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Project-Team VisAGeS

Vision Action et Gestion d'informations en Santé

Rennes - Bretagne-Atlantique

THEME BIO

Activity Report

2008

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2. Overall Objectives

2.1. Overall objectives

Keywords: *3D free-hand ultrasound*, *clinical neurosciences*, *image segmentation and analysis*, *image-guided intervention*, *management of information in medical imaging*, *medical imaging*, *neuroimaging*, *registration*, *statistical analysis in medical imaging*.

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:

- 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).
- The field of image segmentation and structure recognition, with a special emphasis on the difficult problems of i) image restoration for new imaging sequences (new Magnetic Resonance Imaging protocols, 3D ultrasound sequences ...), and *ii*) structure segmentation and labelling based on shape and statistical information.

- The field of image analysis and statistical modelling with a new focus on Voxel Based Analysis (VBA) and group analysis problems. A special attention will be given also to the development of advanced frameworks for the construction of probabilistic atlases since this complicated problem is still only partially solved.
- The field of information management in neuroimaging following the Neurobase project, for the development of distributed and heterogeneous medical image processing systems [1].

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

Keywords: *Rigid registration*, *deformable registration*, *similarity measures*.

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 [48]:

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

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 [55], [65], [59], [61], [54].

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).

[1] http://www.irisa.fr/visages/demo/Neurobase/index.html

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 [56]. 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 [64]). 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

Keywords: *3D ultrasound*, *MRI*, *deformable shape models*, *image restoration*, *level sets*.

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 [46], [47], [49], 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

Keywords: *group analysis*, *image classification*, *probabilistic brain atlas*, *voxel based analysis*.

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 [51], [55], 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 in medical imaging

Keywords: *mediation*, *ontology*, *web services*, *workflows*, *wrapper*.

There is a strong need of a better sharing and a broader re-use of medical data and knowledge in the neuroimaging field. 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. 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.

4. Application Domains

4.1. Neuroimaging

Keywords: *3D ultrasound*, *brain atlas*, *clinical neuroscience*, *image-guided surgery*, *multiple sclerosis*, *multispectral MRI*, *neuroimaging*, *preoperative imaging*.

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 [49], [51], [50], [55],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, 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.

Within this application domain, we aim at developing systems 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.

Per-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 gesture expertise: Research on modeling surgical procedures focused on understanding of complexity and extent of the surgical work domain to be modelled. 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. SPM can be addressed according to different granularity levels and points of view. Internally and with collaborations with the ICCAS research institute (International Center of Computer Assisted Surgery) from Leipzig University (Germany), we addressed two different points of view: one focusing on the main surgical tasks performed by the surgeon and one focusing on physical activities in the operating room. Discussions and works with the ICCAS group started in November 2004 were used as a basis for the creation of a new DICOM group (WG 24: "DICOM in Surgery"). P. Jannin is a co-chair of one of the 10 project groups constituting the WG 24. 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. The initial investment is heavy but the issue is directly proportional. Resulting applications may impact surgical planning, surgical performance as well as surgical education.

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

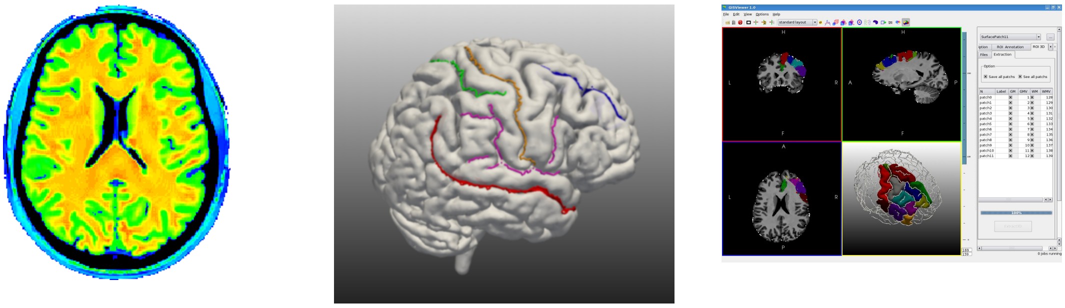
5.1. Introduction

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 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 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. Romeo

Participants: Pierre Hellier, Christian Barillot.

Romeo (**RO**bust **M**ultigrid **E**lastic registration based on **O**ptical flow) is a non-rigid registration algorithm based on optical-flow. Romeo is developed using Vistal (C++ template classes described above). Romeo estimates a regularized deformation field between two volumes in a robust way: two robust estimators are used for both the data term (optical flow) and the regularization term (smoothness of the field). An efficient multiresolution and multigrid minimization scheme is implemented so as to estimate large deformations, to increase the accuracy and to speed up the algorithm [58]. Romeo has been registered at APP with number: IDDN.FR.001.200014.SP.2000.000.21000.

5.4. Juliet

Participants: Pierre Hellier, Christian Barillot.

Juliet (**J**oint **U**se of **L**andmarks and **I**ntensity for **E**lastic regis**T**ration) is a non-rigid registration algorithm that is built on the Romeo software. Juliet makes it possible to incorporate sparse constraints deduced from the matching of anatomical structures such as cortical sulci for instance. A sparse deformation field is introduced as a soft constraint in the minimization to drive the registration process. A robust estimator is used so as to limit segmentation errors and false matching [57]. Juliet has been registered at APP with number: IDDN.FR.001.45001.001.S.A.2001.000.21000.

5.5. Tulipe

Participants: Pierre Hellier, Christian Barillot.

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. 3D freehand ultrasound is a technique 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. From these irregularly distributed B-scans and their positions, a regular 3D lattice volume can be reconstructed. This reconstruction step is needed to apply conventional 3D computer vision algorithms like volumetric registration and segmentation, but is still an acute problem with regards to computation time and reconstruction quality. Tulipe explicitly takes into account the 3D probe trajectory. In the classical distance weighted interpolation, the interpolation kernel is composed of the orthogonal projections of the current point on the closest B-scans. In Tulipe, the interpolation kernel is composed of intersections between the probe trajectory (passing through the current point) and the closest B-scans [52].

5.6. Online applications

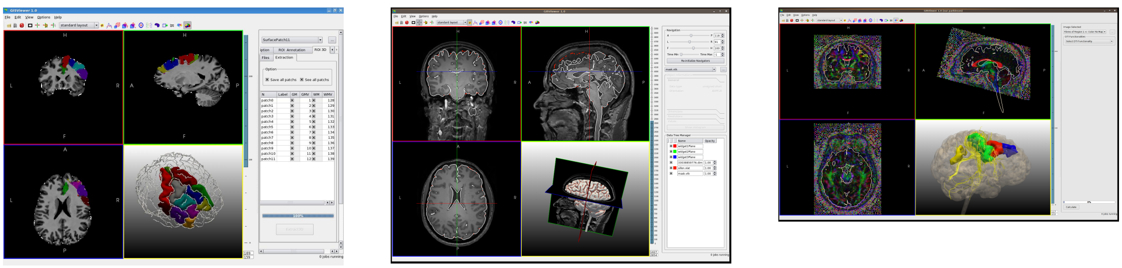
Participant: Alexandre Abadie.

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 550 processes have been launched in 2008.

5.7. 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

5.8. Dbsurg

Participant: Pierre Jannin.

DBSurg is a software for recording descriptions of surgical procedures based on a previously defined ontology [62], [63]. 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.

5.9. CLASH

Participant: Pierre Hellier.

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.

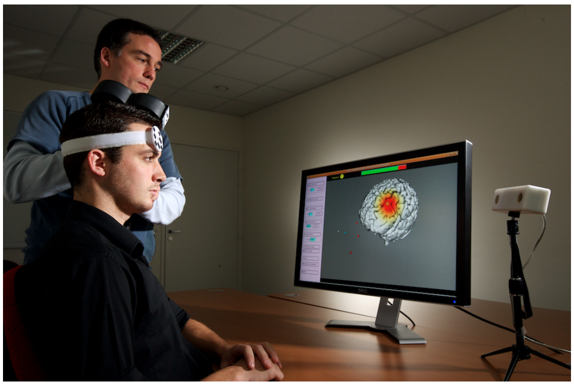


Figure 3. TMS Inria system in action.

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

5.11. InriaNeuroTk

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

InriaNeuroTk (INRIA Neuroimaging Resource Toolkit) 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. InriaNeuroTk is fully developped in Java language and is based on the JBoss SEAM framework. A registration at APP of this software is in progress.

5.12. IGNS

Participants: Romain Carpentier, Vincent Gratsac, 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.

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 [25], 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. Automatic symmetry plane estimation of bilateral objects in point clouds

Participants: Benoît Combès, Sylvain Prima.

We reexamined the problem of automatically estimating the symmetry plane of bilateral objects (having perfect or imperfect mirror symmetry) in point clouds. Classical methods, mostly based on the ICP algorithm, are limited and complicated by an inappropriate parameterization of the problem. First, we showed how an adequate parameterization, used in an ICP-like scheme, can lead to a simpler, more accurate and faster algorithm. Then, using this parameterization, we reinterpreted the problem in a probabilistic framework, and used the maximum likelihood principle to define the optimal symmetry plane. This problem can be solved efficiently using an EM algorithm. The resulting iterative scheme can be seen as an ICP-like algorithm with multiple matches between the two sides of the object. This new algorithm was implemented using a multiscale, multiresolution approach and was evaluated in terms of accuracy, robustness and speed [22], [23].

6.1.3. New algorithms to map asymmetries of 3D surfaces

Participants: Benoît Combès, Sylvain Prima.

We proposed a set of new generic automated processing tools to characterise the local asymmetries of anatomical structures (represented by surfaces) at an individual level, and within/between populations. The building bricks of this toolbox are: 1) a new algorithm for robust, accurate, and fast estimation of the symmetry plane of grossly symmetrical surfaces, and 2) a new algorithm for the fast, dense, non-linear matching of surfaces. This last algorithm was used both to compute dense individual asymmetry maps on surfaces, and to register these maps to a common template for population studies. We showed these two algorithms to be mathematically well-grounded, and we provided some validation experiments. Then we propose a pipeline for the statistical evaluation of local asymmetries within and between populations [24].

6.1.4. Evaluation of non-linear registration methods applied to brain MRI

Participant: Pierre Hellier.

Comparative morphometry and group analysis of functional and physiological data require coregistration of brains to establish correspondences across brain structures. We have participated in an evaluation of nonlinear deformation algorithms applied to brain image registration, including fourteen algorithms from laboratories around the world which have been evaluated using 8 different error measures. One of the most significant findings of this study is that the relative performances of the registration methods under comparison appear to be little affected by the choice of subject population, labeling protocol, and type of overlap measure. This is important because it suggests that the findings are generalizable to new subject populations that are labeled or evaluated using different labeling protocols.

6.1.5. Segmentation of multidimensional MRI using Graph-Cut

Participants: Jérémy Lecoeur, Christian Barillot.

A new segmentation framework has been developed taking advantage of multimodal MR image signature of the different brain tissues (healthy and/or pathological). This is achieved by merging three different modalities of gray-level MIRI sequences into a single RGB-like MIRI, hence creating a unique 3-dimensional signature for each tissue by utilising the complementary information of each MRI sequence. Using the scale-space spectral gradient operator, we have obtained a spatial gradient robust to intensity inhomogeneity [32]. Even though it is based on psycho-visual colour theory, it can be very efficiently applied to the RGB colored images. More over, it is not influenced by the channel assignment of each MRI. Its optimisation by the graph cuts paradigm provides a powerful and accurate tool to segment either healthy or pathological tissues in a short time (average time about ninety seconds for a brain-tissues classification). As it is a semi-automatic method, we run experiments to quantify the amount of seeds needed to perform a correct segmentation (dice similarity score above 0.85). Depending on the different sets of MRI sequences used, this amount of seeds (expressed as a relative number in percentage of the number of voxels of the ground truth) is between 6 to 16%. We have tested this algorithm on Brainweb data set for validation purpose (for healthy tissue classification and MS lesions segmentation), and also on clinical data for tumours and MS lesions detection and tissues classification

6.1.6. Labeling of Cortical Sulci using Multidimensional Scaling

Participants: Meena Mani, Christian Barillot.

The task of classifying or labelling cortical sulci is made difficult by the fact that individual sulci may not have unique distinguishing features and usually need to be identified by a multivariate feature set that takes the relative spatial arrangement into account. In this work, classical multidimensional scaling (MDS), which gives a geometric interpretation to input dissimilarity data, is used to classify 180 sulci drawn from the ten major classes of sulci. Using a leave-one-out validation strategy, we achieve a success rate of 100% in the best case and 78% in the worst case. For these more difficult cases, we propose a second stage of classification using shape based features. One of these features is the geodesic distance between sulcal curves obtained from a new open curve representation in a geometric framework. With MDS, we offer a simple and intuitive approach to a challenging problem. Not only we can easily separate left and right brain sulci, but we also narrow the classification problem from, in this case, a 10-class to a 2-class problem. More generally, we can identify a region-of-interest (ROI) within which one can carry out further classification.

6.1.7. Cortical Parcelization of the human cortex from clustering based on cortical sulci

Participants: Alexandre Abadie, Ammar Mechouche, Bernard Gibaud, Christian Barillot.

This work has been conducted under the summer Internship of Mickael Pincepoche. The spatial resolution of 3D MRI volumes allows a more detailed analysis of the human cerebral cortex. In particular, structures on which the descriptive anatomy of the cerebral cortex is based (cortical paths) can now be viewed in vivo. We have set up a cortical parcelization module able to delineate the different gyri of the human cortex based on the surrounding cortical sulci. This parcelization is made from patches defined on the surface of the brain by an expert by using the results coming from the "Ontology-based annotation of brain MRI images" project (see 6.3.2). The aim of such cortical parcelization is numerous. Indeed, this division corresponds to the different regions of the brain region with a specific functionality (auditory, language, visual or motor cortex for instance). Viewing such a cortical parcelization may be also useful during a surgical preparation in neurosurgery or to study the morphometry of the cortex in order to define local geometrical biomarkers. The results achieved in this work can also be used in future studies such as to initiate tractrography from DT-MRI data. This work is integrated via a plug-in software platform software team (GISViewer).

6.2. Image processing on Diffusion Weighted Magnetic Resonance Imaging

6.2.1. Diffusion Weighted and Diffusion Tensor Image Denoising

Participants: Nicolas Wiest-Daesslé, Sylvain Prima, Pierrick Coupe, Sean Morrissey, Christian Barillot.

Diffusion-Weighted MRI (DW-MRI) is subject to random noise yielding measures that are different from their real values, and thus biasing the subsequently estimated tensors. The Non-Local Means (NLMeans) filter has recently been proposed to denoise MRI with high signal-to-noise ratio (SNR). This filter has been shown to allow the best restoration of image intensities for the estimation of diffusion tensors (DT) compared to state-of-the-art methods. However, for DW-MR images with high b-values (and thus low SNR), the noise, which is strictly Rician-distributed, can no longer be approximated as additive white Gaussian, as implicitly assumed in the classical formulation of the NLMeans. High b-values are typically used in high angular resolution diffusion imaging (HARDI) or q-space imaging (QSI), for which an optimal restoration is critical. In this work, we have proposed to adapt the NLMeans filter to Rician noise corrupted data. Validation is performed on synthetic data and on real data for both conventional MR images and DT images. Our adaptation outperforms the original NLMeans filter in terms of peak-signal-to-noise ratio (PSNR) for DW-MRI [66].

6.2.2. Impact of Rician Adapted Non-Local Means Filtering on HARDI diffusion MRI data

Participants: Nicolas Wiest-Daesslé, Sylvain Prima, Sean Morrissey, Christian Barillot.

In this work conducted in collaboration with the ODYSSEE project-team, we have studied the impact of denoising the raw high angular resolution diffusion imaging (HARDI) data with the Non-Local Means filter adapted to Rician noise (NLMr). We showed that NLMr filtering improves robustness of apparent diffusion coefficient (ADC) and orientation distribution function (ODF) reconstructions from synthetic HARDI datasets. Our results suggest that the NLMr filtering improve the quality of anisotropy maps computed from ADC and ODF and improve the coherence of q-ball ODFs with the underlying anatomy while not degrading angular resolution. These results are shown on a biological phantom with known ground truth and on a real human brain dataset. Most importantly, we show that multiple measurements of diffusion-weighted (DW) images and averaging these images along each direction can be avoided because NLMr filtering of the individual DW images produces better quality generalized fractional anisotropy maps and more accurate ODF fields than when computed from the averaged DW datasets [53].

6.2.3. Motor and sensory fibers for hand function - a diffusion tensor MRI study

Participants: Romuald Seizeur, Sylvain Prima, Nicolas Wiest-Daesslé, Christian Barillot, Xavier Morandi.

We acquired 3D anatomical (T1-weighted), functional (fMRI) and diffusion-tensor (DTI) MR images for a quantitative study of the cortical hand areas in a population of 40 healthy right-handed and left-handed subjects. First, specific paradigms were used to identify cortical motor and sensory areas of the left and right hand in fMRI. DTI tractography was then performed to delineate the fiber tracts connecting these fMRI-defined regions of interest with the brain stem. Quantitative indices (fractional anisotropy, mean diffusivity) were then computed over the tracts of interest and statistics were performed to assess differences between right and left hands in the population of right and left-handed subjects.

6.3. Management of Information in Neuroimaging

6.3.1. Ontology of Datasets and Image processing tools in neuroimaging

Participants: Lynda Temal, Farooq Ahmad, Bernard Gibaud.

OntoNeuroLog is the name of the ontology being built in the context of the NeuroLog project, based on previous work initiated during the NeuroBase project (OntoNeuroBase). This ontology is based on a multi-layered, modular approach to ontology design. We used DOLCE (Descriptive Ontology for Linguistic and Cognitive Engineering) as a foundational ontology, providing the common philosophical foundation, together with several core ontologies developed by MIS (Modélisation, Information et Systèmes) in Amiens. Our achievements in 2008 are a first version (V1.0) of this ontology, including: (1) what we call contextual information (such as Studies, Examinations, Subjects, Centers, etc.); (2) a detailed taxonomy of the major Datasets used in neuroimaging; (3) a detailed taxonomy of Dataset processing (actions). Three manifestations of this ontology are available. The first is a series of OntoSpec documents, semi-informal, with rich semantic content, that constitute a reference documentation for the whole ontology. The second is a OWL-Lite representation; due to its limited expressivity, it will be complemented with rules. The third consists of a relational representation, that is being used as a Federated Schema to map the different site-specific databases. This work was achieved in close cooperation with partners MIS (Gilles Kassel, Amiens) and GIN (Michel Dojat, Grenoble).

6.3.2. Ontology-based annotation of brain MRI images

Participants: Ammar Mechouche, Bernard Gibaud, Xavier Morandi.

In this work, we are interested in showing how symbolic knowledge representing mereo-topological knowledge about cortical anatomical structures can complement other kinds of priors such as statistical probability maps. In our system, probability maps provide a first set of assumptions about brain gyri, from which the system automatically derives a series of assumptions concerning sulci. Image annotations are obtained through a cooperation with the user, who can enforce specific labels for particular gyri and sulci. The system iterates reasoning, which limits the range of labelling possibilities. Resulting annotations are then stored as OWL instance files, referring to 3D binary masks deduced from the surface data. The system uses an OWL ontology of brain cortical structures (focusing of the representation of part-of and topology relationships) and of rules (represented in SWRL), modelling complex dependencies between those relationships. Merging these two kinds of knowledge is made using the KAON2 reasoner[2]. An assessment of the system in 10 subjects with normal anatomy and 5 patients with tumors in the central or frontal areas showed that the system performances were not decreased in presence of pathology. This work has been done in collaboration with Pr Christine Golbreich (University of Versailles Saint Quentin, and LIRMM, Montpellier), who is co-supervisor of Ammar Mechouche's PhD thesis. This work was presented in MICCAI'2008 [35] and AMIA'2008 [34].

6.4. Image Guided Intervention

6.4.1. Non-rigid registration of intraoperative ultrasound and preoperative MRI for brainshift compensation

Participants: Pierrick Coupé, Pierre Hellier, Xavier Morandi, Christian Barillot.

In Image-Guided NeuroSurgery (IGNS), neuronavigation is a very attractive tool for surgical planning and procedure. However, the accuracy and usefulness of such systems is limited due to the presence of soft-tissue deformations called brainshift. In this work, a global approach based on intraoperative tracked US probes is proposed to (a) correct the error of the neuronavigation system concerning image-patient registration and (b) compensate for the deformations of the cerebral structures occurring during a neurosurgical procedure. Experiments were carried out on 4 patients with various lesions such as cavernoma and low-grade glioma. Qualitative and quantitative results on the estimated error performed by neuronavigation system and the estimated brain deformations show very promising results of the overall registration framework

6.4.2. Automatic geometrical and statistical detection of acoustic shadows

Participants: Pierre Hellier, Xavier Morandi, Pierre Meyer, Pierrick Coupé.

[2] http://www.aifb.uni-karlsruhe.de/Projekte/viewProjekt?id_db=62

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 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.

6.4.3. Preoperative brain deformation in neurosurgery

Participants: Omar El Ganaoui, Xavier Morandi, Pierre Jannin.

To our knowledge, there is no study that discusses the possible intraoperative brain deformations before skull opening. The study that we proposed is set within the context of brain tumor surgery. We studied 7 surgical cases and demonstrated the existence of deformation in preoperative phase of IGNS and necessity to update preoperative images in order to allow the recovery of registration error for MIGNS systems due to a new phenomenon that we call " preoperative brain shift ". Preoperative brain shift requires to specify a new clinical protocol for IGNS planning procedures in order to improve the surgical workflow.

6.4.4. Study of surgical process models based on main surgical tasks performed by the surgeon

Participants: Pierre Jannin, Xavier Morandi, Brivael Trelhu.

We first improved the data acquisition software for pre and post operatively describing patient specific surgical process models based on the main surgical tasks. We then adapted the software developed by the ICCAS group for neurosurgical procedures. Second, we applied data analysis approaches (from data mining) on 157 patient specific models of neurosurgical procedures for tumor resection. 322 variables were identified. Predictive and predicted variables were independently classified and matched, and decision trees were computed for defining surgical rules. Results were submitted to a national conference (EGC 09).

6.4.5. Study of surgical process models based on physical activities in the OR

Participants: Pierre Jannin, Xavier Morandi, Brivael Trelhu.

With the german ICCAS group, we performed this year a validation study of patient specific surgical process models (SPM) acquisition involving about 20 peoples during two weeks and providing about 1000 surgical models descriptions for analysis. We defined metrics for comparing surgical models based on measurement of structural outliers, content outliers, structural equivalence, and sequential completeness. Completion time, skills level, knowledge level, and software usability were also acquired during this study. Results will be published in JAMIA in 2009 [20]. Methods were also developed for computing generic surgical patient models from patient specific SPMs and applied for eye surgery.

6.4.6. 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 this year 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. Main objective is the optimisation of information display and retrieval. A paper was submitted to an international journal (in revision process). We are currently working for defining a method for analysis the surgical work domain. This method will be used for assessing information provided by image guided surgery systems for surgical planning.

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

Participants: Pierre Jannin, Xavier Morandi.

This work has been done during the Master Intership of Florent Lalys. Deep Brain Stimulation (DBS) is a technic used from about 20 years mainly for functional neurosurgery of Parkinson disease. It consists of inserting an electrode in deep brain structures such as the sub thalamic nucleus. High frequency electrical stimulation via the electrode will considerably reduce the functional pathology. By using pre and post operative multimodal images and clinical scores and with the participation of JC Ferré and C Haegelen respectively from the radiological and neurosurgical department of the university hospital, we developed an approach for assessing DBS by developing a anatomical and clinical digital atlas gathering information about stimulated plots for a population of 45 patients and related pre and post operative clinical scores. The registration workflow between pre and post operative images and the anatomical MR template was validated on clinical data. Results were submitted to an international conference SPIE Medical Imaging 2009 (paper accepted).

6.4.8. 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 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.

6.4.9. Automated Surgical Planning in Brain Tumor Surgery and DBS

Participants: Omar El Ganaoui, Caroline Villard, Pierre Jannin, Xavier Morandi.

Surgical Planning consists in identifying optimal access to the target based on anatomical references and constrained by healthy functional areas. We started this year two projects for the automatic computation of possible surgical approaches, respecting such constraints expressed from preoperative images (MR and CT). The first project is developping an approach based on restricted surgical field of view and consists in computing neurosurgical convex polyhedra (NSCP). These NSCP will be compared to actual surgical approaches. The second project, with the participation of 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.

6.4.10. Methodological Frameworks for Validation in Medical Image Processing and in Image Guided Interventions

Participant: Pierre Jannin.

We recently developed frameworks for validation in medical image processing and for assessment of image guided interventions [60], [59]. These frameworks were applied this year into different projects and for different applications. Collaborations were started on this project with the ICCAS institute (University of Leipzig, Germany) and this year with the CAMPAR lab at the Technische Universitat Munchen (TUM, Munich, Germany).

6.4.11. Transcranial magnetic stimulation

Participants: Pierre Hellier, Xavier Morandi, Christian Barillot.

We have started a collaboration with the psychiatric hospital in Rennes (Prof. B. Millet and Dr. Cecilia Nauczyciel-Bredoux) concerning transcranial magnetic stimulation for the treatment of depression. More specifically, we have developed a neuronavigation system that is coupled with the magnetic simulation system. This enables to localize in real-time the stimulation locus on the MR image. Compared to the standard empirical localization, we have shown that the neuronavigation is more reliable to stimulate the interface between areas 9 and 46 of the Brodmann atlas.

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, Sylvain Prima, Gilles Edan, Sean Morrissey, Christian Barillot.

We proposed a new algorithm for segmentation of white matter lesions and normal appearing brain tissues in Multiple Sclerosis (MS). Two different segmentation methods were combined to have a better and more meaningful segmentation. On the one hand, a local segmentation approach, the Mean Shift, was used to generate local regions in our images. On the other hand, a variant of the Expectation Maximization was employed to classify these regions as Normal Appearing Brain Tissues (NABT) or lesions [29]. Validation of this method was performed with synthetic and real data. The output is a more powerful algorithm that employs at the same time global and local information to improve image segmentation [27], [37].

6.5.2. The impact of processing workflow in automatic white matter lesion segmentation in MS

Participants: Daniel Garcia-Lorenzo, Sylvain Prima, Jean-Christophe Ferré, Gilles Edan, Sean Morrissey, Christian Barillot.

The design of a robust automatic segmentation workflow is crucial to deal with the shortcomings of images that impact on their analysis. In this work, we have compared different workflows, using state-of-the-art tools, in order to evaluate the role of the different preprocessing tasks. We propose some methods in order to improve the computing time, robustness and accuracy of the segmentation method. We compare with manual segmentation as ground truth the workflows and improvements in the segmentation method. Finally, we propose a new automatic workflow for white matter lesions segmentation in Multiple Sclerosis [30], [28], [38].

6.5.3. Automated DTI analysis of MS lesions and their contralateral regions of interest using the mid-sagittal plane as a reference

Participants: Nicolas Wiest-Daesslé, Sylvain Prima, Jean-Christophe Ferré, Gilles Edan, Sean Morrissey, Christian Barillot.

Diffusion tensor MRI (DT-MRI) allows the in vivo assessment of the abnormalities of white matter in multiple sclerosis (MS). DT-MRI is complementary to conventional MRI sequences where such abnormalities are often not visible. Most studies have shown differences of mean diffusivity (MD) and fractional anisotropy (FA) between patients and controls in MS lesions (MSL) and normal appearing white matter (NAWM) based on histogram analyses. However, the majority of these studies are based on histogram analysis, i.e. local information of DTMRI is lost, and moreover a number of those studies were not conclusive, partly explained by methodological issues, because these tensor indices vary within the brain, which is likely to make such global, histogrambased analyses, fail. We have proposed a new framework to compare these indices between MSL and NAWM and between two populations (patients and controls). First, MSL are manually delineated in MS patients. The mid-sagittal plane is then automatically computed, allowing to define a contralateral region of interest (ROI) in NAWM for each MSL. This allows the local comparison of DTI indices in anatomically similar regions in each MS patient. Second, each MS patient is linearly registered to each control subject, and the same left-right comparison between MSL and contralateral NAWM is then performed in controls. The results (ANOVA with multiple comparisons procedure) show that 1) FA values are lower in MSL than in contralateral NAWM in MS patients ($p < 0.05$) but not in controls, 2) FA values are lower in MS patients (MSL and contralateral NAWM) compared to controls ($p < 0.05$), 3) MD values are not different between MSL/contralateral NAWM in MS patients and controls. We also show that combining different preprocessing methods (3 estimation methods and 3 distortion correction methods) has little impact on such results. Nevertheless, our fully automated approach is superior to manual or semi-automated DT-MRI analyses regarding the robustness of the results (reproducibility and accuracy) [39], [45].

6.6. Anatomical and functional imaging in dysphasia

Participants: Clément De Guibert, Camille Maumet, Alexandre Abadie, Arnaud Biraben, Pierre Jannin, Christian Barillot.

Previous neuroimaging studies have been reviewed, with a distinction of specified and unspecified dysphasias [3]. The study has been designed [Objectives; Method (activation tasks, MRI protocol; data analysis); Subjects (patients' selection and criteria)]. To test the MRI protocol and the processing method, a pilot study has been conducted with normal adult and children subjects. Tests have been conducted with the initial standard preprocessing and processing tool (Statistical Parametric Mapping, SPM02 and SPM05). The preprocessing and processing steps and parameters have been specified. This work has been performed in tight collaboration with University Hospital of Rennes especially with Drs. JC Ferré and E. Le Rumeur from the neuroradiology department and C. Allaire from the 'Language Clinic'.

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. CHGR project

Participants: Vincent Gratsac, Pierre Hellier.

duration : 5 months, from 01/05/2008

This project is a collaboration with the psychiatric university hospital of Rennes, and concerns the development of a dedicated neuronavigation system for transcranial magnetic stimulation. This grant partially funded the position of Vincent Gratsac.

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.

[3] De Guibert C., Allaire C., Le Rumeur E. "Morphologic and functional neuroimaging findings in specified and unspecified dysphasias (specific language impairments): review and perspectives"

7.2.2. ANR “Technologies Logicielles”, NeuroLOG Project

Participants: Lynda Temal, Sylvain Prima, Sean-Patrick Morrissey, Farooq Ahmad, Franck Michel, Daniel Garcia-Lorenzo, Gilles Edan, Bernard Gibaud, Christian Barillot.

duration : 36 months, from 01/10/2006

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.

7.3. International initiatives

7.3.1. INRIA Associated Project NeurOMIMe

Participants: Pierre Hellier, Sylvain Prima, Pierre Jannin, Sean-Patrick Morrissey, Xavier Morandi, Pierre Meyer, Pierrick Coupé, Daniel Garcia-Lorenzo, Nicolas Wiest-Daesslé, Christian Barillot.

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

NeurOMIMe[4] 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.

The officiel three year report is available online http://www.irisa.fr/visages/documents/Neuromime/DOSEval09_NeuroMime.html

7.3.2. Alliance (Egide) joint Project with the MARIARC (Magnetic Resonance And Image Analysis Research Centre) at the University of Liverpool

Participants: Sylvain Prima, Sean-Patrick Morrissey.

duration : 24 months, from 01/01/2007

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

This project is coordinated by Sylvain Prima and Laura Parkes (Univ. Liverpool) and aims to develop methods for the fully automatic detection and quantification of multiple sclerosis (MS) lesions and normal appearing white matter with dynamic Gadolinium enhanced magnetic resonance imaging.

7.3.3. 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.

7.3.4. Visiting scientists

Prof. Tetsuo SATO from Nara University in Japan has spent a one-year sabbatical in our group from February 2008. His work was dedicated to measure diffusion coefficients of same phantom at two different sites toward fusions of MRI and PET research for cancer detection.

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 workshop on Ultrasound imaging in the context of image guided neurosurgery, CARS 2008, Barcelona, Spain. June 2008 (http://cars08.inria.fr/doku.php)
- C. Barillot was chairman (with L. Collins from McGill in Montreal) of the MICCAI workshop on Medical Image Analysis on Multiple Sclerosis" (MIAMS'08), New-York City, NY, Sept. 6 2008 (http://miams08.inria.fr/doku.php)

8.1.3. Peer Reviews of journals

- Reviewing process for 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), Signal Processing (CB), Academic Radiology (PJ), IEEE-TPAMI (CB), International Journal of Computer Mathematics (CB), Magnetic Resonance in Medicine (CB), International Journal of Computer Vision (CB)

8.1.4. Technical Program Committees (TPC) of conferences

- C. Barillot was area chair for SPIE Medical Imaging 2008, Miccai 2008 and TPC member for MICCAI-Grid Workshop 2008, Smart Graphics 2008, JETIM'08, HiPGCoMB'08, IEEE CBMS08, MIAR08, BIOSTEC08, ICRA'08, WSPE´08 at ARES'08
- B. Gibaud was TPC member for CARS 2008
- P. Jannin was area chair and TPC member for SPIE Medical Imaging 2008 and CARS 2008 and TPC member for MICCAI 2008
- P. Hellier was TPC member MICCAI 2008, IEEE ISBI 2008, IEEE ICPR 2008
- S. Prima was TPC member of MICCAI 2007, IEEE ISBI 2007, IEEE MMBIA 2007

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*), 2h (*S. Prima*)
- Master 2 SIBM, University of Angers-Brest-Rennes : 26h (*C. Barillot, S. Prima, B. Gibaud, P. Jannin, X. Morandi, S.P. Morrissey*), C. Barillot, B. Gibaud and P. Jannin are responsible for three different semesters.
- 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 is member of the board of the ”Programme National de Recherche (PNR) Imagerie” (INSERM)
- C. Barillot served as expert for the Austrian Science Fund (FWF)
- B. Gibaud served as expert for ANR (’Blanc’ Program)
- C. Barillot served as external reviewer of an FP6 IST integrated Project
- C. Barillot served as expert for ANR Program "DEFIS SUPCOR 2008"
- C. Barillot serves as a Scientific Delegate to AERES (French National Scientific Evaluation Institute) for the Research Units Section

8.4. Invitation of scientific seminars, visits

- Prof. Neil Roberts, Ph.D., from University of Liverpool, 29/01/2008
- Prof. Ponnada A. Narayana, Ph.D., University of Texas, Houston, 7/02/2008
- Prof. Kevin Cleary, Ph.D., from Georgetown University Medical Center, Washington DC, 20/05/2008

8.5. Dissemination toward non specialists

- Participation to "La Ville Européenne des Sciences", Paris, Grand Palais, November 2008
- Article in "Science Ouest", Le cerveau se lit à la carte, October 2008
- Invited lecture during "Fete de la science", Parthenay de Bretagne, September 2008
- Invited lecture for the "‘semaine du cerveau"’, "‘Espace des Sciences, Rennes, April 2008
- Article in "‘Ouest France"’ in the context of NeuroDON, April 2008
- Presentation in high school for "A la découverte de la recherche", March 2008
- Article in "Interstices", Neuronavigation pour la stimulation magnétique transcranienne, February 2008.

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Year Publications

Doctoral Dissertations and Habilitation Theses

[10] P. COUPÉ. *Methode de compensation des déformations cérébrales par imagerie ultrasonore intraopératoire pour la neurochirurgie guidée par l'image*, Ph. D. Thesis, Université Rennes 1, Rennes, 2008, http://tel.archives-ouvertes.fr/tel-00328179/en/.

[11] L. TEMAL. *Ontologie pour le partage de données et d'outils de traitement dans le domaine de la neuroimagerie*, Ph. D. Thesis, Université Rennes 1, Rennes, 2008.

Articles in International Peer-Reviewed Journal

[12] P. COUPÉ, P. HELLIER, S. PRIMA, C. KERVRANN, C. BARILLOT. *3D Wavelet Sub-Bands Mixing for Image Denoising*, in "International Journal of Biomedical Imaging", vol. 2008, 2008, 11, http://hal.inria.fr/inria-00332001/en/.

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