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Team VisAGeS

Vision Action et Gestion d'informations en Santé

Rennes

THEME BIO

Activity Report

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Table of contents

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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*.

Abstract: 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 macros 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 concerns:

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 labeling based on shape and statistical information.

The field of image analysis and statistical modeling 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.

Concerning the application domains, we emphasize our research efforts on the neuroimaging domain 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, concerns 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*.

Abstract: 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 measure 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:

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

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). $\Phi_{\theta \mathrm{g}}$ is the transformation, ($\theta \in \Theta \mathrm{pg}$ being the set of parameters for this transformation, Δ is the cost (or similarity) function, and Ψ is the optimization method. $\{\Omega \mathrm{s} \Phi \mathrm{s} \Delta \mathrm{s} \Psi\}$ are the four major decisive factors in a registration procedure, the set $\Theta \mathrm{g}$ 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 ([12][25]).

In the domain of **rigid registration**, our research is more focused on new problems coming from the application. 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 is 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. In this domain, we are working in the following three directions:

- Non-rigid registration algorithms benefits 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 a mathematical elegant 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). 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*.

Abstract: 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 ([6][7][30]), 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*.

Abstract: 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 gigantic image data base, 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 function 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 needs to confront his 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 function. Based on our previous work proposing a cooperation between global and local references to build such probabilistic atlases ([11][12])

we are working to develop a probabilistic atlas capable of labeling 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*.

Abstract: Based on the Neurobase project, our objective is to establish the conditions allowing the federation through Internet of information sources in neuroimaging, where sources are distributed in different experimental sites, hospitals or research centres in cognitive neurosciences and contain data and image processing methods.

This topic follows the work currently done within the Neurobase project. Two of the major concerns of researchers and clinicians involved in neuroimaging experiments are on one hand, to manage internally the huge quantity of produced data ($\approx$1 Gb per subject) and, on the other hand, to be able to confront their experiences and the methods they develop, with those existing in other centers or moreover with those described in publications. Furthermore, and this is more particularly true for clinical centers (with limited staff capabilities), the researchers or the clinicians have great difficulties to set up large-scale experiments which are self-important, largely because of lack of human beings and capacities of recruiting subjects. Besides, the statistical validity of the results is sometimes insufficient (the rate of "false negative" is probably not negligible). Finally, it is related to the concern to better insure the profitability of the existing and expensive equipments (for the purchase as well as for the use), by facilitating their access to a wider users community. For all these reasons, we think that the pooling of the experimental results, through a network between collaborative centers, will allow widening the scientific achievement of the conducted experimental studies.

This will also allow increasing the possible panel of people involved in neuroimaging studies, while protecting the excellence of the supplied work.

4. Application Domains

4.1. Neuroimaging

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

Abstract: 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 term of applications since both clinical and neuroscience application share similar problems. Because this domain is very generic by nature, our major contributions are directed toward clinical needs even though our work can address some specific aspects related to the neuroscience domain.

Anatomical and functional brain atlases: 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 neurodegenerative brain diseases (Multiple sclerosis, Epilepsy, Parkinson or even Alzheimer). This is a very competitive research domain, our contribution is based on our previous works in this field ([30][11][12]), and by continuing our local and wider collaborations (local clinical partners, Neurobase collaborators ...).

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 neurodegenerative brain diseases (Epilepsy or Alzheimer for instance).

Multiple sclerosis: Our major objective within this application domain is to find new descriptors for tracking the evolution of the pathology from high dimensional data (e.g. nD+t MRI). This can be used to better assess the efficiency of new drug tests or to better understand the evolution of the pathology. Our contribution in this field bears on our previous work ([20]), our long experience in spatio-temporal and multimodal analysis of medical volumes, and moreover on our proximity with the Neurology Dept., Pontchaillou Hosp., one of the most important recruitment site in Europe (the first one in France).

Brain morphometry analysis: Our major objective within this application domain is to find new descriptors to study the brain anatomy and/or its function (e.g. variation of brain perfusion, evolution in shape and size of an anatomical structure in relation with pathology, computation of asymmetries ...). This is also a very critical research domain, especially for many neurodegenerative brain diseases (Epilepsy or Alzheimer for instance). Our contribution in this field bears on our collaboration with our clinical partners, local or not (through the Neurobase project for instance).

4.2. Image guided intervention

Abstract: This application domain concerns the development of 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 MRI or thermal imagery for the future.

This application domain is covered with tight collaboration with the Neurosurgery Dept., Pontchaillou Hosp. where X. Morandi (PU-PH) spent a year in Montreal working in this field. On the methodological side, we are working in partnership on the augmented reality topic with the Lagadic Team (E. Marchand).

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 estimate brain deformations using 3D ultrasound and video information.

Robotics for 3D echography: This project is conducted jointly with the Lagadic project. 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. This is a very challenging topic and we work in collaboration with local clinical partners (P. Darnault, PU-PH) and others (e.g. F. Tranquart and L. Pourcelot from INSERM Tours or the Robarts Research Institute at UWO, London, ON, Canada).

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. This is developed in collaboration with local clinical partners (P. Darnault, PU-PH and C. Treguier, PH).

5. Software

5.1. Introduction

Our objectives concerning the software development and diffusion is 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. Concerning the diffusion, we intend to disseminate our results via a free software distribution. Complying with both objectives requires software engineering resources, which could be partially covered in the short term by a current PRIR application "PlogICI", but a longer term alternative needs to be already foreseen.

5.2. Vistal

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). 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...). VistaL APP registration number is: IDDN.FR.001.200014.S.P.2000.000.21000.

5.3. Romeo

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 describes 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 ([16]).

5.4. Juliet

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 ([14]).

6. New Results

6.1. Deformable Registration

Participants: Pierre Hellier, Pierrick Coupé, Christian Barillot.

Our work in brain image registration has been directed towards two directions: first, the development of an international evaluation project for non-rigid brain image registration ([13][14]).

We have proposed an evaluation framework, based on global and local measures of the relevance of the registration. We have chosen to focus more particularly on the matching of cortical areas, since intersubjects registration methods are often dedicated to anatomical and functional normalization. Experiments have been conducted on a database of 18 subjects for 7 registration methods, involving the world leading contributors in this field (SPM, Animal, Demons, Romeo.... The global objective measures used show that the quality of the registration is directly related to the number of D.O.F. of the considered transformation. More surprisingly, local measures based on the matching of cortical sulci did not show significant differences between rigid and non rigid methods. Functional activations have been added to this framework in order to evaluate the capability of non-rigid registration method to cope with inter-individual functional variations. We have shown that our hybrid framework performed statistically significantly better than all other global non rigid registration methods tested. The same framework has been used to evaluate the non-rigid local statistical shape modelling using local statistics of brain shapes and a band-limited radial basis function for the functional areas. This new framework has the lower variance among all methods tested in this framework.

6.2. Statistical methods for image restoration

Participants: Arnaud Ogier, Pierre Hellier, Christian Barillot.

The context of this work was primarily the restoration of ultrasound images from 3D US volumes. Our research aim at improving the use of ultrasound images so as to improve diagnosis and therapeutic treatment. However, the presence of multiplicative noise, called speckle, makes the application of image processing methods difficult on these data. After a statistical study of ultrasound images, we develop a scheme of restoration based on Total Variation (TV)[1]. Nevertheless, this classical scheme is not adapted to speckle noise and for the various distributions inherent to ultrasound data. We have adapted the TV formulation in 2D and 3D ([19][34]).

in order to take into account the local noise distribution (Rice, Rayleigh, K, K-Homodyned). The controls involved in the TV are adapted to multiplicative noise assuming an unbiased centered normal distribution. In practice, the kurtosis can be considered as a good tissue and edge descriptor. This method leads to a good restoration of 3D ultrasound volumes which allow applying high level image processing algorithms for segmentation and registration purposes, expecting more robust usages of these methods.

[1] L. Rudin, S. Osher, and E. Fatemi, "Nonlinear total variation based noise removal algorithms", Physica, 1992.

6.3. Image Segmentation and Analysis

Participants: Cybele Ciofolo, Christian Barillot.

This topic consisted to develop accurate and robust segmentation methods of brain structures from 3D MRI volumes. Our goal is to make a contour evolve in order to match the borders of a region of interest. To this end, we take as much advantage as possible of the available information coming from the data and the knowledge of experts. We found fuzzy control as appropriate to drive the evolution of a level set contour and particularly to automatically tune the evolution parameters. We used this method to improve the segmentation on thin and high-contrasted areas such as the ventricles horns ([29]).

Moreover, we added a constraint in the contour evolution with a set of fuzzy labels. These labels give some information about the shape of the structure to segment, and are provided by an atlas. This approach is also very general since the choice of the atlas and the labels can be adapted to the target application. We implemented the method for two applications: the segmentation of the white matter, and the segmentation of the right hemisphere of the brain ([9]).

6.4. Statistical Modeling of Anatomical and Functional Brain Information

Participants: Pierre Hellier, Sylvain Prima, Christian Barillot.

We have proposed a framework for building statistical shape models which has been firstly applied to cortical sulci. The model is built from a training population of sulci extracted from MRI volumes with a parametric representation ([18]).

A coordinate system intrinsic to a sulcus shape is defined in order to align the training population, on which a principal components analysis is then performed. This statistical modeling has been extended to a sulci graph in order to describe not only the morphological features of one sulcus, but also the relationships in terms of relative position and orientation between major sulci. The analysis is concerned with a reduced graph defined by a pair of sulci. This framework has been applied in an international evaluation project of inter-subjects brain registration methods ([13]).

We have also exploited the statistical knowledge acquired by the sulci modelling in the context of anatomical and functional atlases building. More precisely, we have proposed a fusion scheme, local and non-linear, to register inter-subjects functional data (MEG dipoles) toward a single coordinate system linked to the anatomical model of cortical sulci. Experimented on a database of 18 subjects, this method has been shown to reduce the observed inter-individual functional variability ([11]).

Finally, in collaboration with M. Dojat from INSERM U594, the methodology proposed to model cortical sulci shape has been applied to compute a probabilistic atlas of the functional borders delimitating low-order visual areas ([10]).

6.5. Management of Distributed Information in Neuroimaging

Participants: Romain Valabrègue, Bernard Gibaud, Christian Barillot.

In this topic we have continued our work with the Neurobase consortium in order to develop a demonstration environment to exhibits the way neuroimaging information (data and image processing tools) can be shared. Our goal is to elaborate a demonstrator based on some existing modules like Le Select (http://www.le-select.com/), BrainVISA/Anatomist (http://brainvisa.info/) or VIsTAL (http://www.irisa.fr/visages/software-fra.html) extendable to modules largely used in neurosciences community such as SPM (http://www.fil.ion.ucl.ac.uk/spm/). Several functionalities are being implemented such as data wrappers & mediators, medical image processing methods (data access, registration, segmentation, visualization, ...) through a data flow model approach ([27]).

We showed in this paper an example of the Neurobase demonstrator architecture with a generic server model based on the LeSelect architecture with a PostGres/SQL (http://www.postgresql.org/) data base for managing storing of temporary image data computed from Data Flow process. The data flow processes for image processing workflow procedures are executed from a Tomcat (http://jakarta.apache.org/tomcat) server.

This workflow can be designed from any client web browser. In order to build relevant neuroimaging queries, we are actually implementing data flows being able to process brain segmentation, brain tissue classification (white matter, grey matter, CSF), cortical sulci delineation and rigid and non-rigid registration of MR images. At the present time, security aspects are just addressed by using a SSH tunneling for the transactions between the servers and the clients. Confidentiality of the data including anonymization has to be performed by the publisher. This issue should be addressed in future versions. The computation mapping implemented in the current version (i.e. where data meet the image processing codes) can be in principle performed everywhere in the collaborative network. In practice, because we haven't set up efficient processing servers on each collaborative site, in current experiments, codes are executed were the data are located.

At the present time, this demonstrator is being developed and tested in the context of two major applications:

- Clinical application dealing with epilepsy surgery
- Cognitive application dealing with the delineation of the visual cortex areas

6.6. 3D Free-Hand Ultrasound

Participants: Arnaud Ogier, Pierre Hellier, Christian Barillot.

We have developed a new robust and fully automatic method for calibrating three-dimensional (3D) free-hand ultrasound. 3D free-hand ultrasound consists in mounting a position sensor on a standard probe. The echographic B-scans can be localized in 3D, and can be compounded into a volume. However, especially for quantitative use, this process dramatically requires a calibration procedure that determines its accuracy and usefulness. Calibration aims at determining the 3D transformation (translations, rotations, scaling) between the coordinate system of the echographic images and the coordinate system of the localization system. To calibrate, we acquire images of a phantom whose 3D geometrical properties are known. We have proposed a robust and fully automatic calibration method based on the Hough transform and robust estimators ([22]).

Experiments have been carried out with synthetic and real sequences. Our calibration method was shown to be easy to perform, accurate, automatic and fast enough for clinical use ([21]).

6.7. Multiple Sclerosis

Participants: Laure Ait-Ali, Sylvain Prima, Pierre Hellier, Christian Barillot.

There are only a few drugs which are able to slow down the course of multiple sclerosis (MS) in some forms of the disease, and the others have a palliative effect on some of the symptoms. Magnetic resonance imaging (MRI) is a sensitive technique that can be used to provide objective measures of brain pathology in-vivo. MRI was the first method to allow direct visualization of MS plaques in vivo, and has had a major impact on the diagnosis and the understanding of MS and in the last years. However, MRI markers of the disease correlate weakly with clinical observations, which have prohibited their use as primary outcome measures in clinical trials. Sylvain Prima proposed several change-point statistical tests for the detection of evolving voxels in time-series of MR images. These statistics are currently investigated as surrogate markers of the disease activity within collaborations with the McConnell Brain Imaging Centre of the Montreal Neurological Institute (McGill University, Canada) and the Magnetic Resonance and Image Analysis Research Centre (University of Liverpool, UK). An alternative approach is also developed at IRISA by Laure Aït-Ali, based on spatio-temporal segmentation of times series of MR images of patients with MS.

7. Contracts and Grants with Industry

7.1. Medience

Participants: Romain Valabrègue, Christian Barillot.

Medience is a start-up of INRIA. Since 2004, through the ACI project "Neurobases", we have collaboration with Medience (http://www.medience.fr/) to develop a "middleware" system capable of accessing to heterogeneous and distributed resources (data, processing) in the context of the neuroimaging.

8. Other Grants and Activities

8.1. Regional initiatives

8.1.1. CPER initiative: 3D echography capture by a robotics system

Participants: Anne Sophie Tranchant, Christian Barillot.

In fall 2003, we have acquired a new robotics system marketed by Sinters company and dedicated to medical applications, specifically to the remote control of medical ultrasound probes. This system is based on a six degrees-of-freedom intrinsically safe robot. It is equipped with a force/torque sensor mounted at the tip of the robot arm which can move an ultrasonic or Doppler probe on the patient's skin while applying a programmable and constant force. To prove the interest of robotics approaches for medical applications, we will pursue two objectives. First, using ultrasound (US) images recorded over the probe trajectory and the corresponding robot positions, we will work on the 3D ultrasound image volume reconstruction. Second, using an external camera, we will develop visual servoing tasks to achieve an automatically probe positioning, or to control that the probe follows a planned trajectory in order to increase the 3D US reconstruction accuracy.

8.1.2. PRIR contract of Brittany region council PlogICI

Participants: Alban Gaignard, Pierre Hellier, Christian Barillot.

This two years project is devoted to the development of a software platform dedicated to clinical neuroimaging and image guided neurosurgery applications. The objective is to build a software core made of proprietary libraries (e.g. Vistal) and public libraries available in the domain of 3D medical imaging or 3D rendering (e.g. VTK, ITK ...).

8.2. National initiatives

8.2.1. ACI NeuroBase

Participants: Romain Valabrègue, Christian Barillot.

We are coordinating a national proactive concerted action ("ACI") of the French ministry of research entitled "NeuroBase: An information system for the management of distributed and heterogeneous neuroimaging data". period 2002-2005

In addition to our group and the TexMex project from IRISA, this action is performed in collaboration with INRIA teams (Caravel - Rocquencourt and Epidaure - Sophia-Antipolis), INSERM unit U594 and SIC team at CNRS-TIMC, both from Grenoble and the IFR 49 "Functional Neuroimagery" (Paris-Orsay, Dir. D. LeBihan). This IFR includes partners from CHU la Pitié-Salpétrière, INSERM unit U494 and CEA-SHFJ.

8.2.2. AS DSTIC-CNRS Non-rigid registration.

Participants: Pierre Hellier, Christian Barillot.

We are collaborating to a DSTIC-CNRS specific action on "non-rigid registration" coordinated by N. Rougon, period 2003-2004

The objective of this action, which is part of the RTP 25 and 42, is to gather people working in the non-rigid registration domain. Objectives are among: review of the world community especially for the concern of multimodal non-rigid registration, identify the methodological and application bottlenecks, organize the French community in the domain, diffuse and promote this domain in the French community.

8.3. International initiatives

8.3.1. International project on validation of non-rigid registration methods

Participants: Pierre Hellier, Christian Barillot.

We are involved in an international evaluation project led by J. Stern from the University of Minnesota, USA (http://www.neurovia.umn.edu/). This project aims at evaluating the performances of non-rigid inter-subject registration methods. The evaluation is based on the designation of various "goodness of warp" metrics, including anatomical and functional data. This international project also involves the following state-of-the-art registration methods: SPM (London, UK), AIR (UCLA, USA), HAMMER (Upenn, USA), ANIMAL (MNI, Canada) and ROMEO (IRISA, France). The goal is to set up an automated test, which eventually may be distributed on the web, including all relevant data sets and results. So any researcher dealing with deformable registration could make use of the test bed to evaluate and improve their own software or to simply replicate our experiments. Another goal would be to extend the test bed with other relevant datasets.

In order to facilitate automatic computation and storage of many different results and to do "apple-to-apple" comparisons, the U. of Minnesota will treat the results of each registration of source brain image to target brain image as the description of a transformation warp which will be read and evaluated by the test bed software. All of the registration programs that are included in the evaluation phase of the project will be integrated into the test bed and the raw data substrate of evaluation will ultimately be automatically produced by the test bed software.

9. Dissemination

9.1. Leadership within the scientific community

9.1.1. Editorial board of journals

- C. Barillot is Associate Editor of IEEE Transactions on Medical Imaging (IEEE-TMI).
- C. Barillot is member of the Editorial Board of "Technique et Science Informatiques" (TSI).
- C. Barillot serves in the peer review committee of the Journal of Computer Assisted Tomography.
- C. Barillot has been invited to be guest editor of the 2004 year book of International Association of Medical Informatics (IMIA) and is responsible for the synopsis of the "Medical Signal Processing and Biomedical Imaging" section.

9.1.2. Peer Reviews of journals

- Reviewing process for IEEE TMI (CB, PH, SP), IEEE TBE (SP), Medical Image Analysis (CB,PH,SP), Neuroimage (CB), IEEE TBE (CB, PH), Academic Radiology (PH), AMIA Year Book of Medial Informatics (CB), IVC (CB), Information Fusion (CB), AIM (CB)

9.1.3. Conference board organization

- C. Barillot chaired the 2004 edition of the conference MICCAI (http://miccai.irisa.fr)
- P. Hellier was program co-chair of MICCAI'2004
- S. Prima was Poster Coordinator of MICCAI'2004

9.1.4. Technical Program Committees (TPC) of conferences

- C. Barillot was TPC member for ICPR 2004, IEEE-ISBI 04 and JETIM 2004
- P. Hellier was TPC member of IEEE-ISBI 2004
- S. Prima was TPC member of MICCAI'2004

9.1.5. *Scientific societies*

- C. Barillot is Vice President of the MICCAI Society and is member of the board of MICCAI and co-founder of the MICCAI society.
- C. Barillot is member of IEEE EMBS

9.2. Teaching

Teaching on 3D Medical Imaging (visualization, segmentation, fusion, management) in the following tracks:

- DIIC-INC, IFSIC, University of Rennes I : 6h
- DEA GBM, University of Tours-Angers-Nantes-Rennes : 6h
- "Maîtrise de Sciences Biologiques et Médicales : Anatomie Imagerie Morphogenèse", University of Rennes I : 3h
- DEA Informatique Fondamentale et Applications, U. Marne la Vallée: 3h

9.3. Participation to seminars, scientific evaluations, awards

- Christian Barillot served as external reviewer to a PhD Thesis at Univ. Medical Utrecht, Netherlands (M. Letteboer, Sept. 2004)
- C. Barillot has been appointed by the European commission to review project of the 6th FP in the IST program and more especially FET projects and served as a reviewers and a mid-term reviewer in the 5th FP in the "Quality of Life and Management of Living Resources : research and technological development activities of a generic nature"

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