INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

Project-Team Odyssee

Biological and Computer Vision

Sophia Antipolis

THEME BIO

Activity Report

2004

Table of contents

1. Team

Head of project-team

Olivier Faugeras [DR, INRIA, site : INRIA Sophia]

Vice-head of project-team

Rachid Deriche [DR, INRIA, site : INRIA Sophia]
Renaud Keriven [ICPC, ENPC, sites : ENS Paris and ENPC Marne]

Administrative assistant

Marie-Cécile Lafont [TR, INRIA, site : INRIA Sophia]

Research scientists

Maureen Clerc [IPC, ENPC, site : INRIA Sophia]
Pierre Kornprobst [CR, INRIA, site : INRIA Sophia]
Théodore Papadopoulo [CR, INRIA, site : INRIA Sophia]
Thierry Viéville [DR, INRIA, site : INRIA Sophia]

Post-doctoral fellows

Camilo Larota [post-doc INRIA : "ACI OBS-MEG" field, site : INRIA Sophia, from October 2004]
Olivier Rochel [Post-doc associates, Color Spyke funding, from 1st May 2004 until 31st August 2004, site : INRIA Sophia]

Ph. D. students

Geoffray Adde [ENPC grant, site : ENPC Marne]
Guillaume Charpiat [ENS Ph. D. student, site : ENS Paris]
Thomas Deneux [ENS Ph. D. student, site : ENS Paris]
Irène Fasiello [ENS Cachan and Monitorat grant, from the 1st, November 2004]
François Grimbert [Grant half financed from the PACA Region and from INRIA fundings, from the 1st, October 2004, site : INRIA Sophia]
Olivier Juan [ENPC grant, site : ENPC Marne]
Fabien Lejeune [ENPC grant, site : ENPC Marne, until June 2004]
Christophe Lenglet [Grant half financed from the PACA Region and from INRIA fundings, from the 1st, October 2003, site : INRIA Sophia]
Lucéro Lopez-Perez [SFERE/CONACYT grant with INRIA additional funding, Université de Nice Sophia-Antipolis, site : INRIA Sophia]
Pierre Maurel [ENS Ph. D. student, site : ENS Paris]
Jérôme Piovano [MESR and Monitorat grant, Université de Nice Sophia-Antipolis, from the 1st, September 2004]
Gheorghe Postelnicu [ENS Ph. D. student, site : ENS Paris and ENPC Marne, Ph. D. Defense on the 23rd. November 2004]
Emmanuel Prados [MESR grant with INRIA additional funding, Université de Nice Sophia-Antipolis, site : INRIA Sophia, until the 30th, Phd. Defense on the 22nd, October 2004]
Jean-Philippe Pons [IPC ENPC, site : INRIA Sophia and ENPC Marne]
Mikaël Rousson [INRIA grant, Université de Nice Sophia-Antipolis, site : INRIA Sophia until the 30th, October 2004, Ph. D. defense on the 6th December 2004]
Adrien Wohrer [AMX, grant with INRIA additional funding, Ecole Polytechnique, site : INRIA Sophia, from the 1st, September 2004]
Nicolas Wotawa [MESR grant with INRIA additional funding, Université de Nice Sophia-Antipolis, site : INRIA Sophia]

Ph.D. visiting students

Pablo Cancela [Ph. D. student, Universidad de la Republica, Uruguay,until February 2004, site : INRIA Sophia]

Mónica Hernández Giménez [Spanish Governement Funding, Spain, from 1st May 2004 until September 2004, site : INRIA Sophia]
Rodrigo De Luis Garcia [IMAVIS TMR contract, Spain, from the 1st, June 2004 until 30th, September 2004, site : INRIA Sophia]
Michael Fussenegger [IMAVIS TMR contract, Austria, from the 1st, September 2004 until the 31st, January 2005, site : INRIA Sophia]
Carlos Castaño Moraga [[IMAVIS TMR contract, Spain, from the 1st, Octoberber 2004 until the 31st, January 2005, site : INRIA Sophia]

Graduate students interns

Martin De la Gorce [Graduate student intern from ISEP, INRIA Allowance, from the 1st, May 2004 until the 30th, September 2004, site : INRIA Sophia]
Irène Fasiello [Graduate student intern from ENS Cachan, INRIA Allowance, from the 1st, April 2004 until the 30th, September 2004, site : INRIA Sophia]
François Grimbert [Graduate student intern from ENS Cachan, INRIA Allowance, from the 1st, June 2004 until the 30th, September 2004, site : INRIA Sophia]
Riadh Layouni [Graduate student intern, from the University of Nice Sophia-Antipolis, INRIA Allowance, from the 15th, March 2004 until the 20th, September 2003, site : INRIA Sophia]
Karim Lounici [Graduate student intern from ENS Cachan, "Normalien" status, from the 1st, April 2004 until the 31st, July 2004, site : ENS Paris]
Benjamin Orgogozo [Graduate student intern from ENS, INRIA Allowance, from the 1st, February 2004 until the 31st, December 2004, site : Oxford University]
Jérôme Piovano [Graduate student intern from ESSI Engineering School, INRIA Allowance, from the 1st, April 2004 until the 30th, September 2004, site : INRIA Sophia]
Adrien Wohrer [Graduate student intern from ENS Cachan, from the 1st,March 2004 until the 31st, August 2004, site : INRIA Sophia]

Student intern

Elaine Angelino [Student intern from Harvard College, USA, INRIA Allowance, from 10th, June 2004 until 13th, August 2004, site : INRIA Sophia]
Shaun Fitzgibbons [Student intern from Harvard College, USA, INRIA Allowance, from 10th June 2004 until 13th, August 2004, site : INRIA Sophia]
Guillaume Fournol [Student intern from ESSI Engineering School, INRIA Allowance, from the 14th, June 2004 until the 13th, September 2004, site : INRIA Sophia]
Ivan Krastev-Dimov [Student intern, CONYCIT funding, Chili, with INRIA additional funding, from the 3rd, January 2004 until the 9th, May 2004, lieu : INRIA Sophia]

Research scientists (partners)

Michel Barlaud [I3S, Université de Nice Sophia-Antipolis, France]
Emmanuel Risler [UNSA, INLN, France]
Gilles Aubert [UNSA, France]
Annelise Paradis [CR CNRS, from the 1st, October 2001, France]
Guy Orban [Université de Leuven, Belgium]
Patrick Chauvel [INRSEM E9926, Hôpital de la Timone, Marseille, France]

2. Overall Objectives

The Odyssée team is joint to INRIA, the Ecole Normale Supérieure in Paris and the CERTIS laboratory at Ecole Nationale des Ponts et Chaussées. It is located in Sophia-Antipolis, rue d'Ulm in Paris and in Champs-sur-Marne, close to Paris.

The scientific focus of the laboratory is the combined study of **computer and biological vision**. We think that a more detailed knowledge of the visual perception in humans and non-human primates can have a potential impact on algorithm design, performance evaluation and cues on such questions as how to interface an artificial vision system with people, possibly handicapped.

From a more general viewpoint and at another level, biological visual perception, in particular in non human primates and humans is poorly understood and modeled. Making progress in this understanding is a grand scientific and philosophic challenge that frames our work.

We conduct research in the following three main areas.

- Variational methods and partial differential equations for vision
- Observing the brain with functional imagery
- Modeling cortical activity

A detailed presentation of these different areas and related demos are available.

3. Scientific Foundations

3.1. Variational methods and partial differential equations for vision

We are interested in using variational methods and partial differential equations because they are the tools that allow us to

- Mathematically model a large number of computer vision problems such as segmentation, stereo, motion analysis or shape recognition.
- Study the existence and uniqueness of solutions.
- Design efficient algorithms for approximating those solutions.

Within this general framework, we are interested in the following two main areas

- Feature integration, as seen from the algorithmic and biological viewpoints. We are currently investigating:
  - *Shape from shading*, to integrate occluding edges, shadows and textures. This work is done in the context of the theory of viscosity solutions.
  - *Stereo*, a problem that also requires the integration of occluding contours, shadows and textures.
  - The combination of stereo and motion.
  - The combination of color, texture and motion for image segmentation.
- Shape representation and learning. We investigate the problem of acquiring geometric models from image sequences from the algorithmic and biologic viewpoints. We have proposed a number of mathematical formulation of this problem. We work on 3D deterministic and stochastic shapes representation and learning. Results can be included in the work on feature integration and are potentially useful for guiding segmentation and recognition.

3.2. Observing brain activity by functional imaging

Brain imaging is a well-adapted tool to improve our knowledge of brain functioning, in particular of visual perception. Challenging computer vision problems can also be posed by this type of imagery. The evolution of technology gives access to ever increasing spatio-temporal resolutions, resulting in the measurement of cortical areas whose sizes are now compatible with our modelization tools. We focus on the following modalities, Magnetic Resonance (MR), electroencephalography (EEG) and magnetoencephalography (MEG).

- In the case of MR, we use:
  - Functional magnetic resonance images (fMRI).
    This is an indirect way of measuring brain activity through the Blood Oxygenation Level Dependent (BOLD) signal which is thought to be correlated with neuronal activity. Spatial resolution is, at best, of the order of one millimeter while temporal resolution is of the order of a tenth of a second.
  - Diffusion tensor magnetic resonance imagery (DTMRI).
    This particular modality provides a measure of the diffusion of water molecules in tissues from which one can infer the geometry of the neural fibers connecting various areas of the brain (anatomical connectivity). This measure is also correlated to the electrical conductivity.
  - Anatomical magnetic resonance imagery (aMRI)
    This can provide, through an algorithmic process called segmentation, a valuable geometric description of brain areas, e.g. the cortex, the white matter, the cerebrospinal fluid, etc...
- EEG and MEG, which we note MEEG, provide measurements which are highly correlated to the electrical activity of the brain. The spatial resolution is of the order of one centimeter while the temporal resolution is of the order of one millisecond.

These three modalities are complementary from the standpoint of their spatio-temporal resolutions and of the kind of information they can deliver. We work in the following six areas.

- Spatio-temporal modeling of fMRI signals to obtain more accurate and more detailed cortical activity maps than those provided by the currently available software packages.
- Spatio-temporal modeling of MEEG signals.
- The use of DTMRI to describe anatomical connectivities and improve the existing models of electrical conductivities currently used in MEEG.
- The analysis of the well-posedness of the inversed problem in MEEG, i.e. the existence and uniqueness of a particular brain activity that best accounts for the EEG/MEG measurements.
- The development of new numerical methods for solving the MEEG problem.
- The integration of these three modalities for studying visual perception in humans and non human primates.

3.3. Modeling cortical activity

We use the results obtained within our second main research area to model the way the brain completes a visual perception task at a more general level than the "voxel" level. The spatio-temporal activity maps measured on humans and non human primates play an important role in this modeling which carries two main advantages. First we push forward the state of the art of the knowledge of the brain processes underlying visual perception and second we may discover interesting sources of inspiration for our work in computer vision.

We also study cortical activity at a finer level than the "voxel" by fitting models of neurones assemblies to the measurements provided by fMRI, MEEG and possible micro-electrodes. We have two targets

- The use of cortical columns models to analyze the cortical activity measured by fMRI or MEEG goes beyond the use of the classical models of electric dipoles and opens up new perspectives as to what algorithmic complexity underlies this activity. This is also likely to have an impact on our understanding of the inverse problem in MEEG and therefore on the way we solve it.
- Such a description is closely related to the formalism of dynamic systems and, perhaps, partial differential equations. This is a fascinating possibility of connecting with our first main research area.

4. New Results

4.1. Variational methods and partial differential equations for vision

4.1.1. About Some Optical Flow Methods from Structure Tensor: Review and Contribution

Participants: François Lauze, Pierre Kornprobst, Christophe Lenglet, Rachid Deriche, Mads Nielsen.

The paper [14] is about optical flow estimation from structure tensor field analysis of a sequence seen as a spatio-temporal volume. It tackles two issues. The first is to review related recent techniques showing their relations. We essentially discuss the stages of flow extraction from structure tensor fields and the obtention of regularized tensor fields. The second is to propose a nonlinear approach controlled by the intuitive corner measure. The overall approaches will be compared in details on serveral test sequences.

4.1.2. A Coarse To Fine Multiscale Approach For Linear Least Squares Optical Flow Estimation

Participants: François Lauze, Pierre Kornprobst, Etienne Mémin.

Tensor-based approaches for optical flow have been often criticized because of their limitations in handling large motions. In [14] it is shown how to adapt them in a multiscale coarse-to-fine strategy. We show how the same ideas used in the variational framework can be adapted by working with both a multiscale image sequence as well as a multiscale, motion compensated tensor field. Several experiments are presented in order to compare it to some recent well known multiscale techniques. We demonstrate how this approach offers a good compromise between precision and computational efficiency.

4.1.3. Variational Flows over Manifolds

Participants: Rachid Deriche, Lucero Lopez-Perez, Nir Sochen.

In several image processing applications one has to deal with noisy images defined on surfaces, like electric impulsions or diffusion tensors on the cortex. In this work [17], we propose a new regularization technique for data defined on triangulated surfaces: the Beltrami flow over intrinsic manifolds. This technique overcomes the over - smoothing of the L2 and the stair-casing effects of the L1 flow for strongly noised images. To do so, we locally estimate the differential operators and then perform temporal finite differences. We present the implementation for scalar images defined in 2 dimensional manifolds and experimental results.

4.1.4. Symmetric estimation of optical flow with occlusion detection

Participants: Luis Alvarez, Rachid Deriche, Thedorore Papadopoulo, Javier Sànchez.

Traditional techniques of dense optical flow estimation do not generally yield symmetrical solutions: the results will differ if they are applied between images I_1 and I_2 or between images I_2 and I_1. In this work, we present a method to recover a dense optical flow field map from two images, while explicitely taking into account the symmetry across the images as well as possible occlusions in the flow field. The idea is to consider both displacements vectors from I_1 to I_2 and I_2 to I_1 and to minimise an energy functional that explicitely encodes all those properties. This variational problem is then solved using the gradient flow defined by the Euler–Lagrange equations associated to the energy. Experiments clearly show the added value of these properties to improve the accuracy of the computed flows.

4.1.5. Tensor Processing for Texture and Colour Segmentation

Participants: Rachid Deriche, Rodrigo De Luis-Garcia.

In this work, we propose an original approach for texture and colour segmentation based on the tensor processing of the nonlinear structure tensor. While the tensor structure is a well established tool for image segmentation, its advantages were only partly used because of the vector processing of that information. In this work, we use more appropriate definitions of tensor distance grounded in concepts from information theory and compare their performance on a large number of images. We clearly show that the traditional Frobenius norm-based tensor distance is not the most appropriate one. Symmetrized KL divergence and Riemannian distance intrinsic to the manifold of the symmetric positive definite matrices are tested and compared. Adding to that, the extended structure tensor and the compact structure tensor are two new concepts that we present to incorporate gray or colour information without losing the tensor properties. The performance and the superiority of the Riemannian based approach over some recent studies are demonstrated on a large number of gray-level and colour data sets as well as real images. A reserach report is in the process to be published and a slightly shortened version is currently submitted to an international conference.

4.1.6. Implicit Active Shape Models for 3D Segmentation in MR Imaging

Participants: Rachid Deriche, Nikos Paragios, Mikael Rousson.

Extraction of structures of interest in medical images is often an arduous task because of noisy or incomplete data. However, hand-segmented data are often available and most of the structures to be extracted have a similar shape from one subject to an other. Then, the possibility of modeling a family of shapes and restricting the new structure to be extracted within this class is of particular interest. This approach, presented in [19], is commonly implemented using active shape models and the definition of the image term is the most challenging component of such an approach. In parallel, level set methods define a powerful optimization framework, that can be used to recover objects of interest by the propagation of curves or surfaces. They can support complex topologies, considered in h igher dimensions, are implicit, intrinsic and parameter free. In this paper [19], we revisit active shape models and introduce a level set variant of them. Such an approach can account for prior shape knowledge quite efficiently as well as use data/image terms of various form and complexity. Promising results on the extraction of brain ventricles in MR images demonstrate the potential of our approach.

4.1.7. Variational stereovision and 3D scene flow estimation

Participants: Olivier Faugeras, Gerardo Hermosillo, Renaud Keriven, Jean-Philippe Pons.

We present a common variational framework for dense depth recovery and dense three-dimensional motion field estimation from multiple video sequences, which is robust to camera spectral sensitivity differences and illumination changes. For this purpose, we first show that both problems reduce to a generic image matching problem after backprojecting the input images onto suitable surfaces. We then solve this matching problem in the case of statistical similarity criteria that can handle frequently occurring non-affine image intensities dependencies. Our method leads to an efficient and elegant implementation based on fast recursive filters. The computation time is of a few seconds per frame for medium resolution reconstructions. We obtain good results both on real and synthetic images. Preliminary results have been published in .

4.1.8. Point correspondences and tangential velocities in the level set framework

Participants: Olivier Faugeras, Gerardo Hermosillo, Renaud Keriven, Jean-Philippe Pons.

In this work, we overcome a major drawback of the level set framework: the lack of point correspondences. We maintain explicit backward correspondences from the evolving interface to the initial one by advecting the initial point coordinates with the same speed as the level set function. Our method leads to a system of coupled Eulerian partial differential equations. We show in a variety of numerical experiments that it can handle both normal and tangential velocities, large deformations, shocks, rarefactions and topological changes. Applications are many in computer vision and elsewhere since our method can upgrade virtually any level set evolution. We complement our work with the design of non zero tangential velocities that preserve the relative area of interface patches; this feature may be crucial in such applications as computational geometry, grid generation or unfolding of the organs' surfaces, e.g. brain, in medical imaging.

4.1.9. Implementing levelsets using finite element methods

Participants: Rachid Deriche, Théodore Papadopoulo, Jérôme Piovano.

This works aims at implementing the standard level set methods with the replacement of finite differences by a finite element method. This is done by mapping the image domain in a structured mesh. According to the litterature, this has the advantage of better accuracy in the curve evolutions while limiting the size of the band needed to represent it. Furthermore, since the band is smaller, it is much easier to maintain the distance function during the evolution. A first implementation has been done and seems very promising. It has been shown that the non-isotropic meshes that were previously used incurs some anisotropy for the curve evolutions. This effect has been corrected by using more isotropic meshes. We are now working towards generalizing this to 3D, the ultimate goal being to use this framework to produce highly accurate meshes representing the head to use them in the MEEG inverse problem computations developped in the project.

4.1.10. Shape Metrics, Warping and Statistics

Participants: Guillaume Charpiat, Olivier Faugeras, Renaud Keriven.

In this work we propose a framework for dealing with several problems related to the analysis of shapes. Two related such problems are the definition of the relevant set of shapes and that of defining a metric on it. Following a recent research monograph by Delfour and Zolesio [], we consider the characteristic functions of the subsets of $\mathbb{R}^2$ and their distance functions. The L^2 norm of the difference of characteristic functions, the L^∞ and the $W^{1,2}$ norms of the difference of distance functions define interesting topologies, in particular the well-known Hausdorff distance. Because of practical considerations arising from the fact that we deal with image shapes defined on finite grids of pixels we restrict our attention to subsets of $\mathbb{R}^2$ of positive reach in the sense of Federer [], with smooth boundaries of bounded curvature. For this particular set of shapes we show that the three previous topologies are equivalent. The next problem we consider is that of warping a shape onto another by infinitesimal gradient descent, minimizing the corresponding distance. Because the distance function involves an $\inf$, it is not differentiable with respect to the shape. We propose a family of smooth approximations of the distance function which are continuous with respect to the Hausdorff topology, and hence with respect to the other two topologies. We compute the corresponding Gâteaux derivatives. They define deformation flows that can be used to warp a shape onto another by solving an initial value problem. We show several examples of this warping and prove properties of our approximations that relate to the existence of local minima. We then use this tool to produce computational definitions of the empirical mean and covariance of a set of shape examples. They yield an analog of the notion of principal modes of variation. A preliminary version of this work appeared in [4].

4.1.11. Stochastic Mean Curvature Motion and Stochastic Active Contours

Participants: Olivier Juan, Renaud Keriven, Gheorghe Postelnicu.

This works presents a novel framework for image segmentation based on stochastic optimization. During the last few years, several segmentation methods have been proposed to integrate different information in a variational framework, where an objective function depending on both boundary information and region information is minimized using a gradient-descent method. Some recent methods are even able to extract the region model during the segmentation process itself. Yet, in complex cases, the objective function does not have any computable gradient. In other cases, the minimization process gets stuck in some local minimum, while no multi-resolution approach can be invoked. To deal with those two frequent problems, we propose a stochastic optimization approach and show that even a simple Simulated Annealing method is powerful enough in many cases. Based on recent work on Stochastic Partial Differential Equations (SPDEs), we propose a simple and well-founded method to implement the stochastic evolution of a curve in a Level Set framework

4.2. Observing and modeling the brain

4.2.1. Forward and Inverse BEM solutions for EEG and MEG

Participants: Geoffray Adde, Maureen Clerc, Olivier Faugeras, Jan Kybic, Théo Papadopoulo, Renaud Keriven.

We have recently developped a new integral formulation for EEG, which has led to a symmetric Boundary Element Method [8]. We have demonstrated the far superior accuracy of this method over the existing methods in the case of dipolar sources and a head model made of concentric spheres, for which the analytical solution is known. The symmetric BEM is used by G. Adde to solve the inverse problem of MEG -EEG. With Jan Kybic (Czech Technical University), we have developped a fast multipole-based acceleration for the symmetric BEM. By creating a hierarchical structure of the elements and approximating far interactions using spherical harmonics expansions, it accelerate the matrix-vector computations, and reduces the memory requirements. Using the FMM, we were able to solve the forward EEG problem on meshes totalling 30000 vertices [27].

4.2.2. Skull conductivity estimation by Electrical Impedance Imaging

Participants: Geoffray Adde, Jean-Michel Badier, Maureen Clerc, Jan Kybic, Theo Papadopoulo.

Localizing electrical sources of activity in the brain by solving the EEG inverse problem supposes that the conductivity of the head is known. The knowledge of skull conductivity, in particular, is important because its low conductivity gives the skull a shunting effect. We propose to estimate the skull conductivity by Electrical Impedance Imaging (EIT), a problem closely related to Electro-encephalography. In EIT, a known current is applied to the scalp, through a couple of electrodes of the EEG helmet, and the electric potential is measured at the remaining electrodes. The potential V and the current j are related by a homogeneous Poisson equation $\nabla\cdot(\sigma\nabla V) = 0$ with non-vanishing Neumann boundary condition $\frac{\partial V}{\partial n} = j$ on the scalp. In a piecewise constant conductivity model, the forward EIT problem can be solved with the Boundary Element Method, leading to the same system as for the forward EEG problem, only with a different source term. We are currently investigating the resolution of the EIT inverse problem (estimating the skull conductivity) using the symmetric BEM. Skull conductivity estimation by Electrical Impedance Imaging. We are starting this work in collaboration with Jean-Michel Badier from the Neurophysiology and Neuropsychology Laboratory at La Timone hospital, Marseilles (INSERM EMI 9926).

4.2.3. DT-MRI Estimation, Regularization and Fiber Tractography

Participants: Rachid Deriche, David Tschumperlé, Christophe Lenglet.

Diffusion tensor MRI probes and quantifies the anisotropic diffusion of water molecules in biological tissues, making it possible to non-invasively infer the architecture of the underlying structures. In [12], we address some crucial issues encountered in DT-MRI and present a set of new techniques for the estimation and regularization of diffusion tensors MRI datasets as well as a novel approach to the cerebral white matter connectivity mapping. Variational formalisms are proposed that lead to new and improved schemes, thanks to the preservation of important tensor constraints (positivity, symmetry). We illustrate how our complete DT-MRI processing pipeline can be successfully used to construct and draw fiber bundles in the white matter of the brain, from a set of noisy raw MRI images. Numerical experimentations conducted on real diffusion weighted MRI are shown to exhibit promising results [12].

4.2.4. Inferring White Matter Geometry from Diffusion Tensor MRI: Application to Connectivity Mapping

Participants: Rachid Deriche, Olivier Faugeras, Christophe Lenglet.

In this work [15], we introduce a novel approach to the cerebral white matter connectivity mapping from diffusion tensor MRI. DT-MRI is the unique non-invasive technique capable of probing and quantifying the anisotropic diffusion of water molecules in biological tissues. We address the problem of consistent neural fibers reconstruction in areas of complex diffusion profiles with potentially multiple fibers orientat ions. Our method relies on a global modelization of the acquired MRI volume as a Riemannian manifold M and proceeds in 4 majors steps:
1. We establish the link between Brownian motion and diffusion MRI by using the Laplace-Beltrami operator on M.
2. We then expose how the sole knowledge of the diffusion p roperties of water molecules on M is sufficient to infer its geometry. There e xists a direct mapping between the diffusion tensor and the metric of M.
3. Having access to that metric, we propose a novel level set formulation scheme to approximate the distance function related to a radial Brownian motion on M.
4. On that basis, a rigorous numerical scheme using the exponential map is derived to estimate the geodesics of M, seen as the diffusion paths of water molecules.
Numerical experimentations conducted on synthetic and real diffusion MRI datasets illustrate the potentialities of this global approach [15].

4.2.5. Level Set and Region Based Surface Propagation for Diffusion Tensor MRI Segmentation

Participants: Rachid Deriche, Mikael Rousson, Christophe Lenglet.

In Diffusion Tensor Imaging (DTI), tractography is currently the favorite technique to characterize and analyse the structure of the brain white matter. Only a few studies have been proposed to group data of particular interest. Rather than working on extracted fibers or on an estimated scalar value accounting for anisotropy as done in other approaches, we propose in this work [18] to extend classical segmentation techniques based on surface evolution by considering region statistics defined on the full diffusion tensor field itself. A multivariate Gaussian is used to approximate the density of the components of diffusion tensor for each sub-region of the volume. We validate our approach on synthetic data and we show promising results on the extraction of the corpus callosum from a real dataset [18]

4.2.6. Segmentation of 3D Probability Density Fields by Surface Evolution: Application to Diffusion MRI

Participants: Rachid Deriche, Mikael Rousson, Christophe Lenglet.

In this work [16], we propose an original approach for the segmentation of three-dimensional fields of probability density functions that extends our approach developed in [18] by considering a more general dissimilarity measure known as the Kullback-Leibler divergence, or relative entropy. This approach appears to be not only more natural, in the sense that it is strongly rooted and used in the information theory community, but also more versatile since it enables the algorithm to work on non-parametric densities. This presents a wide range of applications in medical images processing, in particular for diffusion magnetic resonance imaging where each voxel is assigned with a function describing the average motion of water molecules. Being able to automatically extract relevant anatomical structures of the white matter, such as the *corpus callosum*, would dramatically improve our current knowledge of the cerebral connectivity as well as allow for their statistical analysis. In a more recent work [29], we extended our contributions in [18] and [16] by considering the 6-dimensional statistical manifold defined by the parameters of the diffusion tensors and propose a segmentation algorithm by rigorously defining the geodesic distance and the intrinsic mean on this Riemannian manifold. The variational formulations of the problems yield three differents level-set evolutions converging towards the respective optimal segmentation. We validate these approaches on synthetical data and show promising results on the extraction of the corpus callosum and of the lateral brain ventricles from a real dataset.

4.2.7. *Statistics on Multivariate Normal Distributions: A Geometric Approach and its Application to Diffusion Tensor MRI*

Participants: Rachid Deriche, Olivier faugeras, Mikael Rousson, Christophe Lenglet.

This work [28] is dedicated to the statistical analysis of the space of multivariate normal probability density functions. It relies on the differential geometrical properties of the underlying parameter space, endowed with a Riemannian metric, as well as on recent works that led to the generalization of the normal law on non-linear spaces. We will first proceed to the state of the art in section 1, while expressing some quantities related to the structure of the manifold of interest, and then focus on the derivation of closed-form expressions for the mean, covariance matrix, modes of variation and normal law between multivariate normal distributions in section 2. We will also address the derivation of accurate and efficient numerical schemes to estimate the proposed quantities. A major application of the present work is the statistical analysis of diffusion tensor Magnetic Resonance Imaging. We show promising results on synthetic and real data.

4.2.8. *Fitting Higher Order Diffusion Tensors to HARDI Data Using the Spherical Harmonics*

Participants: Elaine Angelino, Rachid Deriche, Shaun Fitzgibbons.

The traditional method for analyzing DT-MRI data is to fit the ADC profile to a 2nd order tensor. The result is then visualized by using a level surface corresponding to the quadratic form given by the inverse of the 2-tensor, which corresponds to the probability distribution for a given water molecule starting at the origin after some fixed elapsed time. By diagonalization, it can be shown that these surfaces are ellipsoids. The long axis of the ellipse - or more directly, the long axis of the ADC profile - can be used to determine the orientation of fibers in the voxel being imaged. However, the theoretical basis for the modeling of the ADC profile with a second order tensor is the assumption that the underlying diffusion process is Gaussian. While this approximation is adequate for voxels in which there is only a single fiber orientation, it breaks down for voxels with more complicated internal structure. As such, recent research has been done on possible generalizations of the existing model, whose implementation has been made possible by new higher resolution imaging techniques such as HARDI (High Angular Resolution Diffusion Imaging). One such natural generalization is to model the ADC profile with a higher order tensor. In this work, we have adressed the problem of fitting dtMRI data to higher order tensors.

One proposed possibility for fitting the data to a higher order tensor is to do a direct linear regression analysis. This can be effective, but its robustness to noise is questionable for one primary reason. There does not appear to be any straightforward way in which to impose a viable smoothness maximizing criteria (a standard technique for regularizing data). Therefore, we approach the problem with an alternative method. We first fit our data to a spherical harmonic series, using a variation on the standard least-squares fitting approach, which we generalize to include a smoothness maximizing criterion. Taking this result, we then compute the higher order diffusion tensor corresponding to the given spherical harmonic coefficients. Both steps are simple linear transformations, and thus our algorithm provides a fast method for extracting HODT coefficients in a way that is robust to noise. A research report describing this contribution is in the process to be finalized. This contribution has greatly benefited from the INRIA International Internship Programm. and we kindly acknowledge its important support.

4.2.9. *Extracting Higher Order Spin Displacement Probability Distribution Functions*

Participants: Elaine Angelino, Rachid Deriche, Shaun Fitzgibbons.

Much recent work has been done on addressing the problem of incorporating higher order, non-Gaussian effects into the framework of diffusion MRI imaging. Spherical harmonic series have, in particular, been used to fit the ADC profile in a model-independent framework. Despite some recent interesting attempts, however, no robust, theoretically established, and simply implementable algorithm has been developed to extract fiber directions from ADC modeling. This is largely due to the fact that in general the proper setting for fiber analysis is real space rather than the signal space where the ADC is measured. Other work has been done in developing general techniques to approximate the spin displacement probability distribution function (PDF) or the spin displacement orientation distribution function (ODF) - both measurements of diffusion in real space - from various types of signal data. However, these methods lack a straightforward regularization process, and fail to take into account the useful tools for both estimation and regularization that have been developed for the fitting of the ADC profile. We propose here to give a survey of these existing techniques, and in particular, to develop the theory of the Q-ball imaging sequence. Then we demonstrate that by modeling the signal with spherical harmonics using our previously developed method for the ADC profile, a particularly simple and straightforwardly implemented analytic solution can be obtained for the Q-ball imaging approximation of the ODF. In doing so, we obtain a very fast algorithm for the extraction of a robust model-independent ODF approximation from raw data. Additionally, we propose a general framework for exponential decay assumptions in Q-ball imaging, and propose some fast algorithms for their implementation. Finally, we employ these techniques to discuss the problem of fiber extraction through sharpening transformations. This contribution has greatly benefited from the INRIA International Internship Progrmm. and we kindly acknowledge its important support.

4.2.10. The use of superresolution techniques to reduce slice thickness in fMRI

Participants: Rachid Deriche, Olivier Faugeras, Pierre Kornprobst, Gregoire Malandain, Ronald Peeters, Mila Nikolova, Michael Ng, Stefan Sunaert, Paul Van Hecke, Thierry Vieville.

In this work [9], we consider the problem of increasing the slice resolution of fMRI images without a loss in signal to noise ratio. For this purpose an adapted EPI MRI acquisition protocol is proposed, allowing one to acquire slice shifted images from which one can generate interpolated superresolution images, with an increased resolution in the slice direction. To solve the problem of correctness and robustness of the created superresolution images from these slice shifted datasets, the use of discontinuity preserving regularization methods is proposed. These acquisition and postprocessing techniques have been tested both on real morphological, synthetic functional and real functional MR datasets, by comparing the obtained superresolution datasets with high resolution reference datasets. In the phantom experiments the image spatial resolution of the different types of images are compared. In the synthetic and real fMRI experiments on the other hand, the quality of the different datasets is studied in function of their resulting activation maps. From the results obtained in this study it is concluded that the proposed superresolution techniques can augment the detectability of small activated areas in fMRI image sets acquired with thicker slices.

4.2.11. fMRI data smoothing constrained to the cortical surface: a comparison of the level-set and mesh-based approaches

Participants: Rachid Deriche, Olivier Faugeras, Jean-Philippe Pons, Lucero Lopez, Nicolas Wotawa.

It is well known that fMRI data have low SNR. In order to increase the signal of interest, a spatial smoothing procedure is commonly used. The smoothness of the data is also assumed in Gaussian Random Field theory used in the SPM analysis. However, this smoothing is usually 3D-isotropic, thus mixing voxels from different anatomical tissues (e.g. grey matter, white matter and CSF). This leads to undesirable averaging of signals at neighboring voxels, potentially affecting the analysis sensitivity. Furthermore, due to the highly convoluted geometry of the cortex, the "tissue-blindness" of this smoothing yields a mixing of signals across sulci at voxels close to each other in the volume but distant on the cortical surface, reducing further the spatial discrimination power. Taking into account the cortical geometry in the smoothing process seems to be a natural way to avoid these drawbacks. In our work presented in [24], we have implemented and compared two algorithms for surface-based smoothing, one based on an explicit mesh scheme and the other on a level-set framework. Both aim at minimizing the variations of the values defined along the cortical surface, leading to a partial differential equation (PDE) involving the Laplace-Beltrami operator. The equivalent gaussian kernel FWHM is easily linked to the equation running time. Our conclusion is that surface-based smoothing provides better sensitivity in activation detection, leading to higher statistical values. It furthermore enhances their spatial localization and discrimination. According to our work [24], the level set approach seems more straightforward and more easily adaptable to any functional data analysis framework.

4.2.12. Inverse Problem EEG Problem using the Volumic Finite Element Approach

Participants: Christelle Aziadjonou, Jacques Blum, Jonathan Chetboun, Maureen Clerc, Théodore Papadopoulo.

The volumic approach for the Inverse EEG problem is now working and various regularization methods have been tested. A new approach for H1 regularization that actually reduces the quantity of computations needed has been implemented. This code has also been used to test the sensibility of the direct and inverse problems with respect to conductivities. We know work toward integrating very acurate geometric descriptions of the head, and extending the method to be able to do Electrical Impedance Tomography as well as MEG.

4.2.13. Multimodal registration

Participants: Christophe Chefd'hotel, Olivier Faugeras.

We have transferred the work we have been doing in this area during the last two years to our Leuven partners in the Mapawamo European Project.

4.3. Modeling cortical activity

4.3.1. Could early visual processes be sufficient to label motions?

Participants: Ivan Dimov, Pierre Kornprobst, Thierry Vieville.

Biological motion recognition refers to our ability to recognize a scene (motion or movement) based on the evolution of a limited number of points acquired for instance with a motion capture tool. Much work has been done in this direction showing how it is possible to recognize actions based on these points. In [26], following the reference work of Giese and Poggio [], we propose an approach to extract such points from a video based on spiking neural networks with rank order coding. Using this estimated set of points, we verify that correct biological motion classification can be perfomed. We use some recent results of Thorpe et al. who claim that the neural information is coded by the relative order in which these neurons fire. This allows to select a limited set of relevant points to be used in the motion classification. Several experiments and comparisons with previous neurological work and models are proposed. The result of these simulations show that information from early visual processes appears to be sufficient to classify biological motion.

4.3.2. A biologically plausible model of fast visual categorization

Participant: Thierry Vieville.

Using an Hebbian learning rule for Multi-Class SVM classifiers, allows to re-interpret basic nearest-neighbor classifiers, using the statistical learning theory, and obtaining an optimized version of this basic mechanism. A key feature is that optimizing the statistical property of nearest-neighbor classifiers allows to automatically add/delete prototypes, edit them and remove redundant ones.

We also have made explicit and experimented that SVM like mechanisms can easily be implemented using Hebbian-like correction rules. Such optimization mechanism is not as fast as the standard method, but its biological plausibility is better, while final performances are similar.

This point of view is in deep relation with fast visual recognition in the brain. It may, for instance, explain why biological classifiers have such surprising generalization performances.

More precisely, the Thorpe et al. model complexity is bounded and does not depends on the network size. It is likely bounded because of the quantification steps (in relation with the temporal resolution of neuronal encoding). This explains its very good performances.

Main publications are [11][20] in relation with other publications on biologically plausible models [21][23][22].

4.3.3. *Towards bridging the Gap between Biological and Computational Image Segmentation*

Participants: Rachid Deriche, Olivier Faugeras, Iasonas Kokkinos, Petros Maragos.

In this work [13], we present a biologically motivated model for low and mid-level vision tasks, as well as its interpretations in computer vision terms. As a starting point we briefly present the biologically plausible model of image segmentation developed by Stephen Grossberg and his collaborators during the last two decades, that has served as the backbone of many researchers' work. Subsequently we describe a novel version of this model with a simpler architecture but superior performance to the original system using nonlinear recurrent neural dynamics. This model integrates multi-scale contour, surface and saliency information in an efficient way, and results in smooth surfaces and thin edge maps, without any posterior edge thinning or some sophisticated thresholding process. When applied to both synthetic and true images this model gives satisfactory results, favorably comparable to those of classical computer vision algorithms. Analogies between the functions performed by this system and some commonly used techniques for low- and mid-level computer vision tasks are presented; by interpreting the network as minimizing a cost functional, links with the variational approach to computer vision are established.

Since the presentation of this work in [13], this work has been carried out and a complete research report is in the process to be publised. By interpreting the network's function in a probabilistic manner, we have derived an algorithm for learning the network weights using manually determined segmentations. Using the learned weights, our network outperforms state-of-the-art brightness-based edge detection algorithms; the Berkeley segmentation benchmark has been used for comparisons.

5. Other Grants and Activities

5.1. Regional Grants

5.1.1. *Rotoscoto project*

Participants: Rachid Deriche, Olivier Faugeras, Théo Papadopoulo, Renaud Keriven, Olivier Juan.

Rotoscoto is a Priamm project, in collaboration with Realviz and Duboi. It deals with the problem of rotoscopy which is a widely used technique for postproduction applications.

5.2. National Grants

5.2.1. *Tele-medecine ACI grant: Dir-Inv*

Participants: Maureen Clerc, Olivier Faugeras, Renaud Keriven, Jan Kybic, Théodore Papadopoulo.

This three year grant started in 2001 from the French Ministery of Research is geared towards the study of the direct and inverse problems in Electro- and Magneto-Encephalography. The project is coordinated by INRIA and the participants are the CERTIS in Marne-la-Vallée (ENPC), the "La Timone" hospital in Marseille and the Technologic University in Compiègne. INRIA's participants are the projects Estime, Gamma, Ondes and Odyssée.

Detailed presentation

5.2.2. *Large Dataset ACI: Obs-Cerv*

Participants: Maureen Clerc, Olivier Faugeras, Renaud Keriven, Juliette Leblond, Jan Kybic, Théodore Papadopoulo.

This three year grant has been funded in 2003. Its main purpose is to make progress toward a virtual meta-sensor combining the advantages of the various non-invasive sources of information about the brain activity. This involves manipulating and linking the information provided by some very large heterogenous data sets such as MEG and EEG or various types of MRI images.

Detailed presentation

5.2.3. The ACI RIVAGe pre-project: Feedback during Visual Integration: towards a Generic Architecture

Participants: Rachid Deriche, Olivier Faugeras, Pierre Kornprobst, Théodore Papadopoulo, Thierry Viéville.

The goal of this ACI was to build a strong relationship between a research team working in neurosciences of visual perception and a research team working in artificial vision (i.e. computer vision). The long term objective is to elaborate a common theory about precise questions in both neurosciences and algorithms and their architecture in artificial vision, including computer vision applications [25].

Detailed presentation

5.2.4. Non-rigid registration "specific action"

Participants: Guillaume Charpiat, Christophe Chefd'hotel, Olivier Faugeras, Gerardo Hermosillo, Renaud Keriven.

The contributors are: ENS Cachan (CMLA), INT (ARTEMIS), IMAG TIMC (GMCAO), INRIA (Epidaure, Odyssée), INSA (CREATIS), IRISA (Projet Vista), Louis Pasteur University (LSIIT), Paris V University (MAP5) and Paris XIII University (LAGA).

Web site

5.3. UE Grants

5.3.1. ImaVis: Theory and Practice of Image Processing and Computer Vision

Participants: Rachid Deriche, Olivier Faugeras.

IMAVIS:Theory and Practice of Image Processing and Computer Vision is a four year European project, started on Sept. 2001 and numbered HPMT-CT-2000-00040 working within the framework of Marie Curie Training Sites Fellowships programme which give young researchers pursuing doctoral studies the opportunity to receive training within high-level groups in their specialised area of research. Within IMAVIS, the Inria research groups Ariana, Epidaure and Odyssée (Coord.) located at INRIA Sophia-Antipolis are offering 108 fellow-months for PhD Students, nationals of a Member or Associated State.

Thomas Brox, from Department of Mathematics and Computer Science, Saarland University and Iasonas Kokkinos from National University of Athens spent 4 months each in our lab in 2002/2003.

Rodrigo de luis-garcia (Universidad de Valladolid - ETSI Telecomunicación) joined our group from early June to end of September 2004

Fussenegger Michael (Graz University) joined our group early September 2004 and will stay until the end of January 2005.

Carlos Alberto Castano Moraga (Universidad Las-Palmas) joined our group from early November and will stay within our group until the end of July 2005.

5.3.2. Insight2+ Project: 3D shape and material properties for recognition

Participants: Maureen Clerc, Rachid Deriche, Olivier Faugeras, Pierre Kornprobst, Emmanuel Prados.

Our partners are :

Lab. of Neuro- and Psychophysiology, R.U. Neurophysiology, Dept. of Neurosciences and Psychiatry, K.U.Leuven, Medical School (LEUNEURO) Leuven, Belgium, le centre de recherche cognition cerveau Toulouse,FLUX-Department Physics of Man (Utrecht), COMPVIS2- Centre for Autonomous Systems, KTH (Sweeden), MATH2-University of North Carolina, Mathematical department, USA, Department of Mathematical Sciences, University of Liverpool, Great Britain

INSIGHT2+ deals with 3D shape and material properties for recognition. This European project is funded under the Information Society Technologies (IST) Programme and its duration is from Sept. 2001 to September 2004. The objectives of the project are to

1. Restore the cross fertilization between biological vision (neuroscience and psychophysics) and computer vision.

2. Study the coding of pictorial cues for 3D shape and of material properties in areas TE and V4.
3. Search for grouping of properties in either area and relate to connectivity.
4. Study the perception of 3D shape defined by pictorial cues and of material properties.
5. Develop mathematical theories necessary for implementation of pictorial cue and material processing in computers.
6. Implementation of the theory to create a flexible system.

5.3.3. CogViSys Project: Towards cognitive vision systems

Participants: Rachid Deriche, Olivier Faugeras, Renaud Keriven, Mikael Rousson, Lejeune Fabien.

CogViSys is the acronym for Cognitive Vision Systems. This European project numbered 3E010361 is funded under the Information Society Technologies (IST) Programme and its duration is from May, 1st 2001 to April 30th, 2004. It has been extended and the final review will held on December 2004.

The partners are :
UniversitätKarlsruhe (H.-H. Nagel, Coordinator),
ETH Zürich (L. van Gool,PI),
Katholieke Universiteit Leuven (L. van Gool, PI),
Universität Freiburg (B. Nebel, PI),
Oxford University(J.M. Brady, A. Zisserman, PIs)

The challenge addressed in this project is to build a vision system that can be used in a wider variety of fields and that is re-usable by introducing self-adaptation at the level of perception and by making explicit the knowledge base at the level of reasoning, and thereby enabling the knowledge base to be changed. In order to make these ideas concrete CogViSys aims at developing a virtual commentator which is able to translate visual information into a textual description.

5.3.4. NSF-INRIA Proposal: Computational Tools for Brain Research

Participants: Rachid Deriche, Olivier Faugeras, Chistophe Lenglet, Guillaume Charpiat.

This NSF-INRIA Collaborative scheme includes the Center for Magnetic Resonance Research (K. Ugurbil) et the Department of Electrical and Computer Engineering University of Minnesota (prof. G. Sapiro). Exchange of visits and collaborative work has already started. Christophe Lenglet spent 1 month late 2003 and one month during november 2004 in the CMRR. Key-words : Diffusion Tensor Imaging, Shape statistics Duration : 3 years starting from July 2004

5.3.5. FFCR Canada Proposal: Biomedical Image Analysis

Participants: Rachid Deriche, Olivier Faugeras, Chistophe Lenglet.

Our partner in this project is Prof. Kaleem Siddiqui from Mac-Gill McGill University (School of Computer Science and Centre For Intelligent Machines) Our broad goal is to develop algorithms for use in the analysis and processing of biomedical images, specifically brain images, which are based on formulations using partial differential equations, variational methods and differential geometry. Exchanges of visits has already occured from McGill University to Inria and following these visits, Maxime Descoteaux will join our group to start a PhD thesis at Nice University under the supervision of R. Deriche. Key words :Brain image Segmentation - Duration : 1 year from august 2003 to august 2004. Extended until August 2005.

5.3.6. PAI PICASSO

Participants: Rachid Deriche, Olivier Faugeras, Theo Papadopoulo.

This project includes the Mathematical Image Analysis group leaded by Prof. Luis Alvarez from Las-Palms University and the group leaded by Juan Ruiz Alzola which contributed a lot in DT-MRI. Our goal is to develop algorithms for use in image analysis and DT-MRI based on variational frameworks. Exchanges of visits has already occured from Las-Palmas to Nice and Nice to Las-Palmas. The partners agreed to jointly submit a european proposal within the 6th PCRD Framework. The short proposal *TENSOR* has been submitted end september and the full proposal will be submitted fall 2004. Key words : Optical flow, Biological Vision, Diffusion Tensor Imaging.. Duration : 1 year from early 2004 to the end of 2005.

5.3.7. VISIONET-TRAIN : Computational and Cognitive Models for Vision : A Training European Network

Participants: Maureen Clerc, Rachid Deriche, Olivier Faugeras, Renaud Keriven, Pierre Kornprobst, Theo Papadopoulo, Thierry Vieville.

This Marie Curie RTN proposal has just been accepted for grants by the European Commission. This proposal includes 17 partners and is focused on the training programme of 20 PhD students and will finance salaries for early state researchers (doctoral studies) on the basis of a 3-year contract as well as experienced researchers (less than 10 years of research experience). The ambitious overall objective of this project is to further advance the state of the art in the understanding the computational, cognitive, and biological bases of visual processes. Hiring PhD students and Post-Doc within this program is planned for mid-2005.

5.4. International Bilateral Relations

R. Deriche has been continuously in charge of the International Affairs for the INRIA Sophia Research Unit since 1996, see the corresponding Web site.

T. Viéville has been, with B. Mourrain, in charge of the Doctoral Training Program for the Sophia Research Unit since 1999 and is the INRIA representative in the Univ.of Nice Scientific commitee/ He has been a member of the Director Advisory Board since 2002.

6. Dissemination

6.1. Services to the scientific community

R. Deriche is a member of the advisory board of Realviz and has been part of the VisionIQ advisory boards. He is an expert member of the scientific committee of the 4 year European project (2004-2008) Visitor under the Marie-Curie actions for young researcher mobility. R. Deriche is a member of the editorial board of the International Journal of Computer Vision, a member of the *Expert Commission CS 61 Génie informatique, automatique et traitement du signal* at Nice Sophia-Antipolis University. R. Deriche has been involved in many PhD thesis committees as chairman, reviewer or examiner.

Olivier Faugeras is a member of the Institut de France, Académie des Sciences. He is co-editor in chief of the "International Journal of Computer Vision" (IJCV). He has been invited to a number of companies scientific advisory boards such as RealViZ and VISIONIQ. He chairs the scientific board of the "Institut Français du Pétrole" (IFP).

Renaud Keriven is a member of a number of commitees at the Ecole Nationale des Ponts et Chaussees such as the "CS phD thesis committee", the "phD program committee" and educational committees.

P. Kornprobst is a member of the "Comité de Centre" and the "Comité Local de Formation Permanente" of the Sophia-Antipolis INRIA Research Unit.

Théo Papadopoulo is part of the "Expert Commission CS 27" at Nice-Sophia Antipolis University. He is also a member of several committees of the Sophia-Antipolis INRIA Research Unit such as the "laboratory committee", of the "Software development committee", of the "educational committee" and of the "computer system users committee" of the Sophia research unit.

Thierry Viéville is the scientific animator of the)i(nterstices project.

6.2. Academic teaching

6.2.1. Master STIC

Nice-Sophia Antipolis University -:

Rachid Deriche teaches the *Geometrical Advanced Techniques in Image Processing and Vision* course,
Olivier Faugeras teaches the *Computer and biological Vision* course,
Théodore Papadopoulo teaches the *3D Vision* course.
Thierry Viéville teaches the *biological and computer models of motion perception* course.

Each course includes 15 hours of lectures. Rachid Deriche and Olivier Faugeras are members of the scientific committee of this DEA. Rachid Deriche is in charge of the internships program.

6.2.2. Master "Mathématiques Appliquées", parcours MVA (Mathematics/Vision/Learning)

Ecole Normale Supérieure Cachan - Paris 5 University - Ecole Normale Supérieure Ulm - Paris-Dauphine University - Ecole Nationale Supérieure des Télécommunications - École Polytechnique - Ecole Nationale des Ponts et Chaussées - Ecole Centrale Paris - Ecole Généraliste des Ingénieurs de Marseille.

Olivier Faugeras teaches the Computer and biological Vision course.
Théodore Papadopoulo teaches the 3D Vision course.
Renaud Keriven teaches the Virtual and Augmented Reality course (with Nikos Paragios).

6.2.3. I3 Computer Science DEA: Information, Interaction, Intelligence

Paris Sud University - Centre Scientifique d'Orsay - Paris I University - Panthéon Sorbonne in collaboration with INRIA.

Rachid Deriche teaches jointly with Hervé Delingette (Epidaure project) the module *Modélisation Géométrique et Physique à partir d'images pour la réalité augmentée et virtuelle* course (21 hours).

6.2.4. Algorithmic DEA

Jointly with Ecole Normale Supérieure Paris, Ecole Normale Supérieure Cachan, Paris VI, Paris VII and Paris XI Universities, E.N.S.T.and École Polytechnique, INRIA and ENSTA.

Rachid Deriche teaches the Géométrie, Images et Vision 3D course. This course is part of the Géométrie et Calcul Formel track.

6.2.5. Master Parisien de Recherche en Informatique (MPRI)

Jointly with Ecole Normale Supérieure Paris, Ecole Normale Supérieure Cachan, Paris VI, Paris VII and Paris XI Universities, E.N.S.T., École Polytechnique, CNRS, CEA and INRIA.

Renaud Keriven teaches the Algorithmic Computer Vision course with Rachid Deriche and Nikos Paragios.

Rachid Deriche teaches the *Geometrical flows and Image Modelling* course (since Fall 2004, this series of lectures replace the course given in the section above (*algorithmic DEA*) and is part of the Algorithmic Computer Vision course.)

6.2.6. D.U.T. Informatique (option imagerie numérique)

Pierre Kornprobst teaches the *traitement d'images* course at Nice University.

6.2.7. DEA Informatique Fondamentale et Applications

Renaud Keriven teaches the Computer Vision course at the Marne la Vallée University.

6.2.8. Magistère de Mathématiques Fondamentales et Appliquées et d'Informatique de la Région Parisienne

Renaud Keriven teaches the Algorithmic Computer Vision course, now joint with the previously mentionned MPRI course.

6.3. Other teaching loads

6.3.1. Institut National des Télécommunications- Evry

École d'Ingénieurs - third year - Option: Traitement et Applications de l'Image. Rachid Deriche teaches the Computer Vision and Dynamic Images courses.

6.3.2. Ecole Nationale des Ponts et Chaussées

Maureen Clerc is in charge of a course in the curriculum: Frequency analysis and applications.

Renaud Keriven is in charge of the main Computer Science course and of the two specialisation modules "Modéliser/Programmer/Simuler" and "Vision et Traitement d'Images".

6.3.3. École des Mines - ENSTA

Rachid Deriche teaches Computer Vision at the École des Mines de Paris and at ENSTA.

6.3.4. ESSI

Thierry Viéville teaches Real-Time Motion Perception.

6.4. Participation to workshops, seminars and miscellaneous invitations

Rachid Deriche was an Area Chair for the European Conference on Computer Vision Computer Vision '2004

He is a member of several program committees such as CAIP'2005: 10th International Conference On Computer Analysis of Images and Patterns, Scale-Space'05:4th International Conference on Scale-Space Theories in Computer Vision...

He has been invited by Prof. Yunmei Chen to give a talk at the workshop on "Mathematical Imaging and Image Analysis" held January 24-27, 2004, at the University of Florida, Gainesville.

He has been invited by *Sup'Com* in Tunis (Tunisia) late february 2004. He stayed at the *Sup'Com* school for a week and gave a series of lectures in geometrical approaches in computer vision and image processing.

Olivier Faugeras has been a member of the Conference Board of the European Conference on Computer Vision, ever since he started the Conference in 1990. He is a member of the advisory board of ACCV'04 and invited speaker, on the General Board of Scale-Space'03:4th International Conference on Scale-Space Theories in Computer Vision, a member of the scientific committee of AMAM'03: Applied Mathematics and Applications of Mathematics, ECVP'03: European Conference on Visual Perception, program co-chair of ICCV'03: International Conference on Computer Vision. He has been invited speaker at the 3rd Indian Conference on Computer Vision, Graphics and Image Processing and is general co-chair of the 4th Indian Conference on Computer Vision, Graphics and Image Processing.

Maureen Clerc gave an invited talk at the Spatial Statistics Workshop at Ecole Nationale d'Agronomie Paris-Grignon. She animated a research group on Inverse Problems in MEG/EEG at the CEMRACS research center in Luminy (August 2004), at which she was also invited to give a seminar.

Renaud Keriven has been a member of the Program Committee of the 2004 and 2005 International Conferences on Computer Vision and Pattern Recognition, of the 2004 International Conference on Image Processing, and of the 2005 International Conference on Scale-Space and Diffusion Methods in Computer Vision.

Pierre Kornprobst has been a member of the Program Committee of the 5th International Conference on Scale-Space and Diffusion Methods in Computer Vision 2005 and a reviewer for the 8th European Conference on Computer Vision 2004.

Théo Papadopoulo is a member of the Program Committee of the 2004 European Conference on Computer Vision and of the 2005 International Conference on Computer Vision and Pattern Recognition. He was invited to visit the university of Urbana-Champaign (Illinois) in Jean Ponce group, where he presented the activities of the Odyssée project.

Thierry Viéville was an invited Speaker at the École Nationale Supérieure d'Électronique, Informatique et Radiocommunications de Bordeaux (ENSEIRB).

The researchers involved in the Pole III of the object (modeling of the brain activity) belong the *cortyxee* working group common to the CORTEX project: this every two weeks seminar allows to share scientific inputs, cooperate on bibliographical material, etc..

6.5. Theses and Internships

6.5.1. Theses defenses

- Emmanuel Prados, *"Application de la théorie des solutions de viscosité au problème du calcul de la forme tridimensionnelle à partir d'une image"*, Nice-Sophia Antipolis University; October 2004
- Gheorghe Postelnicu, *"Systèmes dynamiques stochastiques"*, Université Paris-Dauphine; November 2004.
- Mikaël Rousson, *"Cues Integrations and Front Evolutions in Image Segmentation "*, Nice-Sophia Antipolis University; December 2004.

6.5.2. Ongoing Theses

- Geoffray Adde, *"Probleme inverse en MEG"*, ENPC; Site : Odyssée ENPC, Marne.
- Guillaume Charpiat, *"Statistiques de courbes et d'images"*, ENS Paris; Site : Odyssée ENS, Paris.
- Thomas Deneux, *"Modélisation et IRMf"*, ENS; Site : Odyssée ENS, Paris.
- Irene Fasiello, *"Vision biologique"*, ENS Cachan; Site : Odyssée ENS, Paris
- François Grimbert, *"Modélisation d'ensembles de colonnes corticales et application à l'électroencephalographie et à la magnétoencephalographie"*, UNSA; Site : Odyssée Sophia-Antipolis.
- Pierre Maurel, *"Statistiques de formes et croissance du cerveau"*, ENS Paris; Site : Odyssée ENS, Paris.
- Olivier Juan, *"Rotoscopie et applications à la réalite virtuelle"*, ENPC; Site : Odyssée ENPC, Marne.
- Christophe Lenglet, *"Processing and Analysis of Diffusion Tensor Magnetic Resonance Images"*, UNSA; Site : Odyssée Sophia-Antipolis.
- Lucero Lopez-Pérez, *"Image Processing and PDE's on Non Flat Manifolds"*, UNSA; Site : Odyssée INRIA Sophia-Antipolis.
- Jérôme Piovano, *"Extraction automatique de formes complexes : Application à la création de modèles anatomiques de la tête"*, UNSA; Site : Odyssée INRIA Sophia-Antipolis.
- Jean-Philippe Pons, *"Méthodes variationnelles et reconstruction spatio-temporelle"*, ENPC; Site : Odyssée INRIA Sophia-Antipolis
- Nicolas Wotawa, *"IRMf pour la rétinotopie et l'analyse de la perception du mouvement"*, UNSA; Site : Odyssée INRIA Sophia-Antipolis.
- Adrien Wohrer, *"Perception du mouvement par des neurones à impulsions "*, Ecole Polytechnique, Site : Odyssée INRIA Sophia-Antipolis.

6.5.3. Internships

- Martin De La Gorce, *"IRM-TD d'ordre Supérieur"*, ISEP, Location : Odyssée INRIA Sophia-Antipolis, from the 1st, May 2004 until the 30th, September 2004, funding : INRIA Odyssée.
- Ivan Dimov, *"Biological motion recognition based on early visual processes"*, Univ. Santiago Chili, from the 3rd, January 2004 until the 9th, May 2004
- Irene Fasiello, *"Modélisation du cerveau visuel et ensembles de neurones à Spike"*, ENS Cachan, Location : Odyssée INRIA Sophia-Antipolis, from the 1st, April 2004 until the 30th, September 2004, funding : INRIA Odyssée.
- François Grimbert, *"Modélisation d'ensembles de colonnes corticales et applications à l'électroencephalographie et à la magnétoencephalographie"*, ENS Cachan, Location : Odyssée Sophia-Antipolis, from the 1st, June 2004 until the 30th, September 2004, funding : INRIA Odyssée.
- Riadh Layouni, *Modélisation de Neurones à Spike pour la perception de séquences d'images"*, UNSA ED STIC, Location : Odyssée INRIA Sophia-Antipolis, from the 15th, March 2004 until the 20th, September 2003, funding : INRIA Odyssée.
- Karim Lounici, *"Ensemble de Neurones à Spikes"*, ENS Cachan, Location : Odyssée ENS Paris, from the 1st, April 2004 until the 31st, July 2004.
- Jérôme Piovano, *"Méthode par ensembles de niveaux (level sets) et éléments finis"*, UNSA ED STIC, Location : Odyssée INRIA Sophia-Antipolis, from the 1st, April 2004 until the 30th, September 2004, funding : INRIA Odyssée.
- Adrien Wohrer, *"Neurones à Spyke et perception de séquences d'images"*, ENS Cachan, Location : Odyssée INRIA Sophia-Antipolis, finding, INRIA Odyssée.

7. Bibliography

Doctoral dissertations and Habilitation theses

[1] G. POSTELNICU. *Systèmes dynamiques stochastiques*, Ph. D. Thesis, University of Paris IX Dauphine, November 2004.

[2] E. PRADOS. *Application of the theory of the viscosity solutions to the Shape From Shading problem*, Ph. D. Thesis, University of Nice-Sophia Antipolis, 2004.

[3] M. ROUSSON. *Cues Integrations and Front Evolutions in Image Segmentation*, Ph. D. Thesis, Université de Nice-Sophia Antipolis, December 2004.

Articles in referred journals and book chapters

[4] G. CHARPIAT, O. FAUGERAS, R. KERIVEN. *Approximations of shape metrics and application to shape warping and empirical shape statistics*, in "Foundations of Computational Mathematics", Accepted for publication (available on line)., 2004.

[5] C. CHEFD'HOTEL, D. TSCHUMPERLÉ, R. DERICHE, O. FAUGERAS. *Regularizing Flows for Constrained Matrix-Valued Images*, in "Journal of Mathematical Imaging and Vision", vol. 20, n° 1-2, 2004, p. 147–162.

[6] O. FAUGERAS, G. ADDE, G. CHARPIAT, C. CHEFD'HOTEL, M. CLERC, T. DENEUX, R. DERICHE, G. HERMOSILLO, R. KERIVEN, P. KORNPROBST, J. KYBIC, C. LENGLET, L. LOPEZ-PEREZ, T. PAPADOPOULO, J.-P. PONS, F. SEGONNE, B. THIRION, D. TSCHUMPERLÉ, T. VIÉVILLE, N. WOTAWA. *Variational, geometric, and statistical methods for modeling brain anatomy and function*, in "Neuroimage", Special issue: Mathematics in Brain Imaging - Edited by P.M. Thompson, M.I. Miller, T. Ratnanather, R.A. Poldrack and T.E. Nichols., vol. 23S1, 2004, p. S46-S55.

[7] O. FAUGERAS, G. HERMOSILLO. *Well-posedness of two non-rigid multimodal image registration methods*, in "Siam Journal of Applied Mathematics", vol. 64, n° 5, 2004, p. 1550–1587.

[8] J. KYBIC, M. CLERC, T. ABBOUD, O. FAUGERAS, R. KERIVEN, T. PAPADOPOULO. *A common formalism for the integral formulations of the forward EEG problem*, in "IEEE Transactions on Medical Imaging", Accepted for publication., 2004.

[9] R. PEETERS, P. KORNPROBST, M. NIKOLOVA, S. SUNAERT, T. VIEVILLE, G. MALANDAIN, R. DERICHE, O. FAUGERAS, M. NG, P. V. HECKE. *The use of superresolution techniques to reduce slice thickness in functional MRI*, in "International Journal of Imaging Systems and Technology (IJIST), Special issue on High Resolution Image Reconstruction", vol. 14, 2004, p. 131–138.

[10] B. THIRION, O. FAUGERAS. *Feature characterization in fMRI data: the Information Bottleneck approach*, in "Medical Image Analysis", vol. 8, n° 4, December 2004, p. 403–419.

[11] T. VIEVILLE, S. CRAHAY. *Using an Hebbian Learning Rule for Multi-Class SVM Classifiers*, in "Journal of Computational Neuroscience", vol. 17, n° 3, 2004, p. 271–287, http://journals.kluweronline.com/article.asp?PIPS=5384399.

Publications in Conferences and Workshops

[12] R. DERICHE, D. TSCHUMPERLÉ, C. LENGLET. *DT-MRI Regularization & Fiber Tractography*, in "Proceedings of ISBI, Arlington, VA", IEEE, April 2004, http://www.biomedicalimaging.org.

[13] I. KOKKINOS, R. DERICHE, P. MARAGOS, O. FAUGERAS. *A Biologically Motivated and Computationally Tractable Model of Low and Mid-Level Vision Tasks*, in "Proceedings Eighth European Conference on Computer Vision,, Prague", May 2004, ftp://ftp-sop.inria.fr/odyssee/Publications/2004/kokkinos-deriche-etal:04.pdf.

[14] F. LAUZE, P. KORNPROBST, E. MÉMIN. *A Coarse To Fine Multiscale Approach For Linear Least Squares Optical Flow Estimation*, in "British Machine Vision Conference", vol. 2, 2004, p. 767–776.

[15] C. LENGLET, R. DERICHE, O. FAUGERAS. *Inferring White Matter Geometry from Diffusion Tensor MRI: Application to Connectivity Mapping*, in "Proceedings of the 8th European Conference on Computer Vision, Prague, Czech Republic", T. PAJDLA, J. MATAS (editors)., Springer–Verlag, May 2004.

[16] C. LENGLET, M. ROUSSON, R. DERICHE. *Segmentation of 3D Probability Density Fields by Surface Evolution: Application to diffusion MRI*, in "Proc. 7th Intl. Conf. on Medical Image Computing and Computer Assisted Intervention, Saint-Malo, France", September 2004.

[17] L. Lopez-Perez, R. Deriche, N. Sochen. *The Beltrami Flow over Triangulated Manifolds*, in "Computer Vision and Mathematical Methods in Medical and Biomedical Image Analysis: ECCV 2004 Workshops CVAMIA and MMBIA, Prague, Czech Republic, May 15, 2004, Revised Selected Papers", M. Sonka, I. A. Kakadiaris, J. Kybic (editors)., Lecture Notes in Computer Science, vol. 3117, Springer-Verlag Heidelberg, October 2004, p. 135–144, http://www.springerlink.com/link.asp?id=j9q011xee8rllxjx.

[18] M. Rousson, C. Lenglet, R. Deriche. *Level Set and Region Based Surface Propagation for Diffusion Tensor MRI Segmentation*, in "Computer Vision Approaches to Medical Image Analysis (CVAMIA) and Mathematical Methods in Biomedical Image Analysis (MMBIA) Workshop, Prague", May 2004, ftp://ftp-sop.inria.fr/odyssee/Publications/2004/rousson-lenglet-etal:04.pdf.

[19] M. Rousson, N. Paragios, R. Deriche. *Implicit Active Shape Models for 3D Segmentation in MR Imaging*, in "Proc. 7th Intl. Conf. on Medical Image Computing and Computer Assisted Intervention", Springer-Verlag, September 2004.

[20] T. Viéville, S. Thorpe. *A deterministic biologically plausible classifier*, in "8th ICCNS", Boston University, 2004.

[21] T. Viéville. *A biologically plausible trajectory generator*, in "8th ICCNS", Boston University, 2004.

[22] T. Viéville. *Biologically plausible regularization mechanisms*, in "8th ICCNS", Boston University, 2004.

[23] T. Viéville. *Quelques modèles biologiquement plausibles issus des méthodes de vision artificielle*, in "Dynamique des réseaux neuronaux artificiels biologiquement plausibles et applications en robotique autonome", M. Samuelides (editor)., June 2004.

[24] N. Wotawa, J.-P. Pons, L. Lopez, R. Deriche, O. Faugeras. *fMRI data smoothing constrained to the cortical surface: a comparison of the level-set and mesh-based approaches*, in "NeuroImage (HBM'04)", 2004.

Internal Reports

[25] J. Bullier, R. Deriche, O. Faugeras, D. Fieze, P. Girard, R. Guyonneau, P. Kornprobst, T. Papadopoulo, S. Thorpe, T. Vieville. *RIVAGe Feedback during Visual Integration : towards a Generic Architecture*, Technical report, INRIA, 2004, http://www.inria.fr/rrrt/rr-5451.html.

[26] I. Dimov, P. Kornprobst, T. Vieville. *Could early visual processes be sufficient to label motions?*, Technical report, n° 5240, INRIA, June 2004, http://www.inria.fr/rrrt/rr-5240.html.

[27] J. Kybic, M. Clerc, O. Faugeras, R. Keriven, T. Papadopoulo. *Fast Multipole Method for the Symmetric Boundary Element Method in MEG/EEG*, Technical report, n° 5415, INRIA, December 2004, http://www.inria.fr/rrrt/rr-5415.html.

[28] C. Lenglet, M. Rousson, R. Deriche, O. Faugeras. *Statistics on Multivariate Normal Distributions: A Geometric Approach and its Application to Diffusion Tensor MRI*, Technical report, n° 5242, INRIA, June 2004, http://www.inria.fr/rrrt/rr-5242.html.

[29] C. LENGLET, M. ROUSSON, R. DERICHE, O. FAUGERAS. *Toward Segmentation of 3D Probability Density Fields by Surface Evolution: Application to Diffusion MRI*, Technical report, n° 5243, INRIA, June 2004, http://www.inria.fr/rrrt/rr-5243.html.