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Biological and Computer Vision

Sophia Antipolis

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Activity Report

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2. Overall Objectives

The Odyssée team is joint to INRIA, the Ecole Normale Supérieure in Paris and the CERMICS 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.

6. New Results

6.1. Variational methods and partial differential equations for vision

6.1.1. Variational Flows over Manifolds

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

In many medical computer vision tasks, the relevant data is attached to a specific tissue such as the cortex or the colon. This situation calls for regularization techniques which are defined over non flat surfaces. We have introduced the Beltrami flow over manifolds. This new regularization technique overcomes the over-smoothing of the L^2 flow and the staircasing effects of the L^1 flow, that were recently suggested via the harmonic map methods. The key of our approach is first to clarify the link between the intrinsic Polyakov action and the implicit Harmonic energy functional and then use the geometrical understanding of the Beltrami Flow to generalize it to images on explicitly and implicitly defined non flat surfaces. We have shown that once again the Beltrami flow interpolates between the L^2 and L^1 flows on non-flat surfaces. The implementation scheme of this flow is presented and various experimental results obtained on a set of various real images illustrate the performances of the approach as well as the differences with the harmonic map flows. This extension of the Beltrami flow to the case of non flat surfaces opens new perspectives in the regularization of noisy data defined on manifolds [31][30][51]

6.1.2. Active Unsupervised Texture Segmentation on a Diffusion Based Feature Space

Participants: Rachid Deriche, Mikael Rousson, Thomas Brox.

In this work, we propose a novel and efficient approach for active unsurpervised texture segmentation. First, we show how we can extract a small set of good features for texture segmentation based on the structure tensor and nonlinear diffusion. Then, we propose a variational framework that incorporates these features in a level set based unsupervised segmentation that adaptively takes into account their estimated statistical information inside and outside the region to segment. The approach has been tested on various textured images, and its performance compares favorably with recent studies [28][29][48]

6.1.3. Unsupervised Segmentation Incorporating Colour, Texture, and Motion

Participants: Rachid Deriche, Mikael Rousson, Thomas Brox, Joachim Weickert.

In this work we integrate colour, texture, and motion into a segmentation process. The segmentation consists of two steps, which both combine the given information: a pre-segmentation step based on nonlinear diffusion for improving the quality of the features, and a variational framework for vector-valued data using a level set approach and a statistical model to describe the interior and the complement of a region. For the nonlinear diffusion we apply a novel diffusivity closely related to the total variation diffusivity, but being strictly edge enhancing. A multi-scale implementation is used in order to obtain more robust results. In several experiments we demonstrate the usefulness of integrating many kinds of information. Good results are obtained for both object segmentation and tracking of multiple objects [16][43]

6.1.4. Active Shape Models from a Level Set Perspective

Participants: Rachid Deriche, Mikael Rousson, Nikos Paragios.

In this work, we re-visit active shape models, a popular technique to object extraction, 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 while being able to deal with important local deformations and changes of topology. Promising experimental results demonstrate the potential of our approach [47]

6.1.5. Vector-Valued Image Regularization with PDE's : A Common Framework for Different Applications

Participants: Rachid Deriche, David Tschumperlé.

In this work, we address the problem of vector-valued image regularization with variational methods and PDE's. From the study of existing global and local formalisms, we propose a new framework that unifies a large number of previous methods within a generic local formulation. On one hand, resulting equations are more adapted to analyze the local geometric behaviors of the diffusion processes. On the other hand, it can be used to design a new regularization PDE that takes important local smoothing properties into account. Specific numerical schemes are also naturally emerging from this formulation. Finally, we illustrate the capability of our approach to deal with classical image processing applications, such as color image restoration, inpainting, magnification and flow visualization. This work has been awarded by the best student paper at CVPR'2003 [39][36].

6.1.6. 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 [25].

6.1.7. 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. Preliminary results have been published in [49][24].

6.1.8. 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 [53], 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 [54], 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. Preliminary results have been published in [44][17].

6.1.9. 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. In [20], the performance of this method is demonstrated on both synthetic and real images.

6.2. Observing and modeling the brain

6.2.1. Variational Frameworks for DT-MRI Estimation, Regularization and Visualization

Participants: Rachid Deriche, David Tschumperlé.

We address three crucial issues encountered in DT-MRI (Diffusion Tensor Magnetic Resonance Imaging) : diffusion tensor Estimation, Regularization and fiber bundle Visualization. We first review related algorithms existing in the literature and propose then alternative variational formalisms 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 [35][38][37]

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

Participants: Rachid Deriche, Olivier Faugeras, Christophe Lenglet.

In this work, 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 o f probing and quantifying the anisotropic diffusion of water molecules in biolog ical 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 m olecules.

Numerical experimentations conducted on synthetic and real diffusion MRI datasets illustrate the potentialities of this global approach.

6.2.3. A superresolution framework for fMRI sequences and its impact on resulting activation maps

Participants: Rachid Deriche, Olivier Faugeras, Pierre Kornprobst, R. Peeters, Mila Nikolova, Michael Ng, P. Van Hecke.

This work investigates the benefits of using a superresolution approach for fMRI sequences in order to obtain high-quality activation maps based on low-resolution acquisitions. We propose a protocol to acquire low-resolution images, shifted in the slice direction, so that they can be used to generate superresolution images. Adopting a variational framework, the superresolution images are defiend as the minimizers of objective functions. We focus on edge preserving regularized objective functions because of their ability to preserve details and edges. We show that applying regularization only in the slice direction leads more pertinent solutions than 3-dimensional regularization. Moreover, it leads to a considerably easier optimization problem. The latter point is crucial since we have to process long fMRI sequences. The solutions—the sought high resoltion images—are calculated based on a half-quadratic reformulation of the objective function which allows fast minimization schemes to be implemented. Our acquisition protocol and processing technique are tested both on simulated and real functional MRI datasets [18][23][21]

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

Participants: Frédéric Demoors, Théodore Papadopoulo.

Continuing on the volumic approach for the M/EEG problem, an important milestone has been achieved this year with the validation of the adjoint state approach for the EEG problem. This allows for a very fast computation of the gradient of the potential function with respect to the source distribution. This gradient being validated a first simple version of the inverse problem (using a fixed step gradient descent and without regularization) has been implemented and tested and already shows interesting results. A more sophisticated approach using a conjugate gradient, an optimal step and some regularisation constraints is being explored.

6.2.5. Symmetric BEM Formulation for the M/EEG Forward Problem

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

The forward electro-encephalography (EEG) problem involves finding a potential V from the Poisson equation $\nabla \cdot (\sigma \nabla V) = f$, in which f represents electrical sources in the brain, and σ the conductivity of the head tissues. In the piecewise constant conductivity head model, this can be accomplished by the Boundary Element Method (BEM) using a suitable integral formulation. Most previous work is based on the same integral formulation, based on a double-layer potential. In this work, we detail several alternative possibilities and present a dual approach which involves a single-layer potential. Finally, a symmetric formulation is proposed which combines single and double-layer potentials, and which is new to the field of EEG, although it has been applied to other problems in electromagnetism. The three methods have been evaluated numerically using a semi-realistic geometry with known analytical solution, and the symmetric method achieves a significantly higher accuracy [45][14]. A fast multipole method (FMM) for the new, symmetric BEM formulation has also been devised [22].

6.2.6. Anatomy Based regularization for the Inverse M/EEG Problem

Participants: Geoffray Adde, Renaud Keriven, Jan Kybic, Maureen Clerc.

Following the recent breakthrough in the forward MEG/EEG problem described in 6.2.5, we propose and compare two methods for localizing cortex activity from EEG/MEG measurements.

In our BEM formulation, electrical activity of the brain is assumed to be mainly concentrated on the surface of the cortex, this can be biologicaly justified for a large domain of studies of the brain. Thus, sources are modelized by dipole distribution (or dipole density) all over the surface of the cortex. The arising forward problem is then linear. The inverse problem is solved as a constrained reconstruction problem adressed by a PDE. This PDE contains two terms: a data-driven one (least square) and a regularization one. The last implies surface laplacian and can be treated in two ways: firstly in deriving numerical schemes over a triangulated surface, it allows to keep on working on the mesh, where the data-driven term is defined. Secondly, we can embed the mesh into a grid and use a well-studied level set method developed by Bertalmio, Sheng, Osher, and Sapiro; this brings simple, flexible and well-known numerical schemes. Regularization type is a critical point in data-driven recontruction. Whereas the minimal norm constraint may deliver over-scattered source of activity, isotropic filtering force electrical activity to have low spatial gradients. Finaly, anisotropic filtering seek minimal total variation solutions, this implies well-delimited active zones on the cortex (typically piecewise constant) [15].

6.2.7. 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 (see section 8.3.2). They use the corresponding software routinely [9].

6.3. Modeling cortical activity

6.3.1. A biologically motivated model for low and mid-level vision task

Participants: Rachid Deriche, Olivier Faugeras, Iasonas Kokkinos.

This work presents 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.

6.3.2. Biologically plausible models

Participant: Thierry Viéville.

Regarding biological visual classification, recent series of experiments have enlighten that data classification can be realized in the human visual cortex with latencies of about 100 ms, which, considering the visual pathways latencies, is only compatible with a very specific processing architecture,. Surprisingly enough, this experimental evidence is in coherence with algorithms derived from the statistical learning theory, following the work of Vapnik. The present contribution develops this idea and experiments its performances using a tiny sign language recognition experiment. [42][40]

Considering the biological or artificial control of a trajectory generation, we also propose a biologically plausible model based on harmonic potentials, using a related framework. [13]

Another aspect of this study aims at proposing an implementation of regularization mechanisms compatible with biological operators. More precisely, cortical maps code vectorial parametric quantities, computed by network of neurons. In computer vision, similar quantities are efficiently computed using implementations of partial differential equations which define regularization processes, allowing to obtain well-defined estimations of these quantities. [52]

8. Other Grants and Activities

8.1. Regional Grants

8.1.1. Rotoscoto project

Participants: Rachid Deriche, Olivier Faugeras, Théo Papadopoulo.

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.

8.2. National Grants

8.2.1. 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 Cermics 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

8.2.2. 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 progresses 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.

8.2.3. The Amiria project

Participants: Olivier Faugeras, Thierry Viéville.

Thanks to a financial support of the Robea program for an inter-disciplinary research action with the CERCO (CNRS neuro-science research lab) we have been able to analyze the statistical properties of a biological model (the so-called Thorpe model) of fast visual classification.

More precisely, a double link is being developed: on one hand, statistics provide tools to evaluate and analyze the Thorpe model performances and on the other hand, this model is an interesting front-end for algorithms derived from the statistical theory. The present contribution develops this idea and experiments its performances using a tiny sign language recognition experiment.

In a second part of the project, we are considering motion sequences.

Detailed presentation

8.2.4. 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 pre-project is 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.

We consider the comparative study of visual process integration within either a biological system, i.e. the parieto-ventral and parieto-dorsal pathways of the cortical visual system in the primate or an artificial system. Both systems deliver an estimation of [where], that is to say the motion and structure of the observed scene and of [what], i.e. the perceptual grouping and labeling of objects in the scene. Within this framework, the function and behavior of adaptive feedback mechanisms is a key point and on the leading edge of biological studies.

Within the scope of the 3rd topics of this ACI, this project consists in three steps:

(a) A systematic analysis of existing results in neuro-science,

(b) an interpretation of these results from the viewpoint of the variational approach widely used in computer vision

(c) a specification of a simulation tool of parts of the visual cortex, the actual development of this simulator being the goal of a second phase after this pre-project.

Detailed presentation

8.2.5. 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

8.3. UE Grants

8.3.1. 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.

8.3.2. Mapawamo Project

Participants: Rachid Deriche, Olivier Faugeras, Renaud Keriven, Pierre Kornprobst, Théodore Papadopoulo, Thierry Viéville, Christophe Chefd'Hotel, Gerardo Hermosillo, Lucero Lopez, Bertrand Thirion.

Duration: 2000-2003

Our partners in this project can be found on the projects' Web page. The research is conducted in four main areas:

1. Preprocessing of Magnetic resonance data (motion compensation, resolution increase), and registration of intra- and inter subject data.
2. The development of new techniques for generating maps of cortical activity.
3. The study of functional connectivity between active cortical areas.
4. The comparison between visual perception in man and non-human primates.

8.3.3. 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.

8.3.4. 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.

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.

8.4. International Bilateral Relations

R. Deriche has been 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. He has been a member of the Director Advisory Board since 2002.

9. Dissemination

9.1. 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 board for evaluating the projects submitted in the framework of *R&D Plan Régional Textile Habillement de la région Nord* . He is also an expert member in the framework of the national project *Réseau National de Recherche en Télécommunications.* . R. Deriche is a member of the editorial board of the Journal Traitement du Signal. He is the INRIA member at the *Project Leaders Committee of I3S* and is 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).

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.

T. Viéville helps the Direction for Scientific Information and Communication regarding public diffusion of Scientific Knowledge.

9.2. Academic teaching

9.2.1. D.E.A. SIC

Nice-Sophia Antipolis University - Image and Vision track:

Rachid Deriche teaches the *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.

9.2.2. MVA DEA: Mathematics/Vision/Learning

Ecole Normale Supérieure Cachan - Ecole Normale Supérieure Ulm - ENST - École Polytechnique - Paris-Nord University - Paris-Dauphine University - Paris 5 university - ECP - ENPC.

Olivier Faugeras teaches the Computer and biological Vision course.

Théodore Papadopoulo teaches the 3D Vision course.

9.2.3. 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).

9.2.4. 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.

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

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

9.2.6. DEA Informatique Fondamentale et Applications

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

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

Paris VI, VII, IX, XI, XIII Universities and Ecole Normale Supérieure: Renaud Keriven teaches the Computer Vision course.

9.3. Other teaching loads

9.3.1. 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.

9.3.2. Ecole Nationale des Ponts et Chaussées

Maureen Clerc is in charge of and teaches part of two courses in the curriculum: Mathematics and Vision, and 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".

9.3.3. École des Mines - ENSTA

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

9.3.4. ISIA and Master of the Ecole des Mines

Thierry Viéville teaches a course on Symbolic Computation.

9.3.5. ESSI

Thierry Viéville teaches Real-Time Motion Perception.

9.4. Participation to workshops, seminars and miscellaneous invitations

Rachid Deriche and Théo Papadopoulo were local co-chairs of the Ninth International Conference on Computer Vision ICCV'03 held from October 13th to 16th in Nice.

Rachid Deriche is program co-chair of the 2nd IEEE Workshop VLSM'2003 on Variational, Geometric and Level Set Methods in Computer Vision held October 12 and 13th in Nice, Area Chair for the European Conference on Computer Vision Computer Vision '2004, general co-chair of TAIMA'03: Traitement et Analysed'Images - Méthodes et Applications held in Hammamet - Tunisia, held early October 2003.

He is a member of several program committees such as CVPR'2003: IEEE Computer Society Conference on Computer Vision and Pattern Recognition,CAIP'2003: 10th International Conference On Computer Analysis of Images and Patterns, Scale-Space'03:4th International Conference on Scale-Space Theories in Computer Vision

He has been invited by Facultad de Ingeniería, Montevideo (Uruguay) in march 2003. He gave several lectures on PDE's and Level-Sets in Image Processing and Computer Vision at the Departamento de Control y Electrónica Industrial, Instituto de Ingeniería Eléctrica. He visited differents labs. and discussed with several members of the team lead by Prof. G. Randall. He initiated a close collaboration with this group and the venue of Pablo Cancela for 4 months was planned during that time.

He has been invited by *Ecole Nationale des Sciences de l'Informatique* in Tunis (Tunisia) late january 2003. He stayed at the ENSI school for a week and gave a series of lectures in geometrical approaches in computer vision and image processing.

He gave an invited talk on November 6th, 2003 during the *SAGEM* Workshop on 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 Conference on Scale-Space Theories in Computer VisionScale-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.

Renaud Keriven has been a member of the Program Committee of the International Conference on Computer Vision 2003. He gave a talk at the Institut Gaspard Monge seminar in May 2003.

Thierry Viéville was an invited Speaker at the "Journées thématique Support Vector Machines et méthodes à noyau", ENST, Paris [42] and at the "Séminaire Phiteco de Sciences Cognitives de l'UTC de Compiegne" [41].

9.5. Theses and Internships

9.5.1. Theses defenses

- Frédéric Abad, *Contributions à la synthèse de nouvelles vues à partir de photographies*, Nice-Sophia Antipolis University, June 2003.
- Jacques Bride, *Méthodes directes pour le recalage d'images : efficacité et robustesse*, Nice-Sophia Antipolis University, March 2003.
- Quentin Delamarre, *Suivi du mouvement d'objets articulés dans des séquences d'images vidéo*, Nice-Sophia Antipolis University, December 2003.
- Bertrand Thirion, *Analyse de donne'es d' IRM fonctionnelle: statistiques, information et dynamique*, Nice-Sophia Antipolis University, October 2003.

9.5.2. Ongoing Theses

- Geoffray Adde, *"Probleme inverse en MEG"*, ENPC; Place: Odyssée ENPC, Marne.
- Guillaume Charpiat, *"Statistiques de courbes et d'images"*, ENS; Place: Odyssée ENS, Paris.
- Thomas Deneux, *"Modélisation et IRMf"*, ENS; Place: Odyssée ENS, Paris.
- Olivier Juan, *"Rotoscopie et applications à la réalite virtuelle"*, ENPC; Place: Odyssée ENPC, Marne.
- Fabien Lejeune, *"Intégration d'informations 3D et Applications"*, ENPC;Place: Odyssée ENPC, Marne.
- Christophe Lenglet, *"Processing and Analysis of Diffusion Tensor Magnetic Resonance Images"*, Nice-Sophia Antipolis University; Place: Sophia-Antipolis.
- Lucero Lopez-Pérez, *"Image Processing and PDE's on Non Flat Manifolds"*, Nice-Sophia Antipolis University; Place: INRIA Sophia-Antipolis.
- Jean-Philippe Pons, *"Méthodes variationnelles et reconstruction spatio-temporelle"*, ENPC; Place : INRIA Sophia-Antipolis
- 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; Place: INRIA Sophia-Antipolis.
- Mikaël Rousson, *"Multi-valued Image segmentation and Integration "*, Nice-Sophia Antipolis University; Place: INRIA Sophia-Antipolis.
- Nicolas Wotawa, *"IRMf pour la rétinotopie et l'analyse de la perception du mouvement"*, Nice-Sophia Antipolis University; Place: INRIA Sophia-Antipolis.

9.5.3. Internships

- Frédéric Demoors, *"Inverse EEG Problem"*, DEA STIC, Nice Sophia-Antipolis University, Location : Odyssée INRIA Sophia-Antipolis, from April 1st, 2003 to September 30th 2003, funded from the ACI DirInv.
- Sophie Di Martino, *"Half Quadratic Regularization and Superesolution in MRI"*, DEA STIC, Nice Sophia-Antipolis University, Location : Odyssée INRIA Sophia-Antipolis, from April 1st, 2003 to September 30th 2003.
- Christophe Lenglet, *"Diffusion Magnetic Resonance Imaging : Brain Connectivity Mapping, Modelization and Estimation of the Conductivity Tensor"*, DEA MVA Cachan, Location : Odyssée INRIA Sophia-Antipolis, from April 1st, 2003 to September 30th 2003.

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