical data. Finally, we developed a methodology for building an anatomical and clinical digital atlas gathering information about stimulated electrode contacts and related pre and post operative clinical scores. Motor scores as well as neuro-psychological tests were included in the study. We performed statistical analysis of relationships between clusters of 3D points and improvements of clinical scores. This methodology was tested for a population of 9 parkinsonian patients implanted in the STN. It aims at highlighting anatomical areas with better clinical results and lower clinical side effects in order to find the optimal site for STN DBS.

6.4.6. Comparison of Piece-Wise Linear, Linear and Nonlinear Atlas-to-Patient Warping Techniques: Analysis of the labeling of subcortical nuclei for functional neurosurgical applications

Participant: Pierre Hellier.

Digital atlases are commonly used in pre-operative planning in functional neurosurgical procedures performed to minimize the symptoms of Parkinson's disease. These atlases can be customized to fit an individual patient's anatomy through atlas-to-patient warping procedures. We have participated in an evaluation study [13] of eight different registration methods for atlas-to- patient customization of a new digital atlas of the basal ganglia and thalamus to demonstrate the value of non-linear registration for automated atlas-based subcortical target identification in functional neurosurgery. Since a gold standard of the subcortical anatomy is not available, manual segmentations of the striatum, globus pallidus, and thalamus are used to derive a silver standard for evaluation. The results show that nonlinear techniques perform statistically better than linear and piece-wise linear techniques.

6.4.7. Automated Surgical Planning

Participants: Caroline Essert-Villard, Omar El Ganaoui, Xavier Morandi, Claire Haegelen, Pierre Jannin.

Surgical Planning consists in identifying optimal access to the target based on anatomical references and constrained by healthy functional areas. For helping this process, we aim at automatically computing possible surgical approaches, respecting patient specific constraints expressed from preoperative images (MR and CT) and generic constraints expressed from patient-adapted atlases. The first application, with the participation of Dr. C. Haegelen from the neurosurgical department of the university hospital, focuses on the automatic planning of the implant of deep brain stimulation electrodes (DBS) for the treatment of Parkinson's disease. The purpose is to find an optimal trajectory for a cylindrical electrode to a target located in deep structures of the brain (e.g. sub thalamus nucleus). The method we are developing is using a formalization of the expertise of the surgeon as well as preoperative images (MR and CT), sent to a geometrical constraint solver to produce a space of possible solutions weighted with a quantification of their quality. Our latest results allow us to define in a few milliseconds the areas of possible insertion points of DBS electrodes, according to the brain anatomy extracted from the pre-operative images.

6.5. Medical Image Computing in Multiple Sclerosis

6.5.1. Automatic Segmentation of lesions and Normal Appearing Brain Tissues (NABT) in patients with Multiple Sclerosis

Participants: Daniel Garcia-Lorenzo, Jeremy Lecoeur, Gilles Edan, Jean-Christophe Ferré, Christian Barillot.

Graph Cuts have been shown as a powerful interactive segmentation technique in several medical domains.We propose to automate the Graph Cuts in order to automatically segment Multiple Sclerosis (MS) lesions in MRI. We replace the manual interaction with a robust EM-based approach in order to discriminate between MS lesions and the Normal Appearing Brain Tissues (NABT). Evaluation is performed in synthetic and real images showing good agreement between the automatic segmentation and the target segmentation. We compare our algorithm with the state of the art techniques and with several manual segmentations. An advantage of our algorithm over previously published ones is the possibility to semi-automatically improve the segmentation due to the Graph Cuts interactive feature [39].

6.6. Arterial Spin Labelling

6.6.1. Denoising arterial spin labeling MRI using tissue partial volume

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

Arterial spin labeling (ASL) is a noninvasive MRI method that uses magnetically labeled blood to measure cerebral perfusion. Spatial resolution of ASL is relatively small and as a consequence perfusion from different tissue types is mixed in each pixel. An average ratio of gray matter (GM) to white matter (WM) blood flow is 3.2 to 1. Disregarding the partial volume effects (PVE) can thus cause serious errors of perfusion quantification. PVE also complicates spatial filtering of ASL images as apart from noise there is a spatial signal variation due to tissue partial volume. Recently, an algorithm for correcting PVE has been proposed. It represents the measured magnetization as a sum of different tissue magnetizations weighted by their fractional volume in a pixel. With the knowledge of the partial volume obtained from a high-resolution MRI image, it is possible to separate the individual tissue contributions by linear regression on a neighborhood of each pixel. We have proposed an extension of this algorithm by minimizing the total-variation of the tissue specific magnetization. This makes the algorithm more flexible to local changes in perfusion. We show that this method can be used to denoise ASL images without mixing the WM and GM signal.

6.6.2. Improving arterial spin labeling data by temporal filtering

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

Arterial spin labeling (ASL) is an MRI method for imaging brain perfusion by magnetically labeling blood in brain feeding arteries. The perfusion is obtained from the difference between images with and without prior labeling. Image noise is one of the main problems of ASL as the difference is around 0.5-2% of the image magnitude. Usually, 20-40 pairs of images need to be acquired and averaged to reach a satisfactory quality. The images are acquired shortly after the labeling to allow the labeled blood to reach the imaged slice. A sequence of images with multiple delays is more suitable for quantification of the cerebral blood flow as it gives more information about the blood arrival and relaxation. Although the quantification methods are sensitive to noise, no filtering or only Gaussian filtering is used to denoise the data in the temporal domain prior to quantification. We have proposed an efficient way to use the redundancy of information in the time sequence of each pixel to suppress noise. For this purpose, the vectorial NL-means method is adapted to work in the temporal domain. The proposed method is tested on simulated and real 3T MRI data. We have demonstrated a clear improvement of the image quality as well as a better performance compared to Gaussian and normal spatial NL-means filtering.

6.7. Anatomical and functional imaging in dysphasia

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

In the context of a larger study on specific language impairment, we assessed the effects of four language tasks including two reference lexico-semantic tasks and two new tasks designed to avoid reading and metalinguistic requirements on a group of 18 healthy children. To the aim of functional exploration and structural anomaly detection, we integrated SPM-based tools and produced an automated pipeline. On the top of this conventional approach, we performed region of interest analysis focusing on mean activation and laterality indexes. Further work will include between-group comparisons and diffusion data analysis.

7. Other Grants and Activities

7.1. Regional initiatives

7.1.1. SIMUPACE project

Participants: Jérémy Lecoeur, Christian Barillot.

duration : 36 months, from 01/11/2006

This three years project is devoted to the development of a solution for processing medical images from multi-dimensional signatures in order to study brain pathologies and to segment brain structures with complex image representation. This grant is being used for founding the position of Jérémy Lecoeur.

7.1.2. CPER 2007-2013, NeurInfo Platform

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

7.2. National initiatives

7.2.1. ODL Vignes

Participants: Alexandre Abadie, Romain Carpentier, Pierre Hellier, Pierre Jannin, Xavier Morandi.

duration : 24 months, from 01/10/2008

This two years project is devoted to the ongoing development of a software platform for intraoperative imaging. This grant funds the position of Romain Carpentier.

7.2.2. ANR “Technologies Logicielles”, NeuroLOG Project

Participants: Bacem Wali, Farooq Ahmad, Franck Michel, Daniel Garcia-Lorenzo, Bernard Gibaud, Christian Barillot.

duration : 40 months, from 01/04/2007

The NeuroLOG project has for objective to build a software environment in an open environment for the integration of resources in medical imaging (data, images and also image processing tools) and to confront this environment to target applications coming mainly from the neuroimaging and the oncology domains. This project intends to address problems related to:

- The management and the access to semi-structured heterogenous and distributed data in an open environment;
- The control and the security of the access of the sensitive medical data;
- The control of data and computing workflows involved in high demanding processing procedures by accessing grid computing infrastructures;
- The extraction and the quantification of parameters for relevant application such as multiple sclerosis, stroke and brain tumours.

In addition to our Unit/Project and the Paris project from IRISA, this grant is conducted by CNRS/I3S at Sophia-Antipolis and is performed in collaboration with INRIA team Asclepios (Sophia-Antipolis), GIN INSERM Research Center U836 from Grenoble, IFR 49 "Functional Neuroimagery" (Paris La Pitié Salpétrière), the MIS Laboratory at Amiens and Business Objects (now part of the SAP Group) and Visioscopie for the industrial part.

Our current participation within the NeuroLOG project concerned the first work package, especially on the elaboration of the proposed system architecture, and the implementation of the Data Manager and Metadata Manager; the second work package, on the development of the "OntoNeuroLog" ontology, and the Application work package, on the specification of the different test bed applications.

7.2.3. ANR USComp

Participants: Pierre Hellier, Christian Barillot.

We participate in the US comp project, headed by Lagadic project. UScomp aims at developping 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 speckle filter thanks to a GPU implementation of an adapted NL-means approach.

7.2.4. ANR “Neurological and Psychiatric diseases“ NUCLEIPARK

Participant: Christian Barillot.

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.

7.2.5. ANR Cosinus VIP

Participants: Bernard Gibaud, Olivier Luong, 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.

7.2.6. 3D-MORPHINE: Computational methods for the automated analysis of virtual hominid endocasts (2009-2010)

Participants: Benoit Combes, Sylvain Prima.

duration : 24 months, from 01/01/2009

Over the last 15 years, CT has been extensively used to build “virtual” endocranial casts in a precise and non-invasive way. Studying endocasts is of the utmost importance, as they constitute the only way to indirectly assess global (size, shape) and sometimes local characteristics (meningeal/sulcal/gyral patterns) of the external cerebral anatomy of extinct species, and especially hominids. To date, there exist only few tools to study virtual endocasts in an automated or semi-automated way, and in an objective and reproducible manner. The objective of this Collaborative Research Initiative (ARC) coordinated by Sylvain Prima is to devise, implement, validate and apply new computational methods for the automated and objective morphometric analysis of extant and extinct hominid cranial endocasts. This work is jointly led by the Visages Team at INRIA Rennes, the Asclepios Team at INRIA Sophia Antipolis and the ICAR team at CNRS Montpellier, as well as the Museum national d’Histoire naturelle in Paris, the Museum of Toulouse, the Transvaal Museum (Pretoria, South Africa) and the Royal Museum for Central Africa (Tervuren, Belgium). Web: http://3dmorphine.inria.fr.

7.3. International initiatives

7.3.1. INRIA Associated Project NeurOMIMe

Participants: Pierre Hellier, Sylvain Prima, Pierre Jannin, Jean-Yves Gauvrit, Xavier Morandi, Romain Carpentier, Daniel Garcia-Lorenzo, Alexandre Abadie, Christian Barillot.

duration : 36 months, from 01/01/2006, renewed in 15/12/2008

NeurOMIMe[1] stands for "Objective Medical Image Methods Evaluation for Neurological and Neurosurgical Procedures". This International INRIA action is coordinated by Christian Barillot (Visages) and Louis Collins (IPL, Univ. McGill) and relates research dealing with medical image processing in clinical neurosciences performed in both collaborative sites: IRISA/Visages on one part and the Image Processing Laboratory of the McConnell Brain Imaging Centre at the Montreal Neurological Institute (Univ. Mc Gill, Montreal, Canada) on the other part.

[1] http://www.irisa.fr/visages/documents/FormulaireNeurOMIMe.html

The officiel yearly report is available online (http://www.irisa.fr/visages/documents/Neuromime/FormulaireRenouvNeuroMIME2010.html).

7.3.2. Joint Project with the Brain Imaging and Cognitive Disorders group at LIAMA (Sino-French Laboratory in Computer Science, Automation and Applied Mathematics), Beijing, China

Participants: Lei Lin, Christian Barillot.

duration : 12 months, from 01/12/2008

Through this collaboration between BICD Team in LIAMA and TEAM VISAGES - U746, the two teams will share their own, but complementary, expertise by distributing algorithms and data dealing within the clinical needs of early prediction and diagnosis of brain diseases in order to compare and cross-validate the different procedures developed at each site and evaluate their performance on different populations, especially in Chinese and French populations with various brain diseases. Then it can improve on the excellence and efficiency of these procedures. The output of this collaboration will improve our understanding of mechanisms of some brain diseases.

7.3.3. Visiting scientists

Prof. Ponada Narayana, Visiting Scientist,Visiting Professor, University of Texas at Houston, TX, was in sabbatical from 01/05/2009, until 15/10/2009 in the team. His visit was mostly dedicated to work on the MS project and on setting up the Neurinfo imaging platform.

8. Dissemination

8.1. Leadership within the scientific community

8.1.1. 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 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.

8.1.2. Workshop/Symposium Organization

- C. Barillot was chairman (with L. Collins from McGill in Montreal) of the MICCAI workshop on ”Medical Image Analysis on Multiple Sclerosis" (MIAMS'09), London, UK, Sept. 20th, 2009 (http://miams09.inria.fr/doku.php)

8.1.3. Peer Reviews of journals

- Reviewing process for Nature Neurosciences (CB), IEEE TMI (PH, SP, PJ, BG), Medical Image Analysis (CB, PH, SP, PJ), NeuroImage (PH, CB, PJ), Human Brain Mapping (CB), Academic Radiology (PJ), International Journal of Computer Assisted Radiology and Surgery (PH, PJ, SP), Academic Radiology (PJ), IEEE-TPAMI (CB), International Journal of Computer Vision (CB), IEEE Transactions on Information Technology in Biomedicine (SP), Machine Vision and Applications (SP).

8.1.4. Technical Program Committees (TPC) of conferences

- C. Barillot was area chair for SPIE Medical Imaging 2009, Miccai 2009 and TPC member for IPMI'09, MICCAI-Grid Workshop 2009, IEEE CBMS'09, WBIR'09
- B. Gibaud was TPC member for CARS 2009
- P. Jannin was area chair and TPC member for SPIE Medical Imaging 2009 and CARS 2009 and TPC member for MICCAI 2009
- P. Hellier was TPC member MICCAI 2009, IEEE ISBI 2009, IEEE ICPR 2009
- S. Prima was TPC member of MICCAI 2009, IEEE ISBI 2009

8.1.5. 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 and P. Jannin are members of IEEE EMBS
- C. Barillot is senior member of IEEE
- C. Barillot, P. Hellier, S. Prima, P. Jannin are members of the MICCAI society
- P. Jannin is member of SPIE

8.2. Teaching

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

- DIIC-INC, IFSIC, University of Rennes I : 2h (*C. Barillot*), 2h (*P. Hellier*), 2h (*P. Jannin*)
- Master 2 SIBM, University of Angers-Brest-Rennes : 26h (*C. Barillot, S. Prima, B. Gibaud, P. Jannin, X. Morandi, J. Petr, JY Gauvrit*), C. Barillot, B. Gibaud and P. Jannin are responsible for three different semesters. C. Barillot 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*)
- Master "Informatique", Univ. de Bretagne Sud: 2h (*P. Hellier*)
- European School for Medical Physics:3h (*B. Gibaud, P. Jannin*)

8.3. Participation to seminars, scientific evaluations, awards

- C. Barillot served as external reviewer for the recruitment commission of University of Caen and University of Rennes I
- B. Gibaud served as expert for ANR ('Blanc' Program)
- C. Barillot served as the scientific organizer for the INRIA evaluation seminar on " Computational Medicine and Neurosciences" (Research Theme 6)
- C. Barillot served as external reviewer of an FQRNT Quebec grant
- C. Barillot served as external reviewer of an FP6 IST integrated Project

- C. Barillot serves as a Scientific Delegate to AERES (French National Scientific Evaluation Institute) for the Research Units Section in the Health Science domain.

8.4. Invitation of scientific seminars, visits

- Dr. A. Cachia, INSERM-SHFJ, Orsay, 12/02/2009
- Prof. Jan Kibic, Czech Technical University, Prague, 23/04/2009
- Dr. P. Maurel, Département Informatique, ENS, Paris, 23/04/2009
- Dr. J. Mille, Ceremade, Paris Dauphine, Paris, 23/04/2009
- Dr. O. Commowick, Harvard Medical School, Boston, MA, 14/05/2009
- Dr. C. Samir, Department of Mathematical Engineering, Catholic University of Louvain, B, 14/05/2009
- Prof. Benoit DAWANT from University of Vanderbilt, TN, 11/06/2009
- Prof. Ponnada A. Narayana, University of Texas, Houston, 07/07/2009

8.5. Dissemination toward non specialists

- Article in "‘Ouest France"’ in the context of Launching of Neurinfo, June 2009
- Articles in "‘Ouest France"’, Emergence Ouest, INEDIT in the context of Inauguration of Neurinfo, October 2009
- Radio report in France Bleue Armorique in the context of Launching of Neurinfo, June 2009
- TV report in France 3 Ouest in the context of Inauguration of Neurinfo, October 2009

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[11] N. WIEST-DAESSLÉ. *Imagerie du tenseur de diffusion pour l'étude de pathologies cérébrales*, Université Rennes I, January 2009, Ph. D. Thesis FR .

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