Direction des Relations Européennes et Internationales (DREI)

Programme INRIA "Equipes Associées"

I. DEFINITION

EQUIPE ASSOCIEE	**NeurOMIMe**
sélection	**2006**

Projet INRIA : *VisAGeS*	Organisme étranger partenaire : *Montreal Neurological Institute, Univ. Mc Gill-*
Unité de recherche INRIA : INRIA Rennes Thème INRIA : Bio	Pays : CANADA

	Coordinateur français	Coordinateur étranger
Nom, prénom	Christian BARILLOT	Louis COLLINS
Grade/statut	Directeur de Recherche	Assistant Professeur
Organisme d'appartenance	CNRS INRIA Rennes Projet VisAGeS	Montreal Neurological Institute, Univ. Mc Gill McConnell Brain Imaging Centre Image Processing Laboratory
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La proposition en bref

Titre de la thématique de collaboration: **Objective Medical Image Methods Evaluation for Neurological and Neurosurgical Procedures** (*Evaluation objective de méthodes en imagerie médicale appliquées aux procédures neurologiques et neurochirurgicales*)

Descriptif **:**

One important research objective in neuroimaging is to create anatomical and functional cerebral maps under normal and pathological conditions. The goal of this INRIA associated project-team proposal is to combine the respective research efforts in clinical neuroinformatics of the VisAGeS and IPL teams, and thus benefit from the resulting cross-fertilization. We aim at addressing specific aspects of medical image processing for the purpose of neurological disease analysis and their treatment through surgery. Both teams have significant experience in developing medical imaging software aimed at:

- improving neurosurgical practice through pre-operative planning, intra-operative guidance and imaging of brain deformations;
- improving neurological exploitation of the spatio-temporal and multiparametric MRI data produced in the context of brain diseases (e.g. multiple sclerosis -MS- lesions); and
- improving basic understanding of brain anatomy and cerebral function by using computerized procedures to model their relationship, especially in the context of the effect of pathology on brain structures (e.g. epilepsy, dementia, neurodegenerative diseases).

Through this project, the two teams will share their own, but complementary, expertise by distributing algorithms and data dealing within the clinical needs described above, in order to compare and cross-validate the different procedures developed at each site; then improve on the excellence and efficiency of these procedures.

Présentation de l'Équipe Associée

1. Présentation du coordinateur étranger

Voir fichier joint.

2. Historique de la collaboration

- **2.1. entre les équipes :**

Voir fichier joint

- **2.2. entre l'INRIA et l'organisme partenaire :**

Rien avec l'institut neurologique de Montreal. Une équipe associée (Appel d'offre 2002) « McGill-ISA » sur le « calcul de visibilité » entre le projet ISA, INRIA Lorraine et le laboratoire de géométrie algorithmique de l'Université McGill. Quelques autres projets avec l'Université Mc Gill dans le cadre du programme Fonds France-Canada, Appel 2003 (projets **Miro** resp. O. Zendra, **Odyssee**, resp. R. Deriche)

3. Impact :

Voir fichier joint

4. Divers :

Voir fichier joint

II. PREVISIONS 2006

Programme de travail

Voir fichier joint

Budget prévisionnel 2006

Voir détails dans fichier joint et fiche financière jointe

1. Co-financement

ESTIMATION PROSPECTIVE DES CO-FINANCEMENTS	
Organisme	Montant
FCAR team grant: Biomedical Imaging analysis	CAD$45 000/year
NIH1: Human Brain Mapping supplement	CAD$50 000 per year
NIH2 operating grant Neuroimaging Neuroinformatics	CAD$42 000 per year
CIHR1 Operating grant Quantification of cerebral atrophy in multiple sclerosis	CAD$104 551 for year 1
CIHR2 Operating Grant Image-guided neurosurgery: Improving guidance during spinal surgery	CAD$154 000 for year 1
NSERC Operating grant Non-linear registration and image processing for neuro-surgical atlasing	CAD$35,000/year
Total	CAD$430,551

2. Echanges

Voir fichier joint

ESTIMATION DES DÉPENSES		Montant		
	Nombre	Accueil	Missions	Total
Chercheurs confirmés	6	2	4	16 350 €
Post-doctorants	2	1	1	8 907 €
Doctorants	4	1	3	10 769 €
Stagiaires				
Autre (précisez) : Serveur Calcul				15 000,00 €
Total				
		- total des co-financements		25 693,00 €
	Financement "Équipe Associée" demandé			**25 333,00 €**

Remarques ou observations :

PROPOSAL FOR THE 2005 INRIA ASSOCIATED PROJECT-TEAMS PROGRAM

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

Partners:

France: VisAGeS Project, INRIA, Rennes
Canada: Image Processing Laboratory (IPL), Brain Imaging Center (BIC), Montreal Neurological Institute (MNI), McGill University, Montreal

Principal Investigators: C. Barillot (VisAGes), D.L. Collins (IPL, MNI, McGill)
Co-Promoters: *VisAGeS*: B. Gibaud, P. Hellier, P. Jannin, X. Morandi, S.P. Morrissey, S. Prima
BIC: D. Arnold, S. Duchesne

1 Goal and Rationale

One important research objective in neuroimaging is to create anatomical and functional cerebral maps under normal and pathological conditions. Much research is aimed at finding correlations between anatomical structures, such as sulci and gyri, at the site of neuronal activation, with cerebral functions as assessed through various neuroimaging modalities, such as PET (Positron Emission Tomography), fMRI (Functional Magnetic Resonance Imaging), EEG (Electro-EncephaloGraphy) and MEG (Magneto-EncephaloGraphy). A central problem inherent to the formation of such maps is the combination of recordings from different modalities, different times and different subjects. This mapping can be greatly facilitated if one uses MR anatomical brain scans with high spatial resolution as a basis for comparison allowing improved visualization of fine anatomical structures (sulci, gyri, cerebral tracks). Recent improvements in image processing techniques, such as segmentation, registration, delineation of the cerebral cortex, modelling of anatomical structures and multi-modality spatio-temporal fusion make possible reaching this ambitious goal in neuroimaging. Anatomical and functional maps have numerous applications in other research areas, as both clinical and cognitive neuroscience share similar imaging requirements. Since the applicative domain is generic, our major contributions will be directed toward clinical needs, even though our work can be applied to address specific aspects related to the neuroscience domain.

1.1 Motivation

The goal of this INRIA associated project-team proposal is to combine the respective research efforts in clinical neuroinformatics of the VisAGeS and IPL teams, and thus benefit from the resulting cross-fertilization. We aim at addressing specific aspects of medical image processing for the purpose of neurological disease analysis and their treatment through surgery. Both teams have significant experience in developing medical imaging software aimed at:

- improving neurosurgical practice through pre-operative planning, intra-operative guidance and imaging of brain deformations;
- improving neurological exploitation of the spatio-temporal and multiparametric MRI data produced in the context of brain diseases (e.g. multiple sclerosis -MS- lesions); and
- improving basic understanding of brain anatomy and cerebral function by using computerized procedures to model their relationship, especially in the context of the effect of pathology on brain structures (e.g. epilepsy, dementia, neurodegenerative diseases).

Through this project, the two teams will share their own, but complementary, expertise by distributing algorithms and data dealing within the clinical needs described above, in order to compare and cross-validate the different procedures developed at each site; then improve on the excellence and efficiency of these procedures. This workbench will be first tested in the context of three main neurological applications:

- Study of brain deformations in neurosurgical procedures involving open craniotomies;

- Study of MS lesions;
- Study of normal and pathological brain structures via computational anatomy;

In practice, this program will be guided for the first year by the long term visit of Pierre Hellier (VisAGeS) at IPL/MNI in 2006 and by Simon Duchesne (IPL/MNI) at VisAGeS in 2006-2007. Other bi-lateral visits from regular researchers, post-doctoal and Ph.D. students are foreseen. Additional support from INRIA will be provided by our Canadian partner through local grants. We expect to organize a shared workshop in the third year of this project, one possibility being to propose a specific session at the 2007 or 2008 edition of the largest international conference in this domain, MICCAI.

1.2 Neurological and Neurosurgical Applications

1.2.1 Study of neurosurgical procedures involving open craniotomies

Nowadays, neuronavigation systems make it possible to register the patient anatomy during the surgical procedure with the pre-operative images. Therefore, the surgical planning can be used during the procedure and eventually superimposed on the patient (augmented reality systems). Unfortunately, the hypothesis of a rigid transformation that is used by the current systems only holds at the beginning of the procedure. Brain deformations (also called brain shift) during surgery occur and degrade the efficiency of such systems: deformations up to 20 mm have been measured.

The two teams have developed expertise in fields involved in this project, among which: acquisition and reconstruction of 3D freehand ultrasound, image restoration, segmentation of cortical sulci, statistical shape analysis and non-rigid image registration. The collaboration will benefit from these expertises and beyond lead to elaborated methods to correct intraoperative brain deformations.

1.2.2 Study of Multiple Sclerosis lesions

Multiple sclerosis initially presents as a clinically isolated syndrome (CIS) such as optic neuritis, isolated brainstem or spinal cord syndromes in 85-90% of patients. Sixty to eighty percent of patients presenting with CIS suggestive of multiple sclerosis who have MRI-visible brain lesions go on to develop clinically definite multiple sclerosis[1,2]. However, while lesions are associated with the development of MS, there is only limited relationship between lesion accrual and subsequent disability. This may reflect pathological heterogeneity within lesions, with variable effects on nerve conduction and clinical function. Axonal and neuronal damage have become the focus of significant attention[3,4,5,6] and may be more salient when considering long-term outcomes, with atrophy measures potentially acting as a more specific marker of such pathology than lesion volume measures[7]: this is supported by the observation that in multiple sclerosis, atrophy of the brain and spinal cord is more noticeable with increasing disability.

As explained below the two teams have already developed expertise in this field, and through this close collaboration, our goal is to investigate new potential biomarkers from large longitudinal MRI data bases, especially the one related to the atrophy of the brain.

1.2.3 Study of normal and pathological structures via computational anatomy

Developing methods to quantitatively assess the effects of pathology on brain structures is a critical area of research with applications in etiology, diagnosis and therapy. We will have two fundamental objectives within this domain. First, to compare and evaluate methods dedicated to the construction of anatomical and functional brain atlases in the context of functional mapping in pre-surgical planning, as well as the study of brain diseases (epilepsy, dementia). Second, 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 or functional patterns, computation of asymmetries).

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1 Brex PA et al., *N Engl J Med*.;346(3):158-64, (2002)
2 Beck RW et al., *Arch Ophthalmol*: 121(7):944-9. (2003)
3 Trapp BD et al., *N Engl J Med* : 338:278–285, (1998)
4 Bjartmar C et al., *Curr Opin Neurol*.: 14(3):271-8, (2001)
5 Bjartmar C et al., *Neurology* : 57(7):1248-52, (2001)
6 Cifelli A, et al., *Ann Neurol*. : 52(5):650-3, (2002)
7 Miller DH et al., *Brain* : 125(Pt 8):1676-95, (2002)

2 Identification of the foreign partner

The proposed research will be conducted in collaboration with the McConnell Brain Imaging Centre (BIC) of the Montreal Neurological Institute and Hospital (MNI/MNH) at McGill University. The MNI at McGill is one of the most famous institutions worldwide in the domain of clinical and cognitive human neuroscience, especially when dealing with non invasive imagery (PET, MRI). The MNI houses 27 research units and shares a building with the MNH, a 80-bed tertiary care neurological hospital. The BIC is comprised of several laboratories: the MRI, MRS, positron emission tomography (PET), and the Image Processing Laboratory (IPL). The BIC shares two whole body MRI scanners dedicated to research: (i) a Siemens 1.5T system with EPI capability (upgraded in 2003) and (ii) a Siemens 3.0T Trio scanner installed in September 2005. The IPL has an ATL HDI 5000 ultrasound scanner also dedicated to research. Within the BIC, the IPL investigates neuroscientific applications of three dimensional (3D) digital image processing methods using Silicon Graphics imaging computers and personal computers interconnected with the imaging scanners via an Ethernet network. The IPL group has considerable experience in image guided surgery research and works closely with the Neurosurgical Research Unit of the MNI/MNH.

3 History of the collaboration

The collaboration between the VisAGeS project-team and the Brain Imaging Centre at the Montreal Neurological Institute (MNI) started 14 years ago when Christian BARILLOT first visited the MNI in 1991, followed shortly thereafter by a visit from Alan C. EVANS and Louis COLLINS in Rennes in 1993. These led to the arrival of Louis COLLINS as a post doctoral fellow (PDF) with Christian BARILLOT in 1995 and 1996 through a specific grant from HFSPO, effectively launching the collaboration before the two institutions. The major joint research topic at the time was the use of cortical landmarks for constraining non rigid deformation procedures (with the ANIMAL software) [1]. This exchange was continued by the long term PDF visit of G. LE GOUALHER (former PhD student of C. BARILLOT) at MNI/McGill from 1997 to 1999, to model cortical sulcal ribbons of normal brain among individuals (computational anatomy domain) [2-4]. From 1998 to 2001, an international project for comparison and validation of non-rigid registration procedures was supported by a grant from the GIS “Sciences de la Cognition”. The VisAGeS team was designated as principal investigator for this project, and Montreal was a full partner [5, 6]. In 2001, Xavier MORANDI spent a one-year sabbatical within the IPL/BIC with Louis COLLINS to integrate and test 3D ultrasound in neurosurgical procedures for brain shift correction [7]. From 2001 to 2003, Sylvain PRIMA was a PDF under the direction of Louis COLLINS at IPL/BIC to research selective detection of MS lesions using robust statistical procedures [8-10]. More recently, Berengère BROCHE, a former PhD student of B. GIBAUD, has started a PDF under the direction of Louis COLLINS at the IPL/BIC to improve the BrainWEB MRI/fMRI simulator.

4 Provisional Scientific work program

The scientific program will be centered on the three major applications addressed above. Applications within image-guided surgery and multiple sclerosis will be investigated first.

4.1 Study of neurosurgical procedures involving open craniotomies

Concerning image-guided neurosurgery, our program will first consist in setting a common framework to evaluate the correction of brain deformations. Questions are numerous: was the lesion removed? Were brain deformations accurately estimated during surgery? How accurate was the information given to the surgeon during surgery? What is the impact of brain deformation correction on the clinical outcome? It is unlikely that these questions will be solved during this project, but setting an evaluation framework constitutes a first attempt to do so.

A common evaluation framework will make it possible to compare various techniques that have been developed by both teams on the same basis. The evaluation framework is difficult to design, for both technical and ethical issues. It should encompass anatomical images (before and after surgery), and functional images (before and after surgery).

4.2 Study of Multiple Sclerosis lesions

Relatively little investigation of brain atrophy has been undertaken in patients in the earliest stages of MS disease. Studies at the early stage of disease have potential to identify prognostic markers and techniques for therapeutic monitoring and may provide insights into disease pathogenesis. In previous studies in patients with CIS, progressive ventricular enlargement was detected over one year in those with an abnormal MRI[8,9]. A recent study[10] in CIS with a follow-up of three years addressed the questions of location of early brain atrophy, the relationship of early brain atrophy, both global and tissue specific, to the development of multiple sclerosis, and the relationship of early brain atrophy to focal lesion load measures. The findings suggest that progressive grey matter, but not white matter, atrophy is seen in the earliest clinically observable stages of relapse onset MS, and this is only moderately related to lesion accumulation. Another recent MRI study[11], looking at the same patients as Dalton et al. but in addition addressing the role Gd-enhancement in relation to global and regional atrophy, could not detect a direct relationship.

Over the years, the Montreal Neurological Institute (MNI) has established a large collection of longitudinal, multi-sequence of MRI data of patients with Multiple Sclerosis (MS). It also developed automated image processing methods and pipelines to analyse these large MRI datasets and compute markers related to MS, such as the lesion volume and number [11] and global brain atrophy [8, 12]. At IRISA, we developed new methods to detect and measure MRI intensity changes over time using series of multi-sequence MR images, and these changes have been linked with the disease progression in MS [8-10, 13]. A longitudinal approach to measure brain atrophy opens a new window to detect and quantify atrophy in specific brain areas, such as the white matter or the grey matter, but also its regional distribution. With this kind of approach in combination with algorithms of the MNI on their extensive databases we expect to detect correlations between local/regional atrophies and focal lesions as measured on different MR sequences (e.g. especially T1-weighted with and without Gadolinium enhancement).

4.3 Study of normal and pathological structures via computational anatomy

The specific purpose of this research will be to improve the quality of pre-surgical evaluation for intractable temporal lobe epilepsy (TLE) patients. At present, surgically implanted electroencephalography (SEEG) remains the gold standard for localization of the seizure focus and resection target. MRI is used to facilitate the planning, mostly via volumetric measurements of the hippocampus. There have been recent advances however in computational anatomy showing that structural MRI could play a larger role in the pre-surgical evaluation of these patients.

The goal is to complete a unified statistical framework for the high-dimensional analysis of multi-modality data to support the lateralization of seizure focus in TLE. Two objectives are proposed: (1) extend the mono-modality high-dimensional technique developed by Simon DUCHESNE (graduate of IPL/BIC under Louis COLLINS, visiting VisAGeS as a PDF in 2006 and 2007) to accommodate co-registered, multi-modality data (T2-weighted MRI, inter-ictal SPECT) in a single statistical framework; and (2) test this technique on real patient data first retrospectively, and then prospectively, comparing to available SEEG results. The proposed methodological framework will increase the comprehension of structural damage in TLE, its therapeutic follow-up and pre-surgical planning.

5 Exchange of researchers

5.1 Long term visits

Pierre HELLIER will be visiting the IPL/BIC in 2006 under an INRIA sabbatical grant. This visit will focus on the image-guided surgery part of this proposal.

In 2006, Simon DUCHESNE, graduate of the IPL/BIC and supervised by Louis COLLINS, will be starting a one to two year PDF visit at the VisAGeS project team under a “Fond de la Recherche en Santé du Québec / INSERM” scholarship. The main goal of his stay will be to address the computational anatomy research objectives detailed above, and to validate technological advances with Rennes clinicians in epilepsy surgery; in turn, the technology will be shared with the IPL/BIC and the epilepsy group at the MNI.

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8 Brex PA et al., *Neurology*: 54(8):1689-91, (2000)
9 Dalton CM et al., *J Neurol Neurosurg Psychiatry*: 73(2):141-7, (2002)
10 Dalton CM et al., *Brain* : 127:1101–1107, (2004)
11 Tiberio M et al., *Neurology* : 64(6):1001-7, (2005)

5.2 Short term visits

Research staffs from both team and their PhD students related to the proposed research topics will share short term visits (1-2 weeks each) for making specific advances on the different research topics and making diffusion of knowledge through specific local courses and tutorials.

6 Meetings, Workshops and conferences

We expect to organize a shared workshop in the third year of this project. One possibility would be to propose a specific session at the Medical Image Computing and Computer Assisted Intervention (MICCIA) conference in 2007 or 2008. MICCAI is the largest international conference in the domain of medical image processing, medical robotics and computer assisted intervention.

7 Education

We expect to take advantage of the different visiting periods of staff from both teams to organize specific courses on research topics addressed by this proposal; these courses and tutorials will be freely open to the local scientific and student community, in both medical and computer sciences fields.

8 Budget and Co-financing

Concerning the proposed research project, the IPL/BIC partner already has several research grants which could be partly used to support the association (e.g. for travelling and visiting periods). Here is a non exhaustive list of such grants:

- ***FCAR team grant:*** Biomedical Imaging analysis *K. Siddiqi, D.L. Collins and B. Pike 2003-2006, $45 000/year. This grant supports development of new registration algorithms and DTI processing.* <u>This grant will concern the topics “Computational Anatomy” and “Multiple Sclerosis”</u>
- ***NIH1****: Human Brain Mapping supplement* Computational anatomy and visualization *D.A. Rottenberg, D.L. Collins, C. Davatzicos and J. Stern 2003-2005, my share $50 000 per year. This grant supports the development of a gold standard anatomical landmark database for validation of multiple non-linear registration algorithms.* <u>This grant will concern the topics “Computational Anatomy” and “Image-Guided Surgery”</u>
- ***NIH2 operating grant*** Neuroimaging Neuroinformatics *A.C. Evans, G.B. Pike, D.L. Collins, and K. Worsley 2002-2006, my share $42 000 per year. Supports development of new digital brain phantoms for BrainWeb.* <u>This grant will concern the topics “Computation Anatomy” and “Multiple Sclerosis”</u>
- ***CIHR1 Operating grant*** Quantification of cerebral atrophy in multiple sclerosis *D.L. Collins 2003-2006, $104 551 for year 1. Supports development of tools for the analysis of global, regional and local atorphy in MS ; also supports work in lesion detection.* <u>This grant will concern the topic “Multiple Sclerosis”</u>
- ***CIHR2 Operating Grant*** *Image*-guided neurosurgery: Improving guidance during spinal surgery *D.L. Collins and B. Goulet 2005-2009, $154 000 for year 1. Main source of support for development of computerized tools for IGNS.* <u>This grant will concern the topic “Image-Guided Surgery”</u>
- ***NSERC Operating grant*** Non-linear registration and image processing for neuro-surgical atlasing *D.L. Collins, 2001-2006, $35,000/year. Supports development of non-linear registation tools used to align histology with MRI data to build anatomical atlases.* <u>This grant will concern the topics “Image-Guided Surgery” and “Computation Anatomy”</u>

Additionally, the following individuals have secured financial support:

- Pierre HELLIER, sabbatical grant from INRIA for a one year collaboration at the IPL/BIC;
- Simon DUCHESNE, FRSQ/INSERM scholarship for a multi-year post-doctoral fellowship at the VisAGeS project team;

9 Added value of the collaboration

The problem addressed in this collaboration proposal is very relevant with respect to the clinical, theoretical and industrial challenges of medical applications of neuroinformatics. As an illustration, the recent announcement of the OECD on launching a global scientific research project to improve understanding of human brain[12] gives an example of the importance of this domain and how a better understanding of the human brain (at normal or pathological stages) could lead to breakthroughs in the prevention and cure of nervous system disorders, as well as developing or validating new treatments (drugs, interventional procedures, …). Both of our teams share the same vision of this domain, namely addressing the problem of managing large data repository (local or distributed), developing computational models of brain anatomy and function, developing new modelling and analysis tools on brain images, participate to the development of new standards, and software tools to facilitate interoperability across multiple computing platforms. These issues are of great importance and they fit one of the major scientific objectives of INRIA in the upcoming years. Both of our teams believe that this collaborative grant will be a starting point of more durable funding of our joint research in clinical neuroinformatics. In addition, concerning INRIA, this project will have additional outcomes on developing collaboration with other INRIA research teams such as EPIDAURE Project for the concern of Multiple Sclerosis, or ODYSSEE Project for the concern of computational models in Epilepsy.

10 References

[1] D. L. Collins, G. G. le, R. Venugopal, A. Caramanos, A. C. Evans, and C. Barillot, "Cortical Constraints for Non-Linear Cortical Registration," in Visualization in Biomedical Computing, vol. 1131, Lecture Notes in Computer Sciences, K. H. Höhne and R. Kikinis, Eds. Berlin-Heidelberg: Springer-Verlag, 1996, pp. 307-316.

[2] G. Le Goualher, R. Torre, L. Collins, C. Barillot, and A. C. Evans, "Automatic Identification of Cortical Sulci using 3D Probabilistic Atlas," in Medical Image Computing and Computer-Assisted Intervention --MICCAI'98, vol. 1496, Lecture Notes in Computer Sciences, W. M. Wells, A. Colchester, and S. Delp, Eds. Boston, MA: Springer-Verlag, 1998, pp. 509-518.

[3] G. Le Goualher, E. Procyk, L. Collins, R. Venegopal, C. Barillot, and A. Evans, "Automated extraction and variability analysis of sulcal neuroanatomy," IEEE Transactions on Medical Imaging, vol. 18, pp. 206-217, 1999.

[4] G. Le Goualher, A. M. Argenti, M. Duyme, W. F. C. Baare, H. E. Hulshoff Pol, C. Barillot, and A. C. Evans, "Statistical Sulcal Shape Comparisons: Application to the Detection of Genetic Encoding of the Central Sulcus Shape.," Neuroimage, vol. 11, pp. 564-574, 2000.

[5] P. Hellier, C. Barillot, I. Corouge, B. Gibaud, G. Le Goualher, L. Collins, A. Evans, G. Malandain, and A. Ayache, "Retrospective evaluation of inter-subject brain registration.," in Medical Image Computing and Computer-Assisted Intervention - MICCAI 2001, vol. LNCS-2208, Lecture Notes in Computer Sciences, W. J. Niessen and M. A. Viergever, Eds. Utrecht: Springer-Verlag, 2001, pp. 258-265.

[6] P. Hellier, C. Barillot, I. Corouge, B. Gibaud, G. Le Goualber, D. L. Collins, A. Evans, G. Malandain, N. Ayache, G. E. Christensen, and H. J. Johnson, "Retrospective Evaluation of Intersubject Brain Registration," IEEE Transactions on Medical Imaging, vol. 22, pp. 1120-1130, 2003.

[7] T. Arbel, X. Morandi, R. M. Comeau, and D. L. Collins, "Automatic non-linear MRI-unltrasound registration for the correction of intra-operative brain deformations," in Medical Image Computing and Computer-Assisted Intervention -- MICCAI 2001, vol. 2208, Lecture Notes in Computer Sciences, W. J. Niessen and M. A. Viergever, Eds. Utrecht (The Netherlands): Springer-Verlag, 2001, pp. 913-922.

[8] I. Kezele, A. L. Janke, P. Le Nezet, S. Prima, D. L. Arnold, and D. L. Collins, "Regional GM loss in RR and SP multiple sclerosis," presented at 10th International Conference on Functional Mapping of the Human Brain, HBM'2004, Budapest, Hungary, 2004.

[9] S. Prima, D. L. Arnold, and D. L. Collins, "Multivariate statistics for detection of MS activity in serial multimodal MR images," in Medical Image Computing and Computer-Assisted Intervention, MICCAI'2003, vol. 2878, Lecture Notes in Computer Science, R. E. Ellis and T. M. Peters, Eds. Montreal, Canada: Springer, 2003, pp. 663-670.

[10] S. Prima, N. Ayache, A. Janke, S. J. Francis, D. L. Arnold, and D. L. Collins, "Statistical analysis of longitudinal MRI data: applications for detection of disease activity in MS," in Medical Image Computing and Computer-Assisted Intervention, MICCAI'2002, vol. 2488, Lecture Notes in Computer Science, T. Dohi and R. Kikinis, Eds. Tokyo, Japan: Springer, 2002, pp. 363-371.

[11] A. P. Zijdenbos, R. Forghani, and A. C. Evans, "Automatic "pipeline" analysis of 3-D MRI data for clinical trials: application to multiple sclerosis," IEEE Transactions on Medical Imaging, vol. 21, pp. 1280-1291, 2002.

[12] D. L. Collins, J. Montagnat, A. P. Zijdenbos, A. C. Evans, and D. L. Arnold, "Automated estimation of brain volume in multiple sclerosis with BICCR," in Information Processing in Medical Imaging, vol. 2082, Lecture Notes in Computer Science, M. F. Insana and R. M. Leahy, Eds. Davis, USA: Springer-Verlag, 2001, pp. 141-147.

[13] L. S. Aït-Ali, S. Prima, P. Hellier, B. Carsin-Nicol, G. Edan, and C. Barillot, "STREM: A Robust Multidimensional Parametric Method to Segment MS Lesions in MRI," in Medical Image Computing and Computer-Assisted Intervention – MICCAI 2005, vol. 3749, Lecture Notes in Computer Science, J. S. Duncan and G. Gerig, Eds. Palm Springs, CA, USA: Springer-Verlag, 2005, pp. 409.

[12] http://www.oecd.org/document/53/0,2340,en_2649_201185_35225205_1_1_1_1,00.html

BUDGET PREVISIONNEL 2006

PROJET :	VISAGES	PROJET N° :	31353	CHEF DE PROJET:	Christian BARILLOT

MISSIONS :

Personne		INRIA Permanent/ PostDoc	INRIA Doctorant	Monteal Permanent	Total INRIA	Total Montreal	Total
L. Ait-Ali / N. Wiest Daeslé	nombre nuitées		7		2 306 €	- €	L. Ait-Ali / N. Wiest Daeslé
	nombre voyages A/R		1				*2 306 €*
Arnold	nombre nuitées			7	- €	2 481 €	Arnold
	nombre voyages A/R			1			*2 481 €*
Barillot	nombre nuitées	7			2 481 €	- €	Barillot
	nombre voyages A/R	1					*2 481 €*
Broche	nombre nuitées			15	- €	3 945 €	Broche
	nombre voyages A/R			1			*3 945 €*
Collins	nombre nuitées			7	- €	2 481 €	Collins
	nombre voyages A/R			1			*2 481 €*
Coupe	nombre nuitées		21		4 518 €	- €	Coupe
	nombre voyages A/R		1				*4 518 €*
Doctorant	nombre nuitées			15	- €	3 945 €	Doctorant
	nombre voyages A/R			1			*3 945 €*
Duchesne	nombre nuitées	7		7	2 481 €	2 481 €	Duchesne
	nombre voyages A/R	1		1			*4 962 €*
Morandi	nombre nuitées	7			2 481 €	- €	Morandi
	nombre voyages A/R	1					*2 481 €*
Morrissey	nombre nuitées	7			2 481 €	- €	Morrissey
	nombre voyages A/R	1					*2 481 €*
Prima	nombre nuitées	15			3 945 €	- €	Prima
	nombre voyages A/R	1					*3 945 €*
TOTAL		13 869 €	6 824 €	15 333 €	20 693 €	15 333 €	*36 026 €*
	Coût moyen indem. avec nuitée / jour en €	183	158	183			
	Coût moyen transport A/R en €	1200	1200	1200			

MANIFESTATIONS SCIENTIFIQUES : Prévoyez vous l'organisation de manifestations scientifiques cette année ?

Commentaires :

Autre Dépenses de fonctionnement et d'équipement		
Nature	Montant en €	Commentaires
Materiel	15 000,00 €	Serveur de stockage de données (capacité 1 TB)
Frais de réceptions		
Sous-traitance		
Autres frais (à préciser)*		
Total Autres Dépenses	*15 000,00 €*	
TOTAL Projet Année I	51 026,00 €	
Dont autofinancement	25 693,00 €	
Total Aide demandée	25 333,00 €	

BIOGRAPHICAL SKETCH

Provide the following information for foreign collaborator

NAME D. Louis Collins	POSITION TITLE Assistant Professor

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, and include postdoctoral training).*

INSTITUTION AND LOCATION		YEAR(s)	FIELD OF STUDY
Concordia University, Montreal, Canada	B.Sc.	1987	Computer Science
McGill University, Montreal, Canada	M.Eng.	1990	Electrical Engineering
McGill University, Montreal, Canada	Ph.D.	1994	Biomedical Engineering
Laboratoire SIM, U. Rennes I, France	Post-doc	1996	Medical Imaging Science

RESEARCH AND PROFESSIONAL EXPERIENCE: Concluding with present position, list, in chronological order, previous employment, experience, and honors. Include present membership on any Federal Government public advisory committee. List, in chronological order, the titles, all authors, and complete references to all publications during the past three years and to representative earlier publications pertinent to this application. If the list of publications in the last three years exceeds two pages, select the most pertinent publications. **DO NOT EXCEED TWO PAGES.**

ACADEMIC APPOINTMENTS

1995-1996: Research Associate, Department of Neurology and Neurosurgery, Laboratoire SIM, INSERM U335, University de Rennes I, France

1996-1999: Research Associate, McConnell Brain Imaging Center, Montreal Neurological Institute, McGill University, Montreal, Canada

1999-present: Assistant Professor – tenure track
Montreal Neurological Institute
Departments of Neurology and Biomedical Engineering
McGill University, Montreal, Canada

HONORS AND AWARDS

1991: Sylvia Sorkin Greenfield Award for best paper in Medical Physics
1993: K.G. McKenzie Prize, Canadian Congress of Neurological Sciences – best paper
1994: Geddes prize for Biomedical Engineering for PhD Thesis.
1995-1996: Postdoctoral Scholarship, Human Frontier Science Program Organization
2000-2003: Chercheur Bousier J1 Salary Award, Fonds de Recherche Sante Quebec
2004-2008: Chercheur Bousier J2 Salary Award, Fonds de Recherche Sante Quebec

REVIEWER

1. **Journals**: IEEE Transactions on Medical Imaging, Medical Physics, NeuroImage, Human Brain Mapping, Medical mage Analysis, Journal of Computer Aided, IEEE Engineering in Medicine and Biology
2. **Conferences**: Medical Image Computing and Computer Assisted Intervention (MICCAI), Information Processing in Medical Imaging (IPMI), IEEE Workshop on Mathematical Methods in Biomedical Image Analysis (MMBIA), International Workshop on Biomedical Image Registration (WBIR)
3. **Granting Agencies**: Canadian Institutes of Health Research, Natural Sciences and Engineering Research Council of Canada, Fonds de la recherche en sante du Quebec

PEER-REVIEWED PAPERS (**selected** from 74 total, ⌖indicates first author was my student or fellow)

1. **D. L. Collins**, P. Neelin, T. M. Peters, and A. C. Evans, *Automatic 3D inter-subject registration of MR volumetric data in standardized Talairach space*, Journal of Computer Assisted Tomography, vol. 18, pp. 192-205, March/April 1994.
2. **D. L. Collins**, C. J. Holmes, T. M. Peters, and A. C. Evans, *Automatic 3D model-based neuroanatomical segmentation, Human Brain Mapping*, vol. 3, no. 3, pp. 190-208, 1995.
3. **D. L. Collins** and A. C. Evans, *Animal: validation and applications of non-linear registration-based segmentation*, International Journal and Pattern Recognition and Artificial Intelligence, vol. 11, pp. 1271-1294, Dec 1997.
4. **D. L. Collins**, A. P. Zijdenbos, V. Kollokian, J. Sled, N. J. Kabani, C. J. Holmes, and A. C. Evans, *Design and construction of a realistic digital brain phantom*, IEEE Transactions on Medical Imaging, vol. 17, no. 3, pp. 463-468, 1998.
5. **D. L. Collins**, G. LeGoualher, and A. C. Evans, Non-linear cerebral registration with sulcal constraints. Medical Image Computing and Computer-Assisted Intervention, LNCS, pp. 974-984, 1998.
6. C. J. Holmes, R. Hoge, **D. L. Collins**, R. Woods, A. Toga, and A. C. Evans, *Enhancement of MR images using registration for signal averaging*, Journal of Computer Assisted Tomography, vol. 22, pp. 324-333, Mar 1998.
7. **D. L. Collins**, A. P. Zijdenbos, W. F. C. Barre, and A. C. Evans, ANIMAL+INSECT: Improved cortical structure segmentation, Information Processing in Medical Imaging (Kuba, Samal, and Todd-Pokropek, eds.), LNCS 1613, pp. 210-223, Springer, 1999.

8. T. Paus, A. Zijdenbos, K. Worsley, **D. L. Collins**, J. Blumenthal, J. N. Giedd, J. L. Rapoport, and A. C. Evans, *Structural maturation of neural pathways in children and adolescents: In vivo study*, Science, vol. 283, pp. 1908-1911, Mar 19 1999.
9. T. Paus, **D. L. Collins**, A. Evans, G. Leonard, B. Pike, and A. Zijdenbos, *Maturation of white matter in the human brain: a review of magnetic resonance studies*, Brain Res Bull, vol. 54, no. 3, pp. 255-66, 2001.
10. M. K. Chung, K. J. Worsley, T. Paus, C. Cherif, **D. L. Collins**, J. N. Giedd, J. L. Rapoport, and A. C. Evans, *Unified statistical approach to deformation-based morphometry*, Neuroimage, vol. 14, no. 3, pp. 595-606, 2001.
11. **D. L. Collins**, J. Montagnat, A. P. Zijdenbos, A. C. Evans, and D. L. Arnold, Automated estimation of brain volume in multiple sclerosis with BICCR, Information Processing in Medical Imaging (M. F. Insana and R. M. Leahy, eds.), vol. 2082 of LNCS, pp. 141-147, Springer, 2001.
12. S. Duchesne and **D. L. Collins**, Analysis of deformation fields for appearance-based segmentation, in Proceedings of the 2001 MICCAI Conference, (Utrecht, Netherlands), LNCS 2208, p1189, 2001.
13. S. Duchesne, J. Pruessner, and **D. L. Collins**, Appearance-based modeling and segmentation of the hippocampus from MR images Proceedings IEEE Engineering in Medicine and Biology Society, 2001.
14. T. Arbel, X. Morandi, R. Comeau, and **D. L. Collins**, Automatic non-linear MRI-ultrasound registration for the correction of intra-operative brain deformations, MICCAI (Utrecht, Netherlands), LNCS 2208, p. 913, 2001.
15. S. Duchesne, N. Bernasconi, A. Bernasconi, and D. L. Collins, “On the classification of temporal lobe epilepsy based on MR image appearance,” in Proceeding of the Int conf Pattern Recognition, Aug 2002.
16. S. Prima, N. Ayache, A. Janke, S. J. Francis, D. L. Arnold, and D. L. Collins, “Statistical analysis of longitudinal mri data: Applications for detection of disease activity in MS,”, MICCAI, Tokyo, LNCS 2488, pp. 363–371, Springer, 2002.
17. S. Duchesne, J. Pruessner, and D. L. Collins, “Appearance-based segmentation of medial temporal lobe structures,” NeuroImage, vol. 17, pp. 515–531, 2002.
18. S. Antel, L. Li, F. Cendes, D. L. Collins, R. Kearney, R. Shinghal, and D. Arnold, “Predicting surgical outcome in temporal lobe epilepsy patients using MRI and MRSI,” Neurology, vol. 58, pp. 1505–12, May 28 2002.
19. S. Antel, A. Bernasconi, N. Bernasconi, D. L. Collins, R. Kearney, R. Shinghal, and D. Arnold, “Computational models of MRI characteristics of focal cortical dylsplasia improve lesion detection,” NeuroImage, vol. 17, no. 4, pp. 1755–60, 2002.
20. P. Hellier, C. Barillot, I. Corouge, B. Gibaud, G. L. Goualher, D. L. Collins, A. C. Evans, G. Malandain, N. Ayache, G. E. Christensen, and H. J. Johnson, “Retrospective evaluation of inter-subject brain registration,” IEEE Transactions on Medical Imaging, vol. 22, no. 9, pp. 1120–30, 2003.
21. S. Duchesne, N. Bernasconi, A. Janke, A. Bernasconi, and D. L. Collins, “Temporal lobe epilepsy lateralization based on MR image intensity and registration features,” in MICCAI, LNCS 2879, pp. 367–374, Springer, 2003.
22. S. Prima, D. L. Arnold, and D. L. Collins, “Multivariate statistics for detection of ms activity in serial multimodal MR images.,” in MICCAI, LNCS 2879, pp. 663–670, Springer, 2003.
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24. S. Antel, , D. L. Collins, N. Bernasconi, F. Andermann, R. Shinghal, R. Kearney, D. Arnold, and A. Bernasconi, “Automated detection of cortical dylsplasia lesions using computational models of their MRI characteristics and texture analysis,” NeuroImage, vol. 19, no. 4, pp. 1748–59, 2004.
25. Chen, J. T., S. Narayanan, **Collins, D. L**.; Smith, S. M.; Matthews, P. M.; Arnold, D. L. (2004). "*Relating neocortical pathology to disability progression in multiple sclerosis using MRI*." Neuroimage 23(3): 1168-75.
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27. Robbins**, S., A. C. Evans, **Collins, D. L**., Whitesides, S. (2004). "*Tuning and comparing spatial normalization methods*." Med Image Anal 8(3): 311-23.
28. Mangin, J. F., D. Riviere, Cachia**, A.; Duchesnay, E.; Cointepas, Y.; Papadopoulos-Orfanos, D.; **Collins, D. L**.; Evans, A. C.; Regis, J. (2004). "*Object-based morphometry of the cerebral cortex*." IEEE TMI 23(8): 968-82.
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2. **D. L. Collins** and A. C. Evans, Cohort studies, in Medical Image Registration (J. Hajnal, D. Hawkes, and D. Hill, eds.), 2000.