INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

Project-Team Ariana

Inverse Problems in Earth Observation and Cartography

Sophia Antipolis

THEME COG

Activity Report

2006

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Expert Engineer

Sotiris Raptis [Mr. Raptis arrived in October. He is funded by an IFN contract.]

2. Scientific Foundations

2.1. Probabilistic approaches

Following a Bayesian methodology as far as possible, probabilistic models are used within the Ariana project, as elsewhere, for two purposes: to describe the class of images to be expected from any given scene, and to describe prior knowledge about the scene in the absence of the current data. The models used fall into the following three classes.

2.1.1. Markov random fields

Markov random fields were introduced to image processing in the Eighties, and were quickly applied to the full range of inverse problems in computer vision. They owe their popularity to their flexible and intuitive nature, which makes them an ideal modelling tool, and to the existence of standard and easy-to-implement algorithms for their solution. In the Ariana project, attention is focused on their use in image modelling, in particular of textures; on the development of improved prior models for segmentation; and on the lightening of the heavy computational load traditionally associated with these techniques, in particular via the study of varieties of hierarchical random field.

2.1.2. Wavelets

The development of wavelets as an alternative to the pixel and Fourier bases has had a big impact on image processing due to their spatial and frequency localization, and the sparse nature of many types of image data when expressed in these bases. In particular, wavelet bases have opened up many possibilities for probabilistic modelling due to the existence of not one but two natural correlation structures, intra- and inter-scale, leading to adaptive wavelet packet models and tree models respectively. In Ariana, attention is focused on the use of tree models for denoising and deconvolution; adaptive wavelet packet models for texture description; and on the use of complex wavelets for their improved translation invariance and directional selectivity.

2.1.3. Stochastic geometry

One of the grand challenges of computer vision and image processing is the expression and use of prior geometric information. For satellite and aerial imagery, this problem has become increasingly important as the increasing resolution of the data results in the necessity to model geometric structures hitherto invisible. One of the most promising approaches to the inclusion of this type of information is stochastic geometry, which is a new and important line of research in the Ariana project. Instead of defining probabilities for different types of image, probabilities are defined for configurations of an indeterminate number of interacting, parameterized objects located in the image. Such probability distribution are called 'marked point processes'. For instance, two examples that have been developed in Ariana use interacting cuboids of varying length, width, height and orientation for modelling buildings; and interacting line segments of varying length and orientation for modelling road and other networks.

2.2. Variational approaches

2.2.1. Regularization and functional analysis

The use of variational models for the regularization of inverse problems in image processing is long-established. Attention in Ariana is focused on the theoretical study of these models and their associated algorithms, and in particular on the Γ-convergence of sequences of functionals and on projection algorithms. Recent research concerns the definition of and computation in a function space containing oscillatory patterns, a sort of dual space to BV space, which captures the geometry of the image. These variational methods are applied to a variety of problems, for example image decomposition.

2.2.2. Contours and regions

In addition to the regularization of inverse problems, variational methods are much used in the modelling of boundaries in images using contours. In Ariana, attention is focused on the use of such models for image segmentation, in particular texture segmentation; on the theoretical study of the models and their associated algorithms, in particular level set methods; and on the incorporation of prior geometric information concerning the regions sought using higher-order active contour energies.

2.2.3. Wavelets

Wavelets are important to variational approaches in two ways. They enter theoretically, through the study of Besov spaces, and they enter practically, in models of texture for segmentation, and in the denoising of the oscillatory parts of images.

2.3. Parameter estimation

One of the most important problems studied in the Ariana project is how to estimate the parameters that appear in the models. For probabilistic models, the problem is easily framed, but is not necessarily easy to solve, particularly in the case when it is necessary to extract simultaneously from the data both the information of interest and the parameters. For variational models, there are few methods available, and the problem is consequently more difficult.

3. Application Domains

3.1. Denoising and deconvolution

These are perhaps the most basic of the applications with which Ariana is concerned, and two of the most studied problems in image processing. Yet progress can still be made in these problems by improving the prior image models used, for example, by using hidden Markov trees of complex wavelets or by decomposing the image into several components. Ariana is also interested in blind deconvolution.

Figure 1. Left: denoising; middle: a degraded (blurred and noisy) image; right: its restoration.

3.2. Segmentation and classification

Many applications call for the image domain to be split into pieces, each piece corresponding to some entity in the scene, for example, forest or urban area, and in many cases for these pieces to be assigned the appropriate label. These problems too are long-studied, but there is much progress to be made, in particular in the use of prior geometric information.

Figure 2. Left: a satellite image; right: its classification.

3.3. Extraction of structures

As the resolution of remote sensing imagery increases, so the full complexity of the scene comes to the fore. What was once a texture is now revealed to be, for example, an arrangement of individual houses, a road network, or a number of separate trees. Many new applications are created by the availability of this data, but efficient harvesting of the information requires new techniques.

3.4. 3D modelling

Earth observation and cartography is not solely concerned with 2D images. One important problem is the construction of 3D digital elevation models (DEMs) from high-resolution stereo images produced by satellites or aerial surveys. Synthetic aperture radar (SAR) imagery also carries elevation information, and allows the production of more accurate DEMs thanks to interferometry techniques, for example.

3.5. Information mining and database retrieval

Every day, vast quantities of data are accumulated in remote sensing data repositories, and intelligent access to this data is becoming increasingly problematic. Recently, the problem of retrieval from large unstructured remote sensing image databases has begun to be studied within the project.

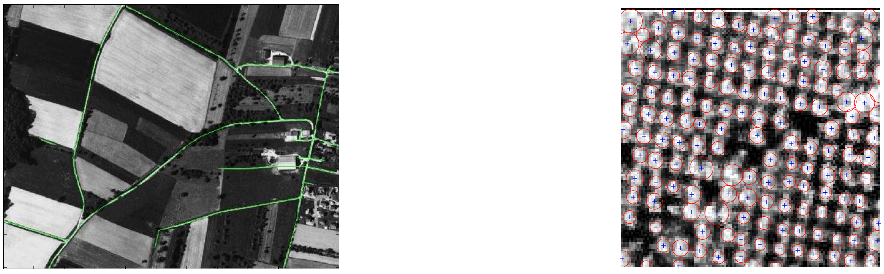

Figure 3. Left: road network extraction; right: tree extraction.

Figure 4. Left: DEM; right: interferometry.

Figure 5. Image registration for the evaluation of retrieval systems. Left: mosaicked aerial image data; right: registered ground truth classification.

4. Software

4.1. EVER2DAY

Keywords: *RJMCMC*, *dense forest*, *marked point process*, *tree crown extraction*.

Participants: Guillaume Perrin, Xavier Descombes, Josiane Zerubia [contact].

Software for tree crown extraction in dense forest (plantations or timber forest) using a Marked Point Process model based on ellipses. It finds the position and the diameter of the tree crowns. Deposited with the APP.

4.2. EVER3DIM

Keywords: *RJMCMC*, *marked point process*, *sparse vegetation*, *tree crown extraction*.

Participants: Guillaume Perrin, Xavier Descombes, Josiane Zerubia [contact].

Software for tree crown extraction in sparse vegetation using a Marked Point Process model based on ellipsoids. It finds the position, the diameter and the height of the tree crowns. Deposited with the APP.

4.3. GRENAT

Keywords: *RJMCMC*, *dense forest*, *marked point process*, *plantations*, *sparse vegetation*, *tree crown extraction*.

Participants: Guillaume Perrin, Xavier Descombes, Josiane Zerubia [contact].

Software for tree crown extraction using a Marked Point Process model based on ellipses or ellipsoids. It finds the position and the diameter of the tree crowns in plantations and dense forest, but also the height of the trees in sparse vegetation, plantations and coppice-with-standards structures. Deposited with the APP. Transferred to the French National Forest Inventory (IFN).

4.4. Quality-Candy

Keywords: *RJMCMC*, *marked point process*, *road network extraction*, *segments*.

Participants: Caroline Lacoste, Xavier Descombes, Josiane Zerubia [contact].

Software for road network extraction using a Marked Point Process model based on segments. Deposited with the APP in 2005. Transferred to the IPAL (joint CNRS/NUS) laboratory in Singapore and to Lycée Lesage, Vannes in 2006.

4.5. CAROLINE

Keywords: *RJMCMC*, *marked point process*, *polylines*, *road network extraction*.

Participants: Caroline Lacoste, Xavier Descombes, Josiane Zerubia [contact].

Software for road network extraction using a Marked Point Process model based on polylines. Deposited with the APP in 2005. Transferred to the IPAL (joint CNRS/NUS) laboratory in Singapore.

4.6. HIMME

Keywords: *Markov Random Fields*, *RJMCMC*, *hydrographic network extraction*, *marked point process*.

Participants: Caroline Lacoste, Xavier Descombes, Josiane Zerubia [contact].

Software for hydrographic network extraction using a Markov Random Field and a hierarchical Marked Point Process model. Deposited with the APP in 2005. Transferred to the IPAL (joint CNRS/NUS) laboratory in Singapore.

5. New Results

5.1. Probabilistic models

5.1.1. A new birth and death algorithm for object detection

Keywords: *Tree crown detection*, *diffusion*, *marked point process*.

Participant: Xavier Descombes.

This study was partially supported by the EGIDE ECONET and has been conducted in collaboration with Prof. E. Zhizhina and Prof. Minlos, IIPT Moscow (Russian Academy of Sciences).

In this work, we propose a new stochastic algorithm to extract objects from images. The algorithm is based on the evolution of macro-objects in the continuum. We consider two models of the evolution of a disc. Each disc in the model is associated with a given object, a tree crown or a bird in the applications we address. The evolution is a birth-and-death equilibrium dynamics on the configuration space of discs (or the configuration space of points) with a given Gibbs measure as its stationary measure. To construct the dynamics, we must choose birth and death rates meeting the so-called detailed balance conditions. In our scheme, we take the intensity of birth to be a constant, but the intensity of death depends on the energy function and the current configuration. To reach the solution, we embed this new dynamics in a simulated annealing scheme. We thus get a non-stationary stochastic process, all of whose weak limit measures are supported by configurations giving the global minimum of the energy function under a minimal number of discs in the configuration. The final step is the discretization of this non-stationary dynamics. The discretization is a Markov chain non-homogeneous in time and in space, with transition probabilities depending on the temperature, the energy function and the discretization step. We have proved that

1. the discretization process converges to the continuous time process at fixed temperature as the discretization step tends to zero;
2. if we apply the discretization process to any initial measure with a continuous density w.r.t. Lebesgue-Poisson measure, then in the limit when the discretization step tends to 0, time tends to infinity, and the temperature tends to 0, we get a measure concentrated on the global minima of the energy function with a minimal number of discs.

Tests on real data in the case of tree crown extraction have proved that this new approach outperforms classical RJMCMC in terms of computation time.

5.1.2. A structural approach to 3D city modelling

Keywords: *3D Reconstruction*, *DEM*, *RJMCMC*, *building*, *marked point process*.

Participants: Florent Lafarge, Xavier Descombes, Josiane Zerubia.

This Ph.D. is co-supervised by Marc-Pierrot Deseilligny, chief scientist of the technical direction of the IGN and is funded by a CNES/IGN grant.

3D building reconstruction is a difficult problem, mainly due to the complexity of the scenes. Urban environments are very dense and composed of many types of buildings, which makes their analysis difficult. In this work, we propose a structural approach to 3D building reconstruction. It consists in reconstructing buildings by assembling simple urban structures extracted from a grammar of 3D parametric models. The method is composed of two stages. The first one [33], [22] consists in extracting the building footprints through configurations of connected quadrilaterals. Marked point processes are used to extract the global shape of the footprints, which are then regularized by improving both the connection of the objects and facade continuity. The second stage corresponds to 3D reconstruction from the DEMs and the building footprints obtained in the first stage [21]. An energy formulation is used within a Bayesian framework, as this is particularly well adapted to including prior knowledge concerning urban structures. A Markov Chain Monte Carlo algorithm coupled with simulated annealing allows us to find the minimum of this energy. Figure 6 shows a result on a typical French town centre.

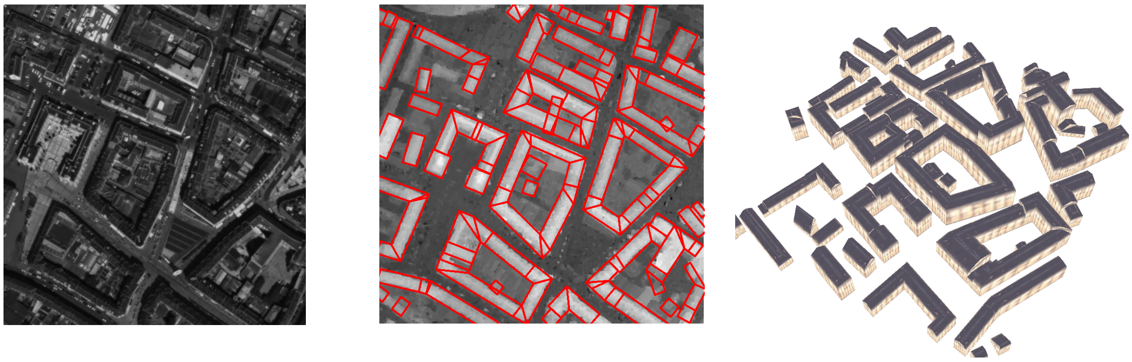

Figure 6. Left: PLEIADES simulation of Amiens town centre (©CNES) - Center: Result of footprint extraction - Right: Result of 3D reconstruction

5.1.3. Target detection through texture perturbation analysis

Keywords: *Markov random field*, *classification*, *segmentation*, *target detection*, *texture*.

Participants: Alexandre Fournier, Xavier Descombes, Josiane Zerubia.

This Ph.D. is done with the support of the French Defense Agency (DGA).

We address the problem of target detection through the changes between two remotely sensed images of the same area. We first use the ENVI©software to process a Rotation Scaling Translation (RST) registration of the two images, and we then use a spectral transform to compensate the missing translation component of the output. We then use a recursive principal component analysis [41] in order to get a per-pixel change probability between the two images. A Markov random field segmentation based on the Potts model is applied to the change probability image to obtain a homogeneous and coherent change map.

The next step is to distinguish changes due to normal or natural circumstances (shadow orientation change, stereoscopic effects, changes in cultivated fields) from real targets (vehicles, camouflage). We address this problem by segmenting the change map with the k-means algorithm based on the intensity pairs (see figure 7). The result is then regularized by a second Potts model.

In order to give a label to each changed category, we are currently developing a region-based algorithm. In addition, in order to automate the process, the k-means algorithm is being replaced by an entropy k-means segmentation.

5.1.4. Damage assessment after forest fires

Keywords: *Support Vector Machines*, *burnt area*, *classification*, *forest fire*.

Participants: Olivier Zammit, Xavier Descombes, Josiane Zerubia.

This work is partly funded by a contract with Silogic. We particularly thank Commandant Poppi (Fire Brigade member and director of the cartography service, SDIS 83, Draguignan) for interesting discussions.

The main objective of this study is to evaluate and quantify the damage caused by forest fires from a single after-fire image. Our approach consists in extracting the radiometric information from the channels of SPOT 5 data [28]. The algorithm developed for mapping the burnt area uses the different spectral domains provided by such data.

Figure 7. left: image date T_1, middle: image date T_2, right : segmented change map.

The automatic discrimination of burnt and unburnt areas is achieved via a classification method based on Support Vector Machines (SVM). This supervised classification technique is well adapted to deal with data of high dimension, such as images. It enables the delineation of the affected areas with a very high degree of accuracy.

A map of the burnt areas is produced and validated. This allows the burnt areas to be referenced and placed in their geographic context, and their surface area estimated. The classification method is applied to images of areas of southern France that were heavily burnt during the summer of 2003. The results of the study show the good performance of this method by comparing its results with other traditional classifiers and with ground truth provided by SERTIT-Strasbourg and ONF-AM.

Figure 8. Left: SPOT 5 image (©CNES); right: Extracted burnt areas (only 4% of error compared to ground truth).

5.1.5. Adaptive brushlet-based probabilistic model of texture

Keywords: *Texture*, *bimodal statistics*, *brushlet*, *probabilistic model*.

Participants: Dan Yu, Ian Jermyn.

This work is being done as part of EU project MUSCLE and is funded by an INRIA CORDI postdoctoral grant [http://www.muscle-noe.org/].

Texture modelling is one of the most important problems in image processing, because texture characterizes many entities of interest in an image. In the case of medium-resolution remote sensing images, such entities include forests, agricultural fields, and urban areas. Texture models must satisfy many desiderata: they should be probabilistic, to produce principled inference algorithms; they should be translation and rotation invariant, but direction-sensitive; and they should capture the important structures in a texture in order best to distinguish one texture from another. In [37], probabilistic models of texture based on adaptive wavelet packet bases were introduced. That work revealed the surprising bimodal statistics of adapted wavelet packet subbands. In order to model the varied subband statistics, a two-parameter quartic model [14] was developed. The latter model captured the one-point statistics of the adapted subbands well, but lacked direction sensitivity, and did not have good translation and rotation invariance. The current work takes the first steps in alleviating the first two drawbacks, by extending the model in [14] to use brushlets [39] as the adaptive basis rather than standard wavelets. Brushlets, being complex, contain phase information. They can thus distinguish more directions than standard wavelets, and behave better under translations. Translation invariance requires that the probability distribution be a function only of the amplitude of the coefficients. The generalization of the subband model of [14] is $P(b|f,g) \propto \exp\{-(f|b|^2+g|b|^4)\}$, where changes in f and g enable the various types of subband statistics to be modelled. The optimal basis and optimal per-subband parameters are found by combining a depth-first tree search with maximum likelihood. An example of an optimal decomposition is shown in the top row of figure 9, where black, grey, and white correspond to Gaussian ($g = 0$), platykurtic ($f > 0$, $g > 0$) and bimodal ($f < 0, g > 0$) subbands respectively. Corresponding scatter plots of the complex brushlet coefficients from these three types of subband are shown in the bottom row of figure 9. The structure of the bimodal subband shows how the model captures the texture structure. There are very few near-zero coefficients; the most probable coefficient values are grouped around a finite amplitude with uniformly distributed phase arising from translation invariance. Texture classification experiments using the model are underway. The extension to rotation-invariant models, and the modelling of the strong and structured inter-subband dependencies revealed by these models remains for future work.

5.2. ARC Mode-de-Vie

5.2.1. Tree crown extraction using marked point processes

Keywords: *RJMCMC*, *automatic feature extraction*, *forest*, *marked point process*, *simulated annealing*, *tree crown*.

Participants: Guillaume Perrin, Xavier Descombes, Josiane Zerubia.

This PhD was funded by a MAS Laboratory grant, with a complement provided by INRIA. It was performed as part of the ARC Mode De Vie [http://www-sop.inria.fr/ariana/Projets/ModedeVie/].

This work addresses the problem of tree crown extraction from Colour InfraRed (CIR) aerial images of forests. Our models are based on object processes, *i.e.* marked point processes [24], [25], [34]. These mathematical objects are random variables whose realizations are configurations of geometrical shapes. This approach yields an energy minimization problem, where the energy is composed of a regularization term (prior density), which introduces some constraints on the objects and their interactions, and a data term, which links the objects to the features to be extracted. Once the reference object has been chosen, we sample the process and extract the best configuration of objects with respect to the energy, using a Reversible Jump Markov Chain Monte Carlo (RJMCMC) algorithm embedded in a simulated annealing scheme.

New results have been obtained this year by proposing new models to deal with different densities of stand. In dense areas, we use an ellipse process, while in sparse vegetation an ellipsoid process is used. As a result, we obtain the number of stems, their position, the diameters of the crowns (see figure 10) and the heights of the trees for sparse areas and coppice-with-standards structures (see figure 11). The resulting algorithms have been tested on high resolution CIR aerial images provided by the French National Forest Inventory (IFN) [16], [26].

5.2.2. Shape recognition for classification of tree species

Keywords: *angle function*, *geodesic path*, *planar shape*, *shape space*, *tree crown*.

Participants: Maria S. Kulikova, Xavier Descombes, Josiane Zerubia.

This internship was funded by ARC Mode de Vie [http://www-sop.inria.fr/ariana/Projets/ModedeVie/] and it was done partly in collaboration with the Professor A. Srivastava from Florida State University, USA.

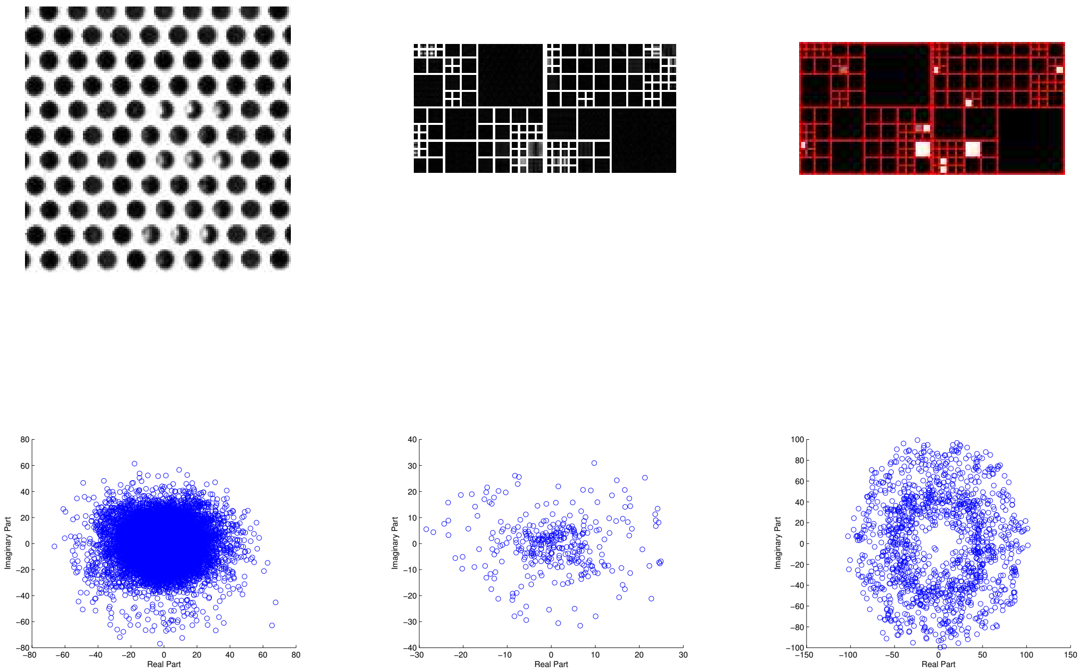

Figure 9. Row 1 - left: texture patch from image hexholes-1.5.2; middle: its optimal brushlet decomposition (magnitude of coefficients); right: the optimal partition tree - different colours correspond to the different models automatically selected within each subband: black, grey and white indicate the Gaussian, platykurtic, and bimodal subbands respectively; Row 2 - Scatter plots of the real and imaginary parts of the brushlet coefficients from a black, a grey, and a white coloured subband respectively.

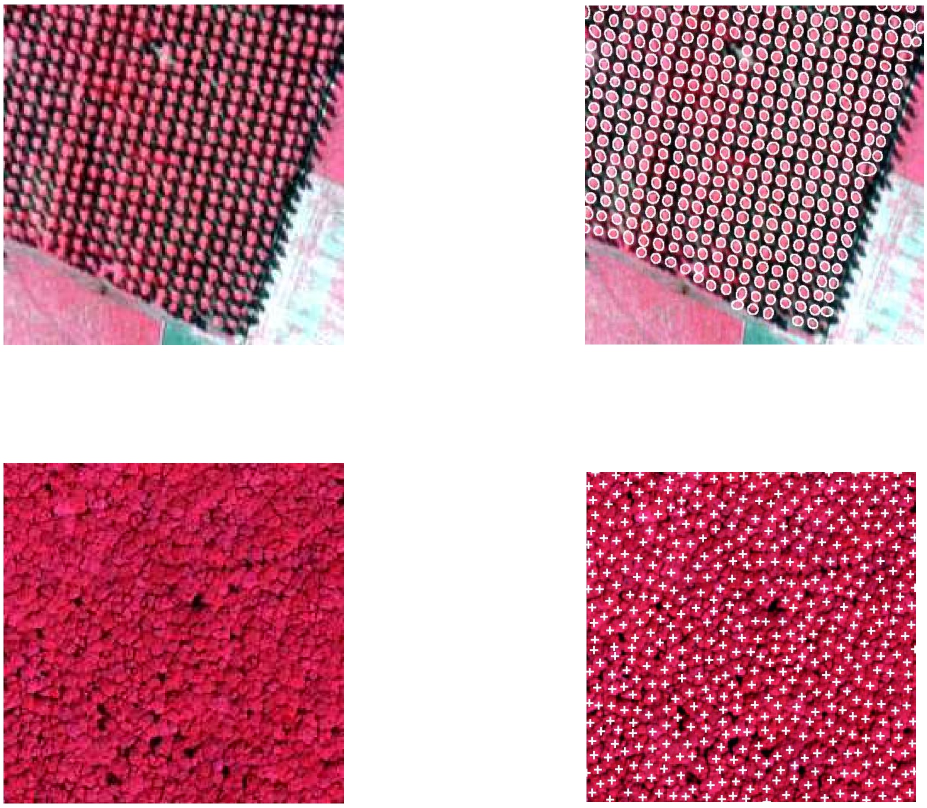

Figure 10. Top left : poplar plantation (©IFN). Top right : tree crown extraction. Bottom left : timber forest (©IFN). Bottom right : position of the extracted tree crowns.

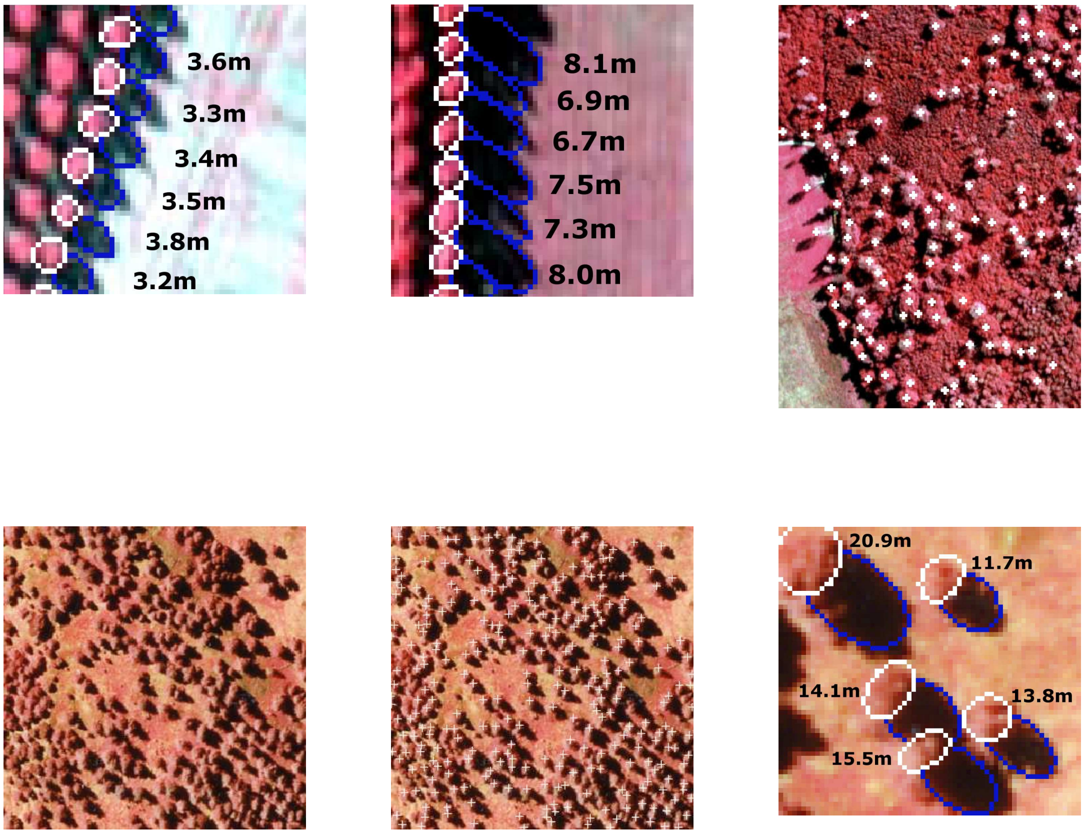

Figure 11. Top left and middle : tree crown extraction on the border of a poplar plantation. Top right : timber extraction on a coppice-with-standards stand. Bottom left : sparse vegetation (©IFN). Bottom middle and right : extraction of the tree crowns in sparse vegetation.

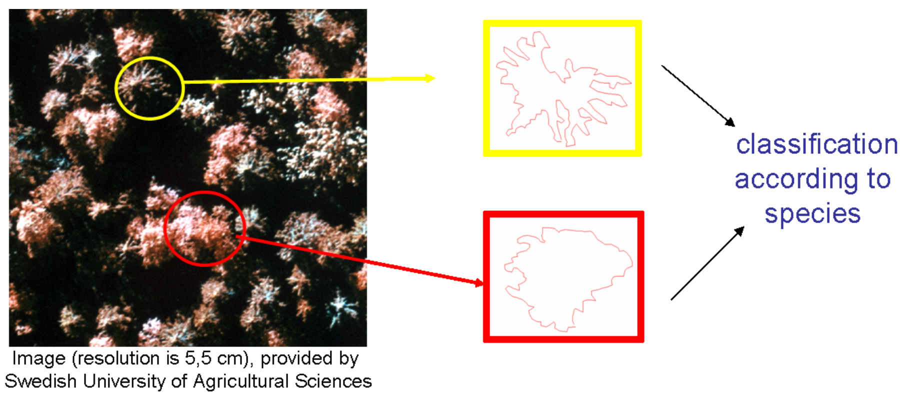

Figure 12. Tree species classification by shape

The objective of this work is the classification of trees according to their species based on the contour of the tree crowns extracted from very high resolution aerial images (see figure 12).

The theoretical part of the work is based on the theory of planar shape analysis using the notion of geodesic path on shape space developed by Klassen *et al.* (see figure 13).

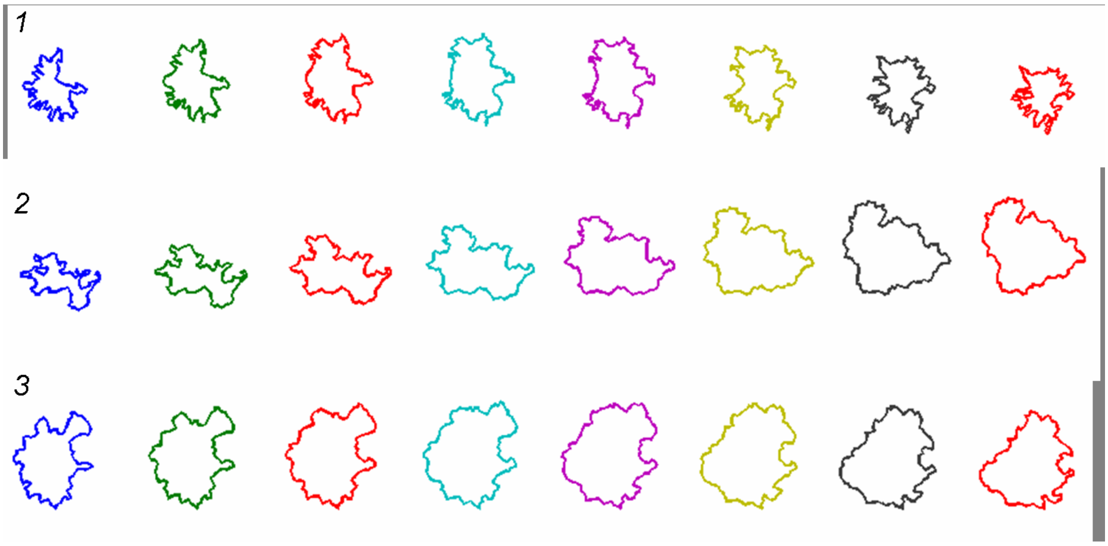

Figure 13. Examples of geodesics

The application of this theory, particularly the use of the geodesic as a metric for classification, did not give the desired results, so a new approach was undertaken: a set of features was developed and used in learning algorithms. Figure 14 shows the results obtained.

5.2.3. Calibration of high resolution aerial images of trees using plant growth models

Keywords: *image calibration*, *parameter extraction*.

Participants: Meena Mani, Xavier Descombes.

This internship was funded by the ARC Mode de Vie project [http://www-sop.inria.fr/ariana/Projets/ModedeVie/] and conducted in collaboration with P.-H. Cournède (MAS Laboratory, ECP and Digiplante project, INRIA).

In this work, we seek to establish a link between parameters extracted from aerial images of forest stands and predictions from a generic plant growth model. The plant model used here was developed by Greenlab, through a collaboration between Paul-Henry Cournède, Phillipe de Reffye, and LIAMA. Two parameters that can be extracted from an image, tree crown size and the spatial density of trees, were used for this calibration. The spatial density served as an input to the plant growth simulation. The model then computed the tree crown surface area for a given stage (chronological age) in the growth process. The calibration was done by verifying that the surface area predicted by the model matched the average size of tree crowns in the images used. In this case, the match was nearly exact: for a 40-year old plantation, the model predicted a surface area of 12.5m^2 while the tree crown distribution in the image yielded an average of $12.4 \pm 4.38\text{m}^2$ (see figure 15).

5.2.4. Texture analysis of tree crowns

Keywords: *co-occurrence matrix*, *forest*, *parameter extraction*.

Participants: Meena Mani, Xavier Descombes.

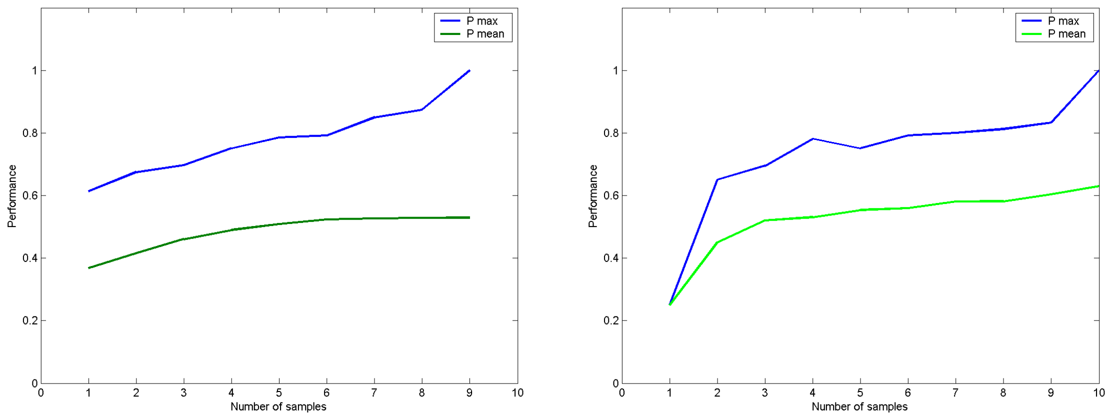

Figure 14. Classification performance. Left: Nearest Neighbour algorithm, right: SVM.

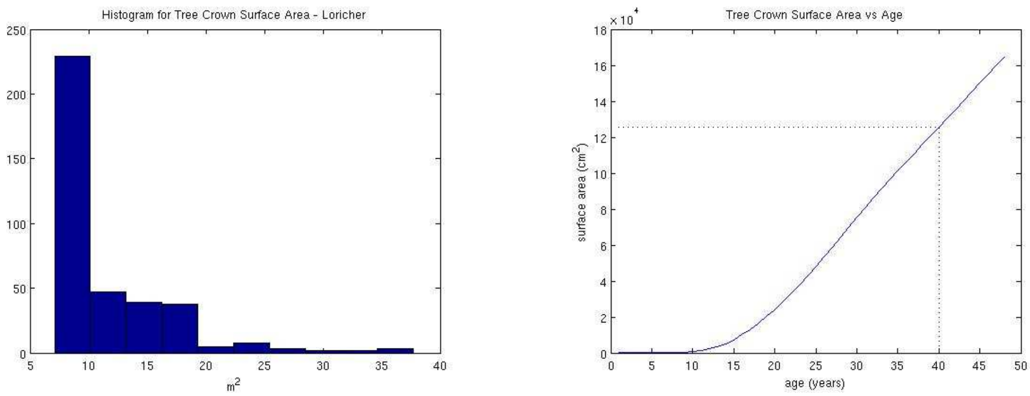

Figure 15. Left: image tree crown distribution, mean = $12.4\mathrm{m}^2$, std. dev = $4.38\mathrm{m}^2$; right: model prediction, surface area = $12.5\mathrm{m}^2$, age = 40 years.

This internship was funded by the ARC Mode de Vie project [http://www-sop.inria.fr/ariana/Projets/ModedeVie/].

In this work, we analyze colour infrared (CIR) images for features that could be incorporated into a classifier. These images, obtained from a Swedish site, had been used by M. Eriksson in his thesis [38]. As Eriksson pointed out, the four classes of trees present—aspen, birch, spruce and pine—could easily be identified as deciduous and coniferous from preliminary summary statistics (mean, standard deviation). This is because deciduous trees reflect a substantially greater percentage of infrared light (figure 16).

To further distinguish within the deciduous and coniferous classes, we performed texture analysis using co-occurrence matrices. A co-occurrence matrix is a two-dimensional quantitative representation of spatial relationship. We generated nine such matrices for each tree, each matrix representing a different direction. We were able to separate the trees into four classes by plotting co-occurrence energies versus contrast. With these two texture features, the two CIR histogram statistics, and shape parameters, we were able to identify parameters to build a successful classifier (see figure 16).

5.2.5. Segmentation and classification of forest stands

Keywords: *classification*, *forest stand*, *image segmentation*.

Participants: Mats Eriksson, Xavier Descombes, Josiane Zerubia.

This post-doc is part of the ARC Mode de Vie project [http://www-sop.inria.fr/ariana/Projets/ModedeVie/] and has been partly funded by an MESR grant.

Before applying an individual tree crown delineation algorithm to an image covering a large region it is necessary to divide the image into forest and non-forest. Furthermore, an algorithm produces different results depending on the denseness of the forest. Thus, it is also important to divide forested areas into different parts according to the crown closure. In this work, the segmentation of the forest is performed by a region growing algorithm based on radiometrical information together with a merging step [16]. The classification of the regions is done using a k-means classifier. Segmentation and classification results on an aerial image can be seen in figure 17.

5.2.6. Tree detection from aerial images

Keywords: *forest stand*, *tree detection*.

Participants: Sotiris Raptis, Xavier Descombes, Josiane Zerubia.

Sotiris Raptis is funded by a contract with the IFN.

The goal of this work is to improve and transfer to the IFN to a software dedicated to tree crown extraction from aerial images. An interface adapted to the final user will be developed. A first step consists in computing a mask which eliminates areas of the image which do not contain any trees. The goal of this mask is twofold. First, it will improve the computational time required for tree detection. Areas such as lakes and urban areas will automatically be removed from the study area, which will reduce the volume of study. The second goal is to eliminate false alarms in the detection process. Preliminary results have been obtained using a k-means algorithm based on a local variance (see figure 18).

5.3. Variational models

5.3.1. Detection of filaments in 2D and 3D images

Keywords: *Ginzburg-Landau*, *filament*, *segmentation*, *variational method*.

Participants: Alexis Baudour, Laure Blanc-Féraud.

This Ph.D. is co-supervised by Gilles Aubert, professor of the J.-A. Dieudonné Mathematics Laboratory of the University of Nice Sophia Antipolis [http://math1.unice.fr/]. It is performed as part of the ANR Detecfine and the CNRS/Math STIC.

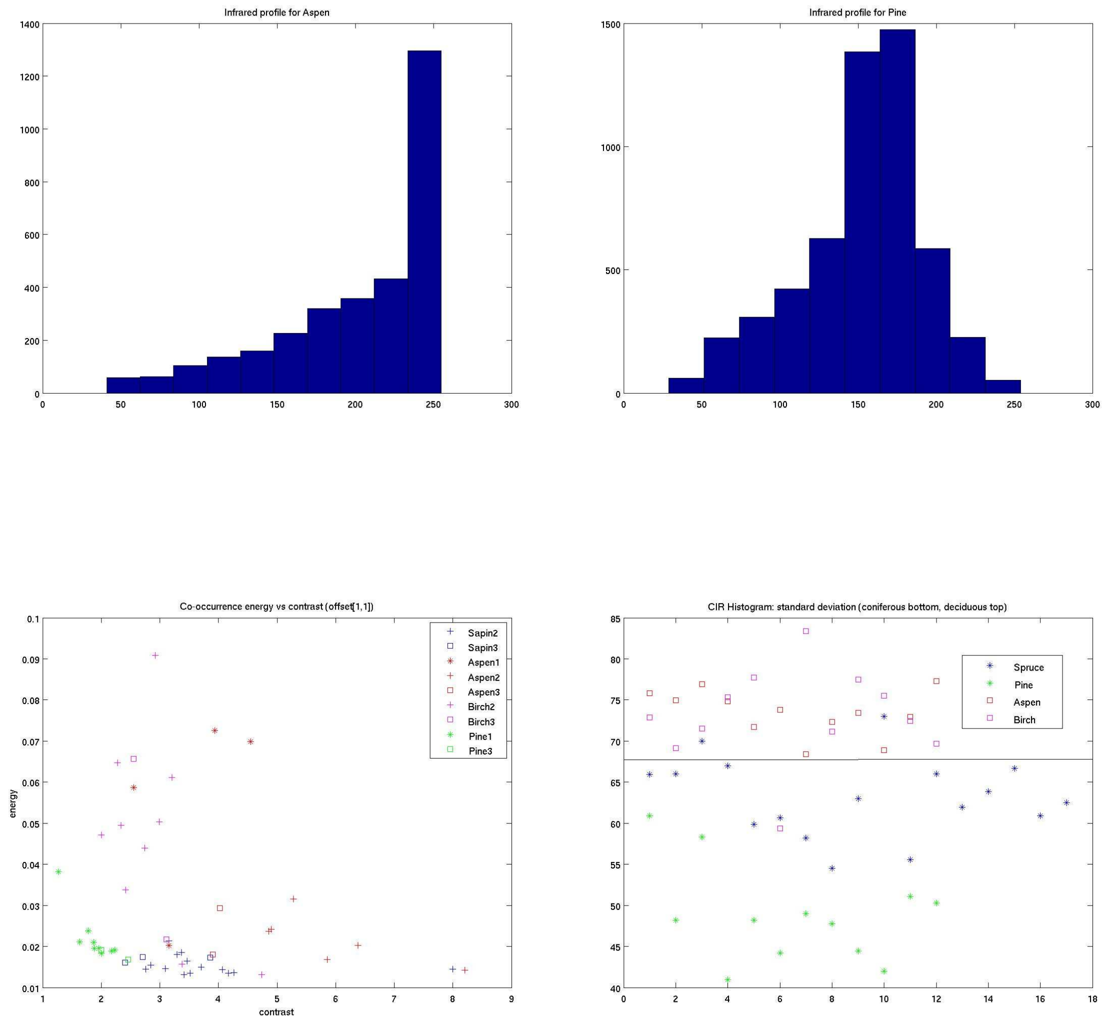

Figure 16. Top left: infrared profile for a deciduous tree (aspen), mean $= 203.8\mathrm{m}^2$*, std. dev* $= 53.8\mathrm{m}^2$*; top right: infrared profile for a coniferous tree (pine), surface area* $= 152.8\mathrm{m}^2$*, age* $= 39.3$ *years; bottom left: co-occurrence energy vs contrast; bottom right: standard deviation separates the coniferous and deciduous trees.*

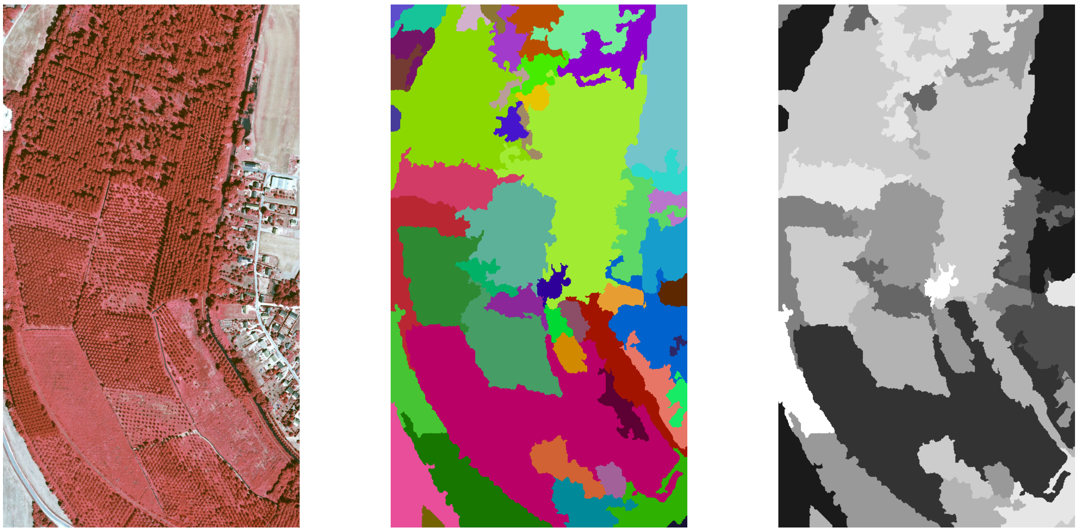

Figure 17. Left: Original image (©IFN); middle: segmentation result; right: classification result.

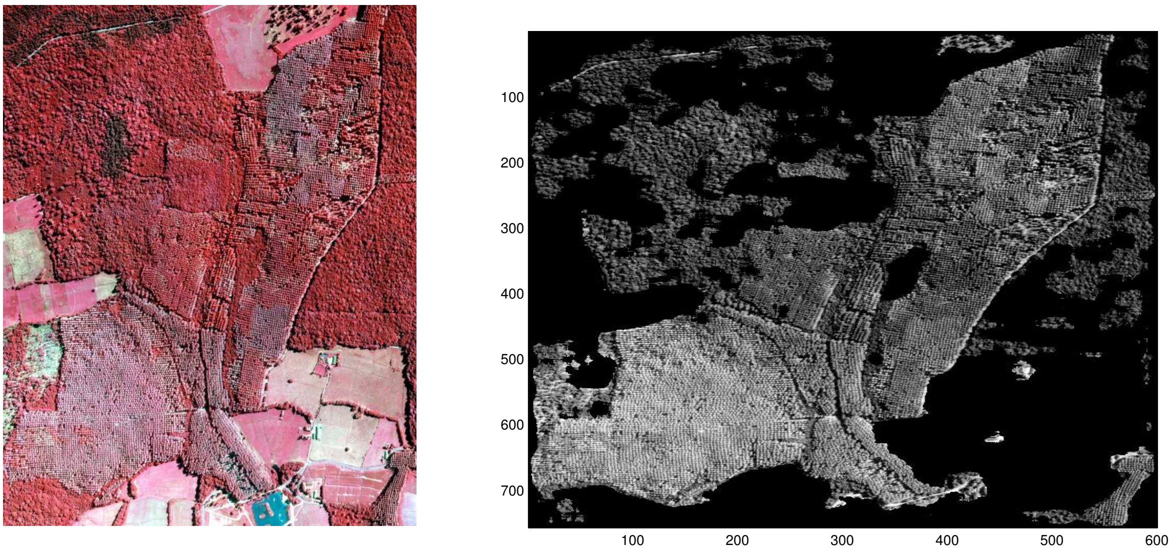

Figure 18. Left: Original image (©IFN); Right : mask of planted areas.

Our work currently deals with filament spotting in skeletons of cells. These filaments are detected by locally approximating the 2D or 3D image function by its second order Taylor polynomial. The direction of the filament is determined from the Hessian matrix of the Taylor polynomial. The results obtained are shown in figure 19. This first method is not sufficiently robust in the presence of noise. Thus we have to complete the missing parts of the filaments.

We use the Ginzburg-Landau model (from physics) to find the filaments, inspired by its use in the inpainting of singularities with codimension greater than one in an image. The filaments are the zero-level set of a complex-valued function defined on 3D space that minimizes an energy derived from the Ginzburg-Landau model. We use variational methods to find this minimum.

Figure 19. Detection of filaments.

We also use the Ginzburg-Landau energy to complete triple junctions (see figure 20).

Figure 20. Completion in a triple junction case.

5.3.2. *Some applications of the L^∞ norm in image processing*

Keywords: *bounded noise*, *compression noise*, *duality*, *$l\infty$ -norm*, *projected subgradient descent*, *quantization noise*, *total variation*.

Participants: Pierre Weiss, Laure Blanc-Féraud.

This Ph.D. is co-supervised by Gilles Aubert, professor of the J.-A. Dieudonné Mathematics Laboratory of the University of Nice Sophia Antipolis [http://math1.unice.fr/].

The goal of this work is to propose algorithms for minimizing generic regularizing functionals under an L^∞-constraint [27].

We show that many models using Total Variation can be stated in this formalism, among others, the Rudin-Osher-Fatemi model, the $BV - l1$ model, the BV-L^∞ model, and Y. Meyer's cartoon-plus-texture decomposition model.

Another class of applications which include L^∞ constraints arises in the processing of bounded noise, for example, quantization noise, or the noise that appears in all compression algorithms (notably JPEG and JPEG2000). For these types of noise, we show that Total Variation is not the only prior which preserves edges, and that simpler priors lead to better results.

All the models we study are difficult to handle both theoretically and numerically, because of the non-differentiability of the functionals and of the domains.

We describe a general convergent algorithm to solve such problems. This technique is the projected subgradient descent algorithm. We also give its worst case rate of convergence. We apply it successfully to all the problems mentioned above. The computation times we obtain are good compared to state of the art methods, and the models prove to be effective. An example of the processing of bounded noise is shown in figure 21.

Figure 21. Left: image quantized into ten levels; right: restored image using a model with L^∞ constraints.

5.3.3. Variational models for road network updating in dense urban areas from very high resolution optical images

Keywords: *GIS*, *active contour*, *dense urban area*, *higher-order*, *multi-scale analysis*, *road network extraction*, *shape prior*.

Participants: Ting Peng, Ian Jermyn, Josiane Zerubia.

This Ph.D. is co-supervised by Baogang Hu, from LIAMA/CASA, Chinese Academy of Sciences [http://liama.ia.ac.cn], and by Véronique Prinet from the same laboratory. The data (Quickbird images and GIS of Beijing urban areas) were respectively provided by DigitalGlobe [http://www.digitalglobe.com] and Beijing Institute of Survey and Mapping [http://www.bism.cn]. It is partially supported by Alcatel Alenia Space.

The aim of this work is the extraction of road networks from very high resolution (VHR) satellite images ($\sim$0.6m/pixel). Rochery *et al.* [40] developed a 'phase field higher-order active contour (HOAC)' model for road network extraction from images of $\sim$10m/pixel, but when applied to VHR data, this model was not sufficient to solve the problem. The main difficulties lie in the appearance of detail invisible in lower resolution images, (*e.g.* cars, road markings, shadows, and other linear but non-road features), which can easily disrupt the recognition process, and in the greater diversity of road widths and behaviours. We aim to overcome these difficulties using a more sophisticated image model, in particular, at multiple scales and including inter-pixel interactions, and a multiscale prior model, still within the phase field HOAC framework. Our preliminary work uses the same prior as [40], but introduces a multiscale image model. The energy is a sum of energies at three different scales. Within each scale we model the one-point statistics of the scaling coefficients using mixtures of two Gaussians, and the two-point statistics (variance histograms) using Gamma distributions. The models were learnt using GIS data to build masks for the main roads and the background.

The original Quickbird image, a GIS mask for the main roads and a preliminary result are shown in figure 22. The result is not perfect, but is very promising considering the complexity of the image. There are still some problems with spurious noise in the background, and there is geometric noise along the boundaries of the road, sometimes resulting in a gap. The former indicates a lack in the image model, while the latter seems more likely to be due to a weakness in the prior model, which therefore needs improving in order to enforce the road geometry more effectively. Our current work is focused on further study of the two-point statistics of the wavelet and scaling coefficients to improve the image model, and also on the development of a coherent multiscale prior (as opposed to data) energy to reduce computational time and to overcome geometric noise.

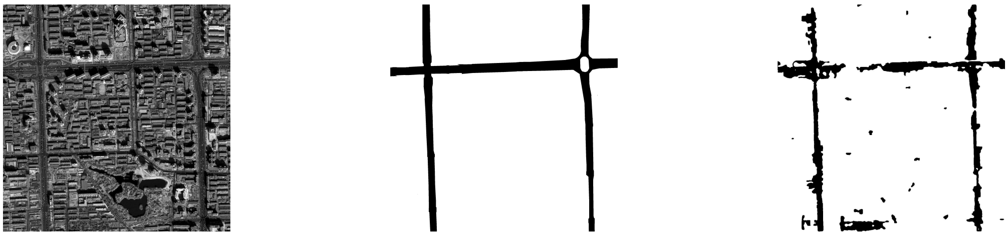

Figure 22. Left: Quickbird ©image; Middle: GIS mask of main roads; Right: Preliminary result of the model.

5.3.4. Higher-order active contours for tree detection

Keywords: *active contour*, *aerial image*, *gas of circles*, *higher-order*, *shape prior*, *tree crown extraction*.

Participants: Peter Horvath, Ian Jermyn, Josiane Zerubia.

This Ph.D. is co-supervised by Zoltan Kato, University of Szeged, Hungary [http://www.inf.u-szeged.hu/~kato]. It is performed as part of an Egide PAI Balaton. The data (aerial images of French forests) were provided by the French National Forest Inventory (IFN) [http://www.ifn.fr].

Many image processing problems involve identifying the region in the image domain occupied by a given entity in the scene. Automatic solution of these problems requires models that incorporate significant prior knowledge about the shape of the region. Many methods for including such knowledge run into difficulties when the topology of the region is unknown a priori, for example when the entity is composed of an unknown number of similar objects. Higher-order active contours (HOACs) represent one method for the modelling of non-trivial prior knowledge about shape without necessarily constraining region topology, via the inclusion of non-local interactions between region boundary points in the energy defining the model.

The case of an unknown number of circular objects arises in a number of domains, *e.g.* medical, biological, nanotechnological, and remote sensing imagery. Regions composed of an a priori unknown number of circles may be referred to as a 'gas of circles'. In the first part of this work, we developed a HOAC model of a 'gas of circles' [18]. In order to guarantee stable circles, we conducted a stability analysis via a functional Taylor expansion of the HOAC energy around a circular shape. Demanding that circles of a given radius be local minima of the energy fixes one of the model parameters in terms of the others and constrains the rest. In conjunction with a suitable likelihood energy, the model was applied to the extraction of tree crowns from aerial imagery. Experimentally, it was found that making a circle of the given radius a local minimum created problems in conjunction with the gradient descent algorithm. Image forces were not always sufficient to overcome these local minima, resulting in the formation of 'phantom circles'. We solved the problem of phantom circles by refining the stability analysis, making circles into energy inflection points rather than minima [19]. This constraint further reduces the number of free parameters, and severely constrains one of the two that remain, while improving the empirical success of the model. The results can be seen in figure 23.

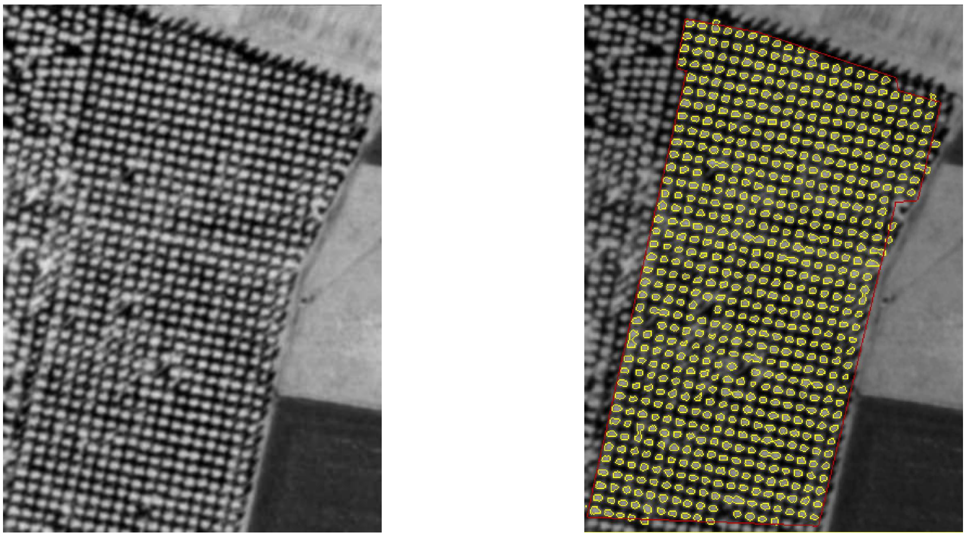

Figure 23. Left: an aerial image of a planted forest; right: the segmentation result

5.4. EU Project MUSCLE

5.4.1. Phase diagram for higher-order active contour models

Keywords: *active contour*, *higher-order*, *phase diagram*, *prior*, *shape*, *stability*.

Participants: Aymen El Ghoul, Saloua Bouatia, Peter Horvath, Ian Jermyn, Josiane Zerubia.

This work was performed as part of, and was partially funded by: ACI QuerySat [http://www.tsi.enst.fr/QuerySat/indexen.html]; the INRIA STIC-Tunisia programme (Sup'Com Tunis); EU project MUSCLE [http://www.muscle-noe.org/] and Egide PAI Balaton.

Higher-order active contours (HOACs) are a region modelling framework that allows the inclusion of sophisticated prior information about the geometry of the region modelled. For example, network shapes (used for road network extraction) and a 'gas of circles' (used for tree crown extraction) can both be modelled in the HOAC framework. Varying the parameters of a model can give rise to widely varying behaviours. For example, the two models cited above differ only in the values of their parameters, yet the information they contain is quite different. This is illustrated in figure 24, where gradient descent evolutions are shown, starting from a rounded square, for different parameter values. As can be seen, the square may evolve into a network shape or a gas of circles, or it may disappear. In order fully to understand these behaviours, we are constructing a 'phase diagram' for the above models, *i.e.* the map between the parameter space and the nature of the local minima. Such a diagram will not only allow the selection of appropriate parameter values for a given application. It will also enable the exploration of regions of the phase diagram where the behaviour is unknown, and hence lead to models incorporating new types of prior information, as well as giving insight into the capabilities of the HOAC framework in general.

To construct the diagram, we study the stability of shapes under the energy functional. The energy is expanded in a functional Taylor series around the shape being analysed, and the conditions defining a local minimum are imposed. This leads to multiple constraints on the parameters, and defines a region in the phase diagram where this shape is stable. Similarly, in parts of the phase diagram where the shape is unstable, its principal instabilities can be described. So far, this analysis has been performed for a circle, corresponding to the gas of circles model, and for a long bar, corresponding to the network model. We are now combining the results of these analyses to produce the phase diagram.

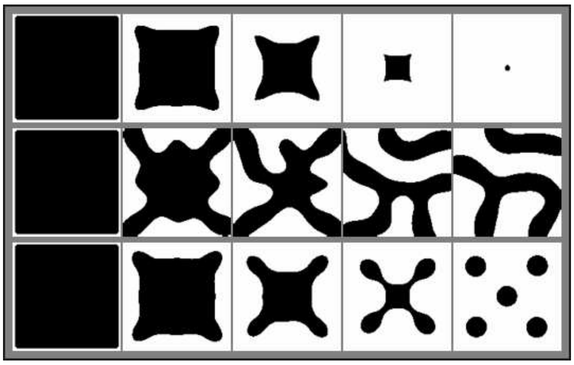

Figure 24. Gradient descent evolutions under a HOAC energy for different parameter values. Top row: leading to a disappearing region; middle row: leading to a network shape; bottom row: leading to a gas of circles.

5.5. ACI MULTIM

5.5.1. Mathematical methods for multi-channel image restoration

Keywords: *Multi-channel image processing*, *restoration*.

Participants: Pierre Weiss, Laure Blanc-Féraud, Xavier Descombes, Josiane Zerubia.

This work is being done as part of the ACI MULTIM [http://www-syscom.univ-mlv.fr/ACI]

The work of the ACI is devoted to the restoration of images with from one to several spectral bands. The teams of the ACI are currently working on image restoration by variational and stochastic approaches. A summer school and a workshop were organized in collaboration with LIAMA in Beijing in July 2006.

5.6. ACI Masses de Données QuerySat

5.6.1. Indexing of remote sensing images using road networks

Keywords: *database retrieval*, *graph matching*, *remote sensing*, *road network*, *skeleton*.

Participants: Avik Bhattacharya, Ian Jermyn, Xavier Descombes, Josiane Zerubia.

This Ph.D. is co-supervised by Henri Maître, deputy director of ENST, Paris, in collaboration with Michel Roux from TSI department, ENST, [http://www.tsi.enst.fr]. QuerySat is partly funded by the French Space Agency (CNES).

Retrieval from remote sensing image archives relies on the extraction of pertinent information from the data about the entity of interest (*e.g.* land cover type), and on the robustness of this extraction to nuisance variables (*e.g.* illumination). Most image-based characterizations are not invariant to such variables. However, other semantic entities in the image may be strongly correlated with the entity of interest and their properties can therefore be used to characterize this entity. Road networks are one example: their properties vary considerably, for example, from urban to rural areas. We study the dependence of a number of network features on the class of the image (‘urban’ or ‘rural’). The chosen features include measures of the network density, connectedness, and ‘curviness’. The feature distributions of the two classes are well separated in feature space, thus providing a basis for retrieval. Classification using kernel k-means confirms this conclusion. A careful study of the features shows that the classes are quite well separated in many of the plots, making it reasonable to use these features for classification (see figure 25).

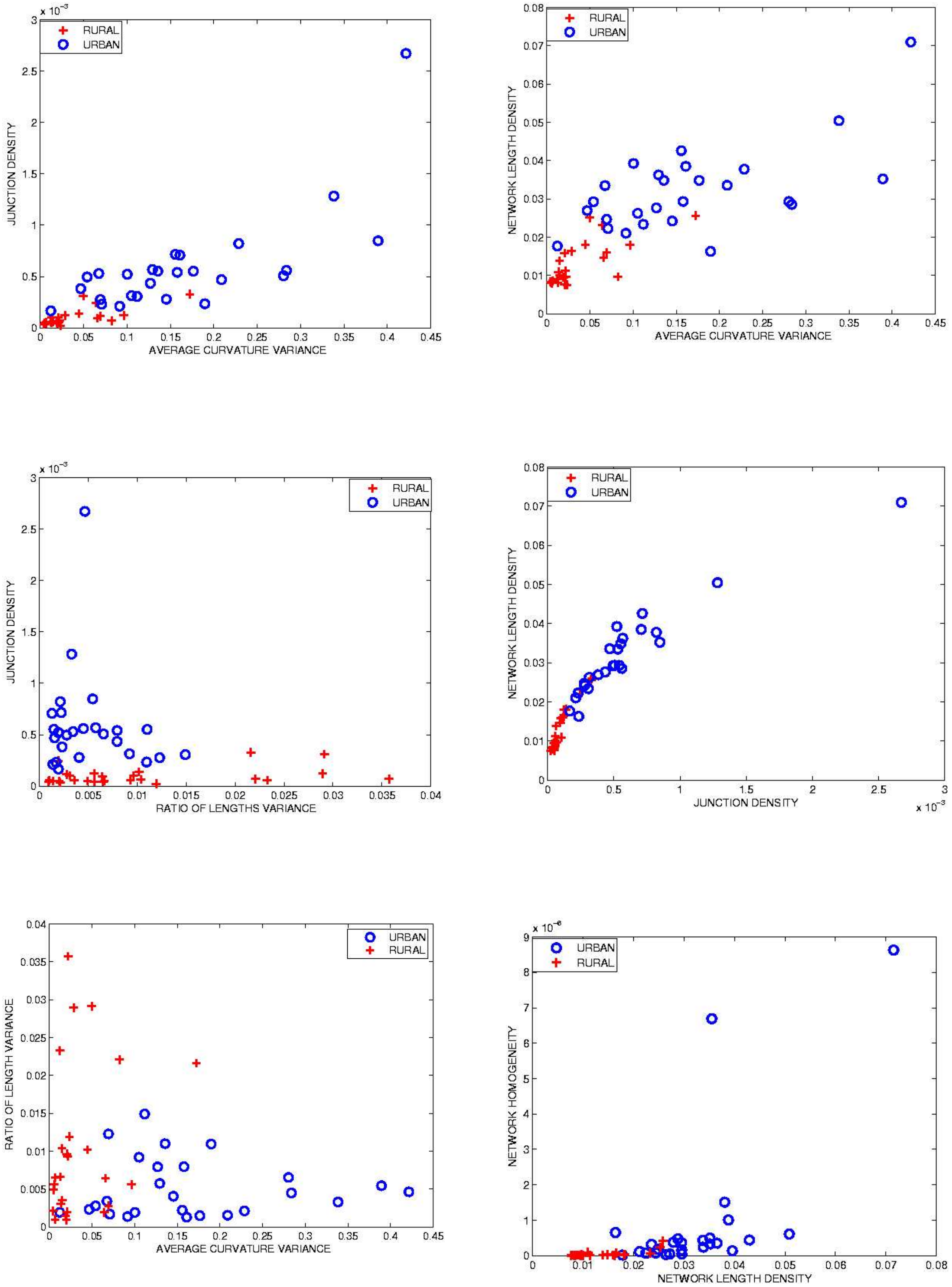

Figure 25. Scatter plots of selected pairs of features. Red stars correspond to rural areas, blue circles to urban areas. From left to right, top to bottom: junction density versus average curvature variance; length density versus average curvature variance; junction density versus variance of ratio of lengths; length density versus junction density; variance of ratio of lengths versus average curvature variance; variance of density of junction edges versus length density.

Table 1. Kernel k-means clustering result with σ=0.5.

	Urban	Rural
Class 1	1	19
Class 2	25	7

The clustering result, displayed in table 1, shows that the two classes can be well partitioned using the above five features. 19 and 25 images from ‘rural’ and ‘urban’ classes respectively were correctly classified, while 1 and 7 images from ‘urban’ and ‘rural’ classes respectively were incorrectly classified.

5.7. Applications to biology

5.7.1. Biological image restoration

Keywords: *Biological image*, *confocal microscopy*, *denoising*, *restoration*.

Participants: Caroline Chaux, Laure Blanc-Féraud, Josiane Zerubia.

This post-doc is partly funded by a CORDI grant and is being done as part of the P2R Franco-Israeli program.

This work is devoted to the restoration of biological images acquired by a confocal microscope. These images are degraded by Poisson noise and blurred due to the acquisition system. Earlier work was dedicated to deconvolution using the Richardson-Lucy algorithm with Total Variation regularization. We focus on restoration using the wavelet transform in order to preserve the texture and fine structures that are usually present in biological images. A 3D complex wavelet transform, proposed by N. Kingsbury, which increases directional selectivity and translation invariance wrt a standard wavelet transform, has already been developed for denoising. We propose to use this transform in the deconvolution process for regularization, together with Total Variation regularization.

5.7.2. Blind biological image deconvolution

Keywords: *Biological image*, *blind deconvolution*, *confocal miscroscopy*.

Participants: Praveen Pankajakshan, Laure Blanc-Féraud, Josiane Zerubia.

This internship was partly funded by an INRIA internship grant and is being done as part of the P2R Franco-Israeli program.

This work is devoted to the automatic estimation of parameters of the PSF (Point Spread Function) modelling the degradation produced during a confocal microscopy acquisition of biological images. It has been shown [29], [13] that the PSF can be modelled by a Gaussian function. The problem is then to estimate the variance of the Gaussian function from an observed degraded image. We propose to use maximum likelihood to estimate the parameter, taking into account that the noise is Poisson distributed on the observed image. Tests are currently being performed.

6. Contracts and Grants with Industry

6.1. Industrial

6.1.1. CNES Toulouse

Participants: Avik Bhattacharya, Ian Jermyn, Xavier Descombes, Josiane Zerubia [PI].

Extraction and characterization of line networks in satellite images for retrieval from image databases. Contract #293

6.1.2. Silogic Toulouse

Participants: Olivier Zammit, Xavier Descombes, Josiane Zerubia [PI].

Evaluation of the damage after a forest fire from high resolution satellite images. Contract #1156.

6.1.3. CS Toulouse

Participant: Josiane Zerubia [PI].

Evaluation of the scientific work of CS-SI in space imaging. Contract #1451.

6.1.4. IFN Nogent sur Vernisson

Participants: Guillaume Perrin, Sotiris Raptis, Xavier Descombes, Josiane Zerubia [PI].

Semi-automatic methods for forestry cartography using aerial and high resolution satellite images. Contract #1467.

6.1.5. Alcatel Alenia Space Cannes

Participants: Ting Peng, Ian Jermyn, Josiane Zerubia [PI].

Road network updating in dense urban areas from very high resolution optical images. Contract #1675.

6.1.6. IGN Saint Mandé

Participants: Florent Lafarge, Xavier Descombes, Josiane Zerubia [PI].

Automatic building extraction from digital elevation models. Grant from the IGN and the CNES.

6.1.7. DGA/CTA Arcueil

Participants: Alexandre Fournier, Xavier Descombes, Josiane Zerubia [PI].

Target detection through texture perturbation analysis. Grant from the DGA and CNRS.

7. Other Grants and Activities

7.1. Regional

7.1.1. INRIA COLORS project 'FIGARO'

Participants: Pierre Gernez, Xavier Descombes [PI], Josiane Zerubia.

In collaboration with the Nice Côte d'Azur Observatory (A. Bijaoui, E. Slezak), and INRA, Avignon (R. Stoica).

7.1.2. CNRS MATH/STIC grant 'Détection de structures fines en imagerie 3D'

Participants: Alexis Baudour, Laure Blanc-Féraud [PI].

In collaboration with the J.-A. Dieudonné Laboratory, CNRS/UNSA (G. Aubert).

7.2. National

7.2.1. ANR programme blanc : project 'DETECFINE'

Participants: Alexis Baudour, Laure Blanc-Féraud [PI].

In collaboration with the J.-A. Dieudonné laboratory of CNRS/UNSA (G. Aubert, L. Almeida), the Pasteur Institute in Paris (J-C Olivo-Marin, C. Zimmer), SAGEM DS at Argenteuil (D. Duclos), and ENS Cachan (J.F. Aujol).

7.2.2. ANR programme blanc : project 'Micro-Réseaux'

Participant: Xavier Descombes.

In collaboration with IMFT (F. Plouraboue (PI), L. Risser), CERCO (C. Fonta), and ESRF (P. Cloetens).

7.2.3. ARC Mode de Vie

Participants: Guillaume Perrin, Mats Erikson, Meena Mani, Maria Kulikova, Xavier Descombes [PI], Josiane Zerubia.

In collaboration with the Digiplante project-team (INRIA Rocquencourt, MAS, AMAP of CIRAD (O. Chassagneux, P.H. Cournède, P. de Reffye)), the MAS laboratory (C. Saguez), and LIAMA, Beijing, China (C. Cassissa, T. Fourcaud, M. Jaeger, V. Prinet). Web site: http://www-sop.inria.fr/ariana/Projets/ModedeVie/MODEdeVIE.html.

7.2.4. ACI Masse de Données 'QuerySat: Heterogeneous and multi-scale descriptors for retrieval from remote sensing image databases'

Participants: Avik Bhattacharya, Aymen El Ghoul, Ian Jermyn, Xavier Descombes [Ariana PI], Josiane Zerubia.

In collaboration with the Signal and Image Processing laboratory of ENST (M. Campedel, Y. Kyrgyzov, B. Luo, H. Maître, M. Roux), INRIA project-team IMEDIA (O. Besbes, S. Boughorbel, N. Boujemaa, M. Crucianu, M. Ferecatu, V. Gouet) and URISA of Sup'Com Tunis (Z. Belhadj, A. Ben Azza, R. Tebourbi).

7.2.5. ACI NIM 'MULTIM: Nouvelles methodes mathematiques pour la restauration d'images multi-canaux'

Participants: Pierre Weiss, Laure Blanc-Féraud [Ariana PI], Xavier Descombes, Josiane Zerubia.

In collaboration with the J-L Lions Laboratory (P. L. Combettes, A. Cohen); J.-A. Dieudonné Laboratory, CNRS/UNSA (G. Aubert); CMAP, École Polytechnique (A. Chambolle); Applied Maths Laboratory, Univ. Paris V (L. Moisan); INFO-IGM Laboratory, Univ. Marne La Vallée (J.-C. Pesquet); and the Observatoire Midi Pyrennées/Univ. Paul Sabatier Toulouse (S. Rocques).

7.3. European

7.3.1. Egide PAI Balaton 'Efficient shape priors for colour textured image segmentation'

Participants: Olivier Zammit, Peter Horvath, Ian Jermyn [Ariana PI], Josiane Zerubia.

In collaboration with the University of Szeged, Hungary (P. Horvath, Z. Kato).

7.3.2. EU project MUSCLE

Participants: Dan Yu, Peter Horvath, Ian Jermyn [Ariana PI], Josiane Zerubia.

The Ariana project-team is a participant in the European Union Sixth Framework Network of Excellence MUSCLE (Multimedia Understanding through Semantics, Computation and Learning), contract FP6-507752, in collaboration with 41 other participants around Europe, including four other INRIA project-teams. Web site: http://www.muscle-noe.org

7.4. International

7.4.1. ECONET project 'Méthodes de la physique statistique pour l'analyse d'image'

Participants: Maria Kulikova, Guillaume Perrin, Xavier Descombes [PI], Josiane Zerubia.

In collaboration with the Dobrushin Laboratory in ITTP of the Russian Academy of Science (R. Minlos, E. Pechersky, E. Zhizhina) and the Slavophil University of Yerevan (B. Nahapetian).

7.4.2. China PRA programme

Participant: Xavier Descombes [Ariana PI].

In collaboration with LIAMA (Véronique Prinet) and VISTA project (Patrick Bouthemy, Jian-Feng Yao).

7.4.3. INRIA STIC-Tunisia

Participants: Aymen El Ghoul, Avik Bhattacharya, Ian Jermyn [Ariana PI], Josiane Zerubia.

In collaboration with INRIA project-team Imedia (N. Boujemaa, V. Gouet, N, Grira), and URISA of Sup'Com Tunis (Z. Belhadj, A. Ben Azza, S. Bougharel, A. El Ghoul, R. Tebourbi).

7.4.4. P2R Franco-Israeli collaborative programme 'Blind deconvolution in 3D biological microscopy'

Participants: Praveen Pankajakshan, Laure Blanc-Féraud, Josiane Zerubia [PI].

In collaboration with the Pasteur Institute, Paris (J-C. Olivo-Marin, B. Zhang), the Weizmann Institute (Z. Kam) and the Technion (A. Feuer), Israel.

8. Dissemination

8.1. Conferences, Seminars, Meetings

- The members of the Ariana project-team participated actively in GdR ISIS and GdR MSPCV.
- The members of the Ariana project-team participated in the Sophia Forum at Palais des Festivals in Cannes in February and in the INRIA/UNSA Fête de la Science at INRA in Sophia Antipolis in October. In particular, G. Perrin, O. Zammit and J. Zerubia made presentations.
- The Ariana project-team organized numerous seminars in image processing during 2006. Seventeen researchers were invited from the following countries: Belgium, Czech Republic, France, Hungary, India, Ireland, Israel, Italy, Portugal, Spain, Tunisia, USA. For more information, see the Ariana project-team web site.
- As in previous years, members of the Ariana project-team participated actively in the visits to INRIA Sophia Antipolis of students from the Grandes Écoles (École Polytechnique, ENS Cachan, ENPC, Sup'Aéro), and helped students of the Classes Préparatoires with TIPE in France.
- All the members of the Ariana project-team participated in a 'brain-storming' session in Sospel in June.
- Alexis Baudour made a presentation as part of the 'Journées Mathématiques de l'Image', at the University of Nice-Sophia Antipolis, France, in January. He also made a presentation at the Conference on Imaging Science SIAM, Minneapolis, USA in May and participated in the workshop 'Mathematics in Image Analysis', Paris, France in September.
- Avik Bhattacharya gave a cross-seminar (ARIANA/MAESTRO) in May. He attended a meeting with an Indian delegation in Sophia Antipolis. He gave a seminar at ENST (TSI Department), Paris, France, in June. He presented a poster in the CompIMAGE symposium, Coimbra, Portugal, in October.
- Mats Eriksson had a poster presentation at ISPRS Commission I, Marne-la-Vallée, Paris, France, in July.
- Alexandre Fournier presented a poster at the International Summer School on Pattern Recognition, Plymouth, United Kingdom. He presented a poster at the 'Doctoriales DGA 2006' event, Agay, France.
- Peter Horvath gave a talk at the workshop 'Microscopy and Medical Image Processing', Linz, Austria, in May. He gave a talk at the 'Summer School on Image Processing and Robotics', Montpellier, France, in July. He gave a presentation at the conference ICVGIP, Madurai, India, in December. While in India, he gave a seminar at the French Institute of Pondicherry.
- Maria S. Kulikova presented her work at a EURANDOM workshop, Eindhoven, the Netherlands, in December.

- Florent Lafarge visited LIAMA, Beijing, China, for the Mathematical Methods for Multi-Channel Image Processing workshop in July, at which he presented his work. He gave a talk at the 'Journées de la Recherche de l'IGN', Saint-Mandé, France, in March. He presented a paper at the conference ICASSP, Toulouse, France, in May, at the ISPRS Commission I Symposium, Marne-La-Vallée, France, in July, and at the conference ICIP, Atlanta, USA, in October. He gave a talk at the 'Journées jeunes chercheurs CNES', Toulouse, France, in October. He presented his work at a EURANDOM workshop in Eindhoven, the Netherlands, in December.
- Ting Peng organized and participated in the workshop Mathematical methods for multi-channel image processing (MULT-IM), Beijing, China, in July. She participated in the workshop Mathematics in Image Analysis, Paris, France, in September. She presented her work at Alcatel Alenia Space, Cannes, in September, and Alcatel Alenia Space, Toulouse in November.
- Guillaume Perrin presented a paper at the conference RFIA (Reconnaissance des Formes et Intelligence Artificielle), Tours, France, in January. He presented a paper at the International Precision Forestry Symposium, Stellenbosch, South Africa, in March. He gave a cross-seminar (ARIANA/MAESTRO) in May. He presented a paper at the conference ICPR, Hong Kong, in August. He also gave a seminar at LIAMA, Beijing, China, in August.
- Pierre Weiss gave talks at the SIAM conference on Imaging Science, Minneapolis, USA, in May, and at the workshop Mathematics in Image Analysis, Paris, France, in September.
- Olivier Zammit presented a paper at the International Conference on Forest Fire Research, Figueira da Foz, Portugal, in November and attended the Euromediteranean workshop on forest fire detection in Valabre, France, in December.
- Ian Jermyn gave an invited talk in January at the Workshop on the 'Journées Mathématiques de l'Image', at the University of Nice-Sophia Antipolis. In May, he presented the work of the Ariana project-team as part of a visit to INRIA Sophia Antipolis by the head of NSF Europe and in June as part of a visit by the heads of LIAMA/CASIA (China). In July, he presented the work of the Ariana project-team to a delegation from the University of Houston. In September, he chaired a session and gave a presentation at the conference EUSIPCO06, Florence. In November, he visited the University of Szeged, Hungary, and gave a seminar. In December, he attended a meeting of FP6 Network of Excellence MUSCLE in Paris, and made a presentation.
- Xavier Descombes attended a meeting with the Russian delegation at MIPIM in March. He presented his work on image restoration using a diffusion process in the workshop Mathematical methods for multi-channel image processing (MULT-IM), Beijing, China, in July, he spent 2 weeks at IIPT (Russian Academy of Sciences) in Moscow in August, funded by the Econet project. He presented his work on marked point processes at a conference organized by PopSud at I3S, Sophia Antipolis, France. He presented a paper at the conference ICASSP, Toulouse, France, in May, presented the project Mode de Vie at the ARC workshop in Grenoble, France, in October and gave invited talks in several workshops (Rennes, Paris VI,...).
- Laure Blanc-Féraud presented the work conducted within the P2R program at the Status Seminar on Medical and Biomedical Imaging in February in Jerusalem, Israel. She made an invited keynote talk at the conference ADAIV, Marseille, France, in September. She presented work on image restoration using L^1 regularization in the workshop Mathematical methods for multi-channel image processing (MULT-IM), Beijing, China, in July.
- Josiane Zerubia made a presentation of Ariana work at Popsud, participated at the workshop 'Journées Mathématiques de l'Image', at the University of Nice-Sophia Antipolis and visited Astrium/EADS in Toulouse in January. She attended a meeting on orbital systems organized by the French Space Agency (CNES) in Labége and visited CS as well as Thales in Toulouse in February to present the research work conducted in Ariana. She also made a presentation at Magellium in Toulouse in March and went twice to Toulouse to evaluate the R and D of the French Space Agency (CNES), and to participate, as one of 30 experts of CERT, in writing of a report on the subject sent

to the President of CNES. Still in March, she participated to a Franco-Israeli workshop organized by Pasteur Institute within the P2R Program and attended an ORFEO workshop located at CNES in Paris. In April, she visited Sanofi-Aventis Research and CNES both in Toulouse and participated to an Optitec meeting on deconvolution at I3S in Sophia Antipolis. In May, she participated to ICASSP'06 in Toulouse as an organizing member and attended the BISP Technical Committee of the IEEE Signal Processing Society. In June, she organized the Ariana 'brain storming" meeting in Sospel, went to EPFL in Lausanne to visit the Biological Imaging Group (M. Unser) and to be part of a PhD committee in the Audiovisual Communications Laboratory (M. Vetterli) and presented Ariana work at the Carnot Foundation. In July, she presented a paper at the ISPRS Commission I Symposium in Marne la Vallée. In September, she organized and attended the administration committee of the SFPT Society at INRIA Sophia Antipolis and gave an invited talk. In October, she attended the scientific committee of TechforFood organisation representing INRIA at CNES in Paris. In november, she organized the visit of the head of Ecology Department of the French Institute in Pondicherry at INRIA Sophia Antipolis. She also visited Silogic and Sanofi-Aventis in Toulouse. In December, she participated to the third meeting of the scientific committee of TechforFood at the French Development Agency in Paris.

8.2. Refereeing

- G. Perrin was a referee for SFPT (Revue Française de Photogrammétrie et de Télédétection).
- Ian Jermyn was a referee for IEEE TIP and IEEE TPAMI, and for the conferences CIMCV06, EUSIPCO06, IFMIP06, POCV06, and SITIS06.
- X. Descombes was a referee for 1 PhD thesis and member of 2 PhD committees. He was referee for the journals IEEE TIP, IEEE TMI, IEEE TPAMI, IJCV, and for the conferences ECCV06, ICIP06, ICASSP06, and EUSIPCO06.
- L. Blanc-Féraud was a referee for 4 PhD theses and 1 HDR, and member of 1 HdR committee. She was referee for the journals IEEE TIP, Signal Processing Letters, JMIV, and the conferences ECCV06, ICIP06, and ACIVS06.
- Josiane Zerubia was a referee for 2 PhD theses and 1 HdR, and member of 1 PhD and 1 HdR committees. She was a referee for IJCV, IEEE TIP, and SFPT (Revue Française de Photogrammétrie et de Télédétection), and for the conferences ICASSP06, ISBI06, ICIP'06, SPIE-ISPRS06 ('Image and Signal Processing for Remote Sensing'), TAIMA06, CARI'06 and EUSIPCO'06.

8.3. Organization

- Ian Jermyn is a member of the Comité de Suivi Doctoral at INRIA Sophia Antipolis. He is the coordinator of an Egide PAI Balaton collaboration with the University of Szeged, Hungary, and coordinator of the Ariana project-team's efforts within the FP6 Network of Excellence MUSCLE. He is the Ariana coordinator for an INRIA STIC-Tunisia project. He was a member of the Technical Committee for EUSIPCO06. He was a member of the programme committees for SITIS06, IFMIP06, IEEE POCV06, and the ECCV06 workshop 'Computation Intensive Methods for Analysis of Vision Data'.
- Xavier Descombes is member of the scientific committee of the Optitec 'pole de competitivité', and member of the strategic committee of PopSud. He is also member of the expert committee 'multi' of CNRS. He is computer systems coordinator for the Ariana project. He was member of the technical committee for ICASSP06 and RFIA06. He is the coordinator of an EGIDE ECONET project with the University of Yerevan and the Institute for Information Transmission Problems (Moscou), and of the ARC Mode de Vie.

- Laure Blanc-Féraud is vice director of the I3S Laboratory (CNRS/UNSA). She is member of the managing committee of GdR ISIS. She is member of the Scientific Committee of the École Doctorale STIC. She is member of the Commision de Spécialiste section 61 of UNSA. She was a member of the examining jury for the position of Maître de Conférence of the CNECA 3 (Commission nationale des enseignants-chercheurs relevant du ministre chargé de l'agriculture). She is a member of the selection committee for the doctoral and post-doctoral INRIA CORDI grants. She was co-organizer of the 'Journées Mathématiques de l'Image' at the University of Nice, and of the GdR ISIS/Gretsi Summer School on Signal and Image Processing in Peyresq. She is the coordinator of the 'ANR Blanc' programme DETECFINE.
- Josiane Zerubia is an IEEE Fellow. She is a member of the Biological Image and Signal Processing Technical Committee of the IEEE Signal Processing Society. She is an Area Editor for IEEE TIP, and she is a member of the Editorial Boards of IJCV and the Revue Française de Photogrammétrie et de Télédétection of SFPT. She was member of the organization committee of ICASSP06 in Toulouse and co-chair of the special sessions. She was a programme committee member for ICASSP06, ISBI06, ICIP06, SPIE-ISPRS06 ('Image and Signal Processing for Remote Sensing'), and TAIMA06. She was a member of the CERT Committee, as one of 30 experts nominated by the Director of the French Space Agency (CNES) to evaluate the future research and development of CNES. She was a member of the evaluation boards for the Gerhard Herzberg Canada Gold medal and for the French Defense Agency (DGA/REI). She is principal investigator for the P2R Franco-Israeli collaborative programme. She is also principal investigator for the seven current industrial contracts and grants of the Ariana project-team. She is a member of the ORFEO group (CNES) and of the 3D working group of CNES. She is a member of the scientific committee of TechforFood and participated in the organization of the TechforFood day at the 'Salon de l'Agriculture' in Paris in March 2007. She is a consultant for Sanofi-Aventis Research in Toulouse. She conducted a scientific evaluation of the Space Imaging Laboratory of CS-SI in Toulouse.

8.4. Teaching

- Alexis Baudour was lab instructor for 'Mathematics for digital images' (64h), at the IUT of Nice Sophia Antipolis.
- Alexandre Fournier was an advisor for an Image Processing project (21h) at the EPU of Nice Sophia Antipolis.
- Florent Lafarge was lab instructor for 'Computer science' (32h) at the Université René Descartes, Paris, and 'Image processing' (8h) at ENSG, Marne-La Vallée.
- Pierre Weiss was lab instructor for 'Logical circuits' (60h) and 'Signal processing' (36h) at Poly'Tech (UNSA).
- Ian Jermyn taught 'Image analysis' (6h) at Poly'Tech (UNSA), and 'Filtering and segmentation of space imagery' (2.5h) at Sup'Aéro.
- Xavier Descombes taught at Sup'Aero (20h), in Poly'Tech (UNSA) (15h). He was teacher for the workshop Mathematical methods for multi-channel image processing (MULT-IM), Beijing, China, in July, and for the summer school on MCMC methods organized by GdR Isis at Peyresq in July.
- Laure Blanc-Féraud taught at the workshop Mathematical methods for multi-channel image processing (MULT-IM), Beijing, China, in July, and in the Masters 2 course IGMMV at the University of Nice-Sophia Antipolis (15h).
- Josiane Zerubia taught the module 'Stochastic models in image processing' for the Masters 2 course IGMMV at the University of Nice-Sophia Antipolis (15h). She was director of the course 'Filtering and segmentation of space imagery' at Sup'Aéro (40h, of which 20h taught), where she also taught as part of the course 'Variational methods for image processing' (2.5h).

8.5. PhDs

8.5.1. In progress

1. Alexis Baudour: 'Segmentation and deconvolution of 3D images', University of Nice-Sophia Antipolis. Defence expected in 2008.
2. Avik Bhattacharya: 'Indexing of remote sensing images using road networks', Ecole Nationale Supérieure des Télécommunications, Paris. Defence expected in 2007.
3. Alexandre Fournier : 'Détection de cibles par une analyse des perturbations de la texture', École Nationale Supérieure de l'Aéronautique et de l'Éspace, Toulouse. Defence expected in 2008.
4. Peter Horvath: 'Image Segmentation with Shape Priors', University of Szeged, Hungary and University of Nice-Sophia Antipolis. Defence expected in 2007.
5. Maria S. Kulikova: 'Shape recognition for scene analysis', University of Nice-Sophia Antipolis. Defence expected in 2009.
6. Florent Lafarge: 'Reconstruction 3D de zones urbaines denses à partir d'images satellitaires haute résolution', Ecole Nationale Supérieure des Mines, Paris. Defence expected in 2007.
7. Praveen Pankajakshan: 'Blind biological image deconvolution', University of Nice-Sophia Antipolis. Defense expected in 2009.
8. Ting Peng: 'Variational models for road network updating in dense urban areas from very high resolution optical images', CASIA, Chinese Academy of Sciences, Beijing, China and University of Nice-Sophia Antipolis. Defence expected in 2008.
9. Pierre Weiss: 'Multispectral image processing with PDEs', University of Nice-Sophia Antipolis. Defence expected in 2008.
10. Olivier Zammit: 'Forest fire damage assessment from satellite images', University of Nice-Sophia Antipolis. Defence expected in 2008.

8.5.2. Defended in 2006

1. Guillaume Perrin: 'Etude du couvert forestier par processus ponctuels marqués', Ecole Centrale, Paris. Defended October 2.

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