Activity Report 2012

Team AYIN

Stochastic models for remote sensing and skincare image processing

RESEARCH CENTER
Sophia Antipolis - Méditerranée

THEME
Vision, Perception and Multimedia Understanding

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Team AYIN

Keywords: Image Processing, Inverse Problem, Markovian Model, Stochastic Geometry, Graphs, Environment, Biological Images

Beginning of the Team: 2012-01-01, End of the Team: 2012-12-31.

1. Members

Research Scientists

Josiane Zerubia [Team Leader, Senior Researcher Inria, HdR]

Yuliya Tarabalka [Junior Researcher Inria since September 2012. She has been a Postdoctoral Fellow in Inria funded by CNES in January - August 2012.]

PhD Students

Sylvain Prigent [Mr. Sylvain Prigent was funded by Galderma R&D. He defended his PhD in November 2012.]

Yannick Verdie [Mr. Yannick Verdie is funded by an Inria fellowship. He started his PhD in November 2010.]

Aurélie Voisin [Ms. Aurélie Voisin defended her PhD in October 2012. It was funded both by DGA and by Inria.]

Jia Zhou [Ms. Jia Zhou was funded by Université Montpellier II. She defended her PhD in November 2012.]

Post-Doctoral Fellows

Ikhlef Bechar [Dr. Bechar is funded by the EADS Foundation. He started his two-year postdoc in April 2011.]

Vladimir Krylov [Dr. Krylov was funded by an Inria fellowship. He completed his postdoc in May 2012.]

Zhao Liu [Dr. Liu is funded by an Inria LIRA fellowship. She started her postdoc in August 2012.]

Visiting Scientists

Qiyin Fang [Prof. Fang (McMaster University, Canada) was funded by the French Embassy in Canada one week in September.]

Joseph Francos [Prof. Francos (Ben-Gurion University, Israel) was funded by BGU one week in March and one week in July.]

Ian Jermyn [Prof. Jermyn (Durham University, UK) was funded by the EADS Foundation one week in July.]

Zoltan Kato [Prof. Kato (Sveged University, Hungary) was funded by Inria one week in July.]

Nataliya Zagorodna [Prof. Zagorodna (Ternopil Ivan Pul'uj Technical University, Ukraine) was funded by the French Embassy in Ukraine one month in July.]

Administrative Assistant

Christine Foggia [Inria]

2. Overall Objectives

2.1. Overall Objectives

The objective of the AYIN team is to provide image processing tools to aid in the solution of problems in remote sensing and in dermato/cosmetology. From the methodological point of view, the AYIN team is focused on the development of hierarchical and stochastic models for image processing. The two principal applicative axis of the team are:

- Analysis of very high resolution images (optical and radar), which includes image quality (denoising, deconvolution and super-resolution), object extraction (extraction of structures, population counting), change detection and temporal tracking in image sequences.
- Hyperspectral imagery, which includes modelling of physics of hyperspectral sensors, dimensionality reduction adapted for specific applications, development of spectral-spatial approaches for automatic classification.

2.2. Highlights of the Year

- Yuliya Tarabalka was recruited as Inria CR2 to the AYIN team in September 2012.
- Yuliya Tarabalka received Best Reviewer Award of Transactions on Geoscience and Remote Sensing in July 2012.
- A new book was published: *Zoltan Kato and Josiane Zerubia. Markov Random Fields in Image Segmentation. Collection Foundation and Trends in Signal Processing. Now editor, World Scientific, 168 pages, September 2012.*
- A patent on skin care was deposited in collaboration with Galderma and the Morpheme research team in November 2012.

3. Scientific Foundations

3.1. Probabilistic approaches

Following a Bayesian methodology as far as possible, probabilistic models are used within the AYIN team for three purposes: to describe the class of images to be expected from any given scene, to describe prior knowledge about the scene and to incorporate specific constraints. The models used in AYIN fall into the following two classes.

3.1.1. 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 AYIN team, 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 fields.

3.1.2. 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 an important line of research in the AYIN team. 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’. Such processes have been recently applied to skin care problems.

3.2. Parameter estimation

One of the most important problems studied in the AYIN team is how to estimate the parameters that appear in the models. For probabilistic models, the problem is quite easily framed, but is not necessarily easy to solve, particularly in the case when it is necessary to extract simultaneously both the information of interest and the parameters from the data.

3.3. Hierarchical models

Another line of research in the AYIN team concerns development of graph-based, in particular, hierarchical models for very high resolution image analysis and classification. A specific hierarchical model recently developed in AYIN represents an image by a forest structure, where leaf nodes represent image regions at the finest level of partition, while other nodes correspond to image regions at the coarser levels of partitions. The AYIN team is interested in developing multi-feature models of image regions as an ensemble of spectral, texture, geometrical and classification features, and establishing new criteria for comparing image regions. Recent research concerns extension of hierarchical models to a temporal dimension, for analyzing multitemporal data series.

4. Application Domains

4.1. Remote sensing

The first application domain of the AYIN team concerns analysis and classification of remote sensing images. The very high spatial, spectral and temporal resolution of the last generation of imaging sensors (for instance, GeoEye, Ikonos, Pleiades, COSMO-SkyMed, TerraSAR-X, ...) provides rich information about environment and is very useful in a range of applications, such as investigating urban environments, precision agriculture, natural disasters and mineralogy. The development of these applications presents new challenges of high-dimensional and high-volume data analysis. The methods proposed by the AYIN team are applied for analysis of SAR, multi- and hyperspectral remote sensing images. In particular, the team develops approaches for image segmentation and classification, change detection, extraction of structures and object tracking.

4.2. Skin care

The second application domain of the AYIN team is skin care imaging which mainly consists in image analysis and classification for dermatology and cosmetology. Here we also deal with very high spatial, spectral and temporal resolution of the most recent imaging sensors. In dermatology we are particularly interested in hyperpigmentation detection and disorders severity evaluation (for instance, for melasma, acne, ...). In cosmetology our main goals are analysis, modeling and characterization of the condition of human skin, as well as evaluation of means to influence that condition. Some of the changes in skin over time have to do with chronological aging (such as pinheads for teenagers or wrinkles for mature people), others with extrinsic aging, caused for instance by sun exposure and smoking.

5. Software

5.1. Software

5.1.1. Transfers

- The software MAD V2.0 was transfered to Galderma R&D in November 2012.
- The software Scombo v1.1 was transfered to Cutis laboratory (Galderma R& D, Sophia Antipolis) in May 2012, and to the French-Singaporean laboratory IPAL (Image and Pervasive Access Lab) in November 2012.

5.1.2. Deposits

- The software MAD (Melasma Automatic Detector) V2.0 was deposited with the APP in November 2012. A patent has also been deposited jointly by Galderma R& D and Inria during the same month. It deals with the melasma severity scoring from multi-spectral imaging.

- The software Scombo (Supervised Classifier of MultiBand Optical images) v1.1 was deposited with the APP in April 2012. It deals with the supervised classification of multiband optical images by using Markov random fields. It was developed with Aurélie Voisin, Vladimir Krylov and Josiane Zerubia.

6. New Results

6.1. Markov random fields and Marked point processes

6.1.1. Stochastic modeling for very high resolution SAR image processing

Participants: Aurélie Voisin, Vladimir Krylov, Josiane Zerubia [contact].

This work was done in collaboration with DITEN, University of Genoa, with Dr. Gabriele Moser and Pr. Sebastiano B. Serpico with partial financial support of the French Defense Agency, DGA (http://www.defense.gouv.fr/dga/). The data were provided by the Italian Space Agency, ISA (http://www.asi.it/en) in the framework of the project "Development and validation of multitemporal image analysis methodologies for multirisk monitoring of critical structures and infrastructures (2010-2012)".

The classification of remote sensing images including urban areas is relevant in the context of the management of natural disasters (earthquakes, floodings...), and allows to determine land-use and establish land cover maps, or to localise damaged areas. Given the huge amount and variety of data available nowadays, the main difficulty is to find a classifier that takes into account multi-band, multi-resolution, and possibly multi-sensor data. A minor part of our work was also dedicated to the change detection [14], still in the frame of the management of natural disasters.

We developed a supervised Bayesian classifier that combines a joint class-conditional statistical modeling and a hierarchical Markov random field. The first classification step deals with the statistical modeling for each target class (e.g. vegetation, urban, etc.) by using a finite mixture model, estimated by resorting to a modified stochastic expectation maximization (SEM) algorithm. Such a model is well-adapted to deal with heterogeneous classes, and each mixture component reflects the contribution of the different materials contained in a given class. When considering optical images, the statistics are modeled by using finite mixtures of Gaussian distributions. In the case of SAR amplitude imagery, we favor a finite mixture of generalized Gamma distributions. Then, at each considered resolution, the different input bands are statistically combined by using multivariate copulas. The second classification step relies on the integration of this statistical modeling in a hierarchical Markov random field integrated in a quad-tree structure. Such contextual classifier helps improving the robustness of the method with respect to noise, or to SAR speckle. A variety of algorithms were proposed to estimate the labels on hierarchical graphs. The consideration of a specific graph, here a quad-tree, allows to benefit from its good properties (e.g. causality) and to apply non iterative algorithms. Among the different algorithms employed in the literature, we chose to take into account an exact estimator of the marginal posterior mode (MPM). The cost function associated to this estimator offers the possibility to penalize the errors according to their number and the scale at which they occur: an error at the coarsest scale is stronger penalized than an error at the finest scale. Moreover, we introduce a prior estimation update that experimentally leads to improved results.

The first experiments were run on single-polarized, mono-resolution synthetic aperture radar (SAR) amplitude images. The challenge of the problem considered here is that the given input is at a single resolution and should be integrated in a multi-scale tree. Thus, we extract an extra information in the form of a multi-scale wavelet decomposition from the initial image. Then, at each level, a textural feature map (e.g. Haralick's variance) is obtained from each image in the decomposition stack, and integrated as an additional information that aims at discriminating the urban areas. Finally, at each level, the wavelet image is combined with the textural image by using copulas, as described previously. These results were presented in [10], [23].

Such a classifier is sufficiently flexible to take into account different types of data [21], [22]. Thus, we also tested coregistered data of a given area acquired at different resolutions (e.g., multiresolution SAR images), directly integrated at the different levels of the hierarchical tree. The classification of multisensor (optical/SAR) data is illustrated in Fig. 1. In this specific example, we consider a GeoEye acquisition (resolution: 65 centimeters) and a coregistered COSMO-SkyMed SAR acquisition (resolution: 2.5 meters) of the Port-au-Prince quay (Haiti). Spatially disjoint training and test areas were manually annotated. The classification is done following 5 classes: urban areas, natural landscape, sand, containers and wet areas.

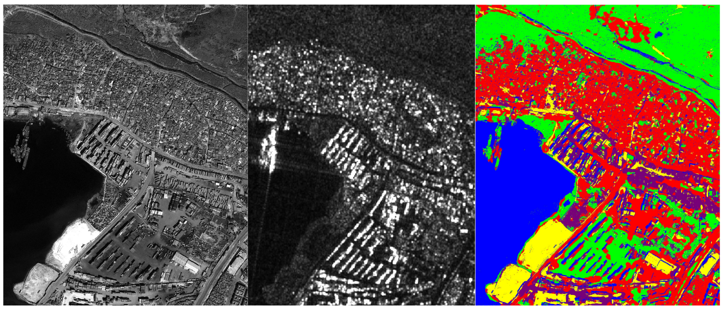


Figure 1. Left: Initial optical image of Port-au-Prince (Haiti) (©GeoEye, 2010). Middle: Initial SAR image of Port-au-Prince (Haiti) (©ISA, 2010). Right: Classification map obtained with the proposed hierarchical method for the 5 classes (Blue: wet areas; Green: vegetation; Red: urban areas; Yellow: sand; Purple: containers).

We have also run experiments on other types of acquisitions, such as histological images [22], to prove the robustness of the proposed algorithm with respect to different image sources.

6.1.2. Satellite image classification using Bootstrap EM

Participants: Siddharth Buddhiraju, Josiane Zerubia [contact].

This program has been partially funded by the Direction of International Relations of Inria (DRI).

We implemented both Bootstrap EM and Iterated Conditional Expectation algorithms for parameter estimation of first order Markov Random Field models followed by Simulated Annealing, for optimal segmentation of gray-scale images. The objective was to perform a quantitative comparison of the two methods. Apart from successful implementation of these algorithms, an extension of these to multispectral images was performed, and the obtained results were found to be of superior quality compared against the original gray-scale ones (see Fig. 2).

First, Bootstrapped EM or Iterated Conditional Expectation were performed based on the user's requirement. The estimated parameters were then used to obtain the optimal segmentation of the image via simulated annealing. The algorithm was extended using multivariate Gaussian models to perform the same for multispectral images.

6.1.3. Boat detection and counting in Mediterranean Harbors using Marked Point Processes

Participants: Paula Craciun, Josiane Zerubia [contact].

This work has been conducted in collaboration with ACRI-ST (http://www.acri-st.fr/) and the French Space Agency (http://www.cnes.fr/), which provided the high resolution satellite images.

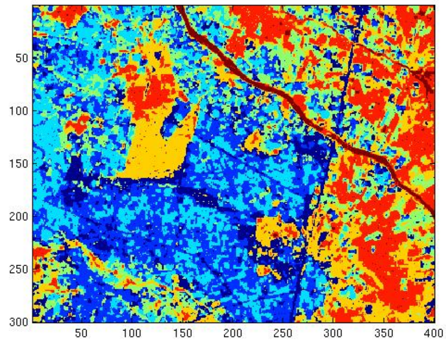


Figure 2. A sample result for a 4-band IRS-1A satellite image of a village in India. 7 clusters were considered to segment the image using Bootstrapped EM. The image was provided by Prof. Krishna Mohan Buddhiraju of CSRE, Indian Institute of Technology Bombay.

Marked point processes have been successfully applied in image processing analysis, when dealing with high resolution images in the purpose of feature extraction. The objective of this research was to improve the already existing marked point process model of ellipses to better fit the detection of boats in a harbor. The model involved two types of energy terms: a data term, used to determine the fidelity to the existing data (i.e. image) and a prior energy term, used to describe relationships between the objects. We proposed new energy components to model boat detection. The proposed model relied on a high number of parameters. While most of these parameters had an intuitive meaning and could be, thus, set manually, others were difficult to determine. We therefore used a parameter estimation method, based on the Stochastic Expectation - Maximization (SEM) algorithm, which proved to provide good results when combined with marked point processes. Furthermore, we proposed additional automatic procedures based on mathematical morphology to determine critical parameters of this model. Experimental results of boat detection are shown on Fig. 3.

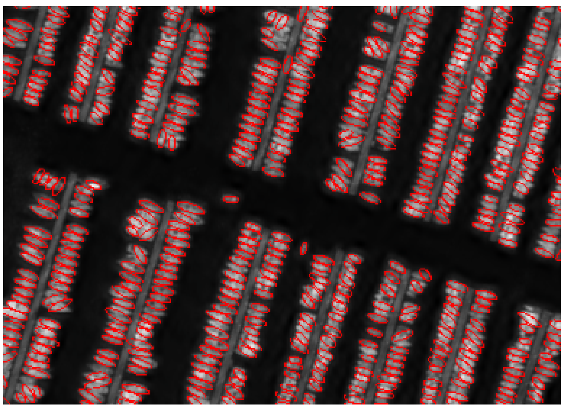


Figure 3. Result of boat detection using Marked Point Processes.

6.1.4. Contribution of object recognition on forest canopy images to the building of an allometric theory for trees and natural, heterogeneous forests

Participants: Jia Zhou, Josiane Zerubia [contact].

This work was done in collaboration with Xavier Descombes (Morpheme team, Inria-SAM), Dr. Pierre Coureron and Dr. Christophe Proisy at IRD, UMR AMAP (http://amap.cirad.fr/), Montpellier.

This work aimed at providing information on the forest structure through the analysis of canopy properties as described by the spatial distribution and the crown size of dominant trees. Our approach was based on the Marked Point Processes (MPP) theory, which allows modeling tree crowns observed in remote sensing images by discs belonging to a two dimensional space. The potential of MPP to detect the trees crowns automatically was evaluated by using very high spatial resolution optical satellite images of both *Eucalyptus* plantations in Brazil and mangrove forest in French Guyana. LIDAR and simulated reflectance images were also analyzed for the mangrove application. Different adaptations (parameter settings, energy models) of the MPP method were tested and compared through the development of quantitative indices that allowed comparison between detection results and tree references derived from the field, photo-interpretation or the forest mockups.

In the case of mangroves, the estimated crown sizes from detections were consistent with the outputs from the available allometric models (Fig. 4 (Left and Middle)). Other results indicated that tree detection by MPP allowed mapping the local density of trees of young *Eucalyptus* plantations (Fig. 4 (Right), [11]) even if crown size was close to the image spatial resolution (0.5 m). However, the quality of detection by MPP decreased with canopy closeness. To improve the results, further work may involve MPP detection using objects with finer shapes and forest data measurements collected at the tree plant scale.

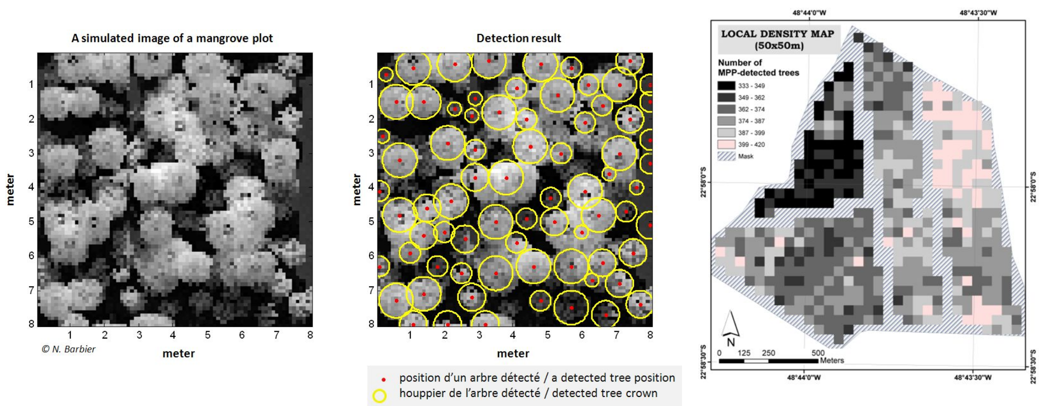


Figure 4. (Left and Middle) Result of detection on an image of mangrove. (Right) Example of a local tree density map computed over the entire plantation at 50 m resolution of the marked point process modeling. Masked areas are centered along the road network.

6.1.5. Detection of the hyperpigmentation of the skin on color images using Marked Point Process and Mathematical Morphology

Participants: Adrien Lacage, Josiane Zerubia [contact].

The source images were provided by the AYIN team itself for the study of folliculitis, and by an industrial leader in skin care for acne.

Automatic detection of the skin hyperpigmentation helps in estimating the severity of some skin diseases like *acne vulgaris* and *folliculitis*. We compared two methods for studying acne and folliculitis lesions and hyperpigmentation of the skin. We adapted a model based on Marked Point Processes and initially developed for flamingo's population counting to dermatological images of acne and folliculitis. Then, we developed an algorithm which uses mathematical morphology together with volume and shadows compensation. Finally, we compared results in term of detection accuracy.

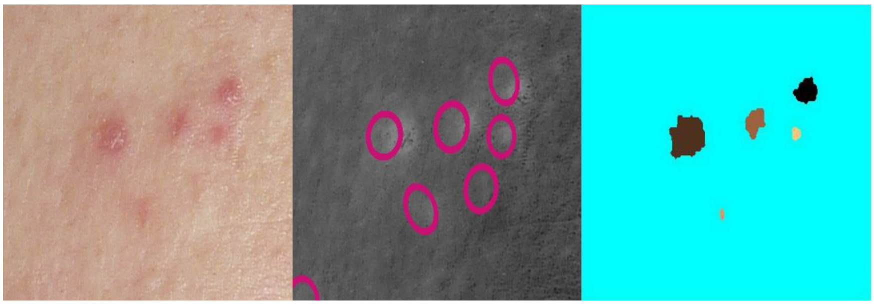


Figure 5. Source image of folliculitis (Left) and results obtained with Marked Points Processes (Middle), then with Mathematical Morphology (Right)

6.1.6. Efficient Monte Carlo sampler for detecting parametric objects in large scenes

Participants: Yannick Verdie, Florent Lafarge [contact].

This work is supervised by Florent Lafarge (Geometrica team, Inria-SAM) in collaboration with the AYIN team.

Point processes have demonstrated both efficiency and relevance when addressing object recognition problems in vision. However, simulating these mathematical models is a difficult task, especially on large scenes. Existing samplers suffer from average performances in terms of computation time and stability. We propose a new sampling procedure based on a Monte Carlo formalism. Our algorithm exploits Markovian properties of point processes to perform the sampling in parallel. This procedure is embedded into a data-driven mechanism such that the points are non-uniformly distributed in the scene. The performances of the sampler are analyzed through a set of experiments on various object recognition problems from large scenes, and through comparisons to the existing algorithms.

6.2. Statistical methods

6.2.1. Change detection on synthetic aperture radar images based on hypothesis testing

Participants: Vladimir Krylov, Josiane Zerubia [contact].

This work was conducted in collaboration with DITEN, University of Genoa with Dr. Gabriele Moser and Prof. Sebastiano Serpico (http://spt.dibe.unige.it/) with the support of the Italian Space Agency, ASI (http://www.asi.it/en).

Modern synthetic aperture radar (SAR) sensors represent an essential source of all-weather and 24-hour imagery with a fixed re-visit cycle at competitive high resolution. Two-date change detection from SAR images is a process that employs two SAR images acquired over the same geographical area with possibly the same (or close) acquisition characteristics at two different times to map the areas where changes occur between the two acquisition dates. The central disadvantage of the SAR imagery is given by an inherent multiplicative speckle noise, which restricts the direct application of optical-based change detection methods to SAR imagery.

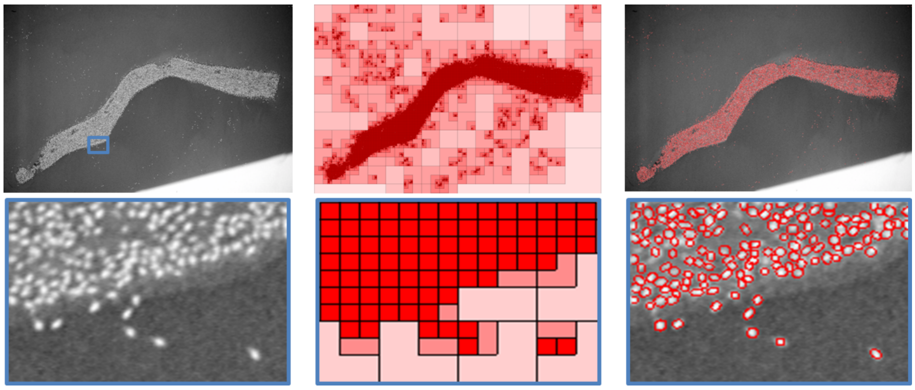


Figure 6. Bird counting by a point process of ellipses. (right) More than ten thousand birds are extracted by our algorithm in a few minutes from (left) a large scale aerial image. (middle) A quad-tree structure is used to create a non-uniform point distribution. Note, on the cropped parts, how the birds are accurately captured by ellipses in spite of the low quality of the image and the partial overlapping of birds.

We have developed a non-parametric statistical change detection approach. We avoided the ambiguity of choosing a restrictive clutter model by assuming no specific probability distribution function model [25] for the statistics of SAR. We developed a modified hypothesis test which is based on the classical Wilcoxon two-sample test that verifies whether one of two samples of independent observations tends to have larger values than the other. The choice of the Wilcoxon statistic as compared to the other available goodness-of-fit test statistics, such as, e.g., that of Cramér-von Mises' test, is a compromise solution to have simultaneously an analytically tractable asymptotic distribution (which is needed to formulate the likelihood ratio test) and a non-parametric testing procedure. Furthermore, the experimental validation demonstrated the adequacy of this statistic to the considered problem. To be able to take a decision at each pixel of the coregistered image pair we considered samples originating from the local windows centered in each pixel. Finally, we constructed a likelihood ratio test on the image with Wilcoxon statistic values. This formulation allowed to overcome the limitation of a classical independency assumption for the Wilcoxon test which is violated (at least, locally) with the local window samples. The resulting technique is related to the statistical false discovery rate approach developed for "large-scale simultaneous hypothesis testing" problems, however the derivation and interpretation are different.

Encouraging detection results were obtained on XSAR and very high resolution COSMO-SkyMed images [14].

6.2.2. *Statistical analysis of skin pigmentation under treatment*

Participants: Sylvain Prigent, Xavier Descombes, Josiane Zerubia [contact].

This work was partially funded by a contract with Galderma R&D (http://www.galderma.com/RampD.aspx). It was a collaboration between AYIN (Josiane Zerubia) and Morpheme (Xavier Descombes) teams.

One of the steps to evaluate the efficacy of a therapeutic solution is to test it on a clinical trial involving several populations of patients. Each population receives a studied treatment and a reference treatment for the disease. For facial hyper-pigmentation, a group of N_e patients receives the treatment on one cheek and a comparator on the other. The comparator can be a reference treatment or a placebo. To this end patients are selected to have the same hyper-pigmentation severity on the two cheeks. Then multi-spectral images are taken at different time t along the treatment period.

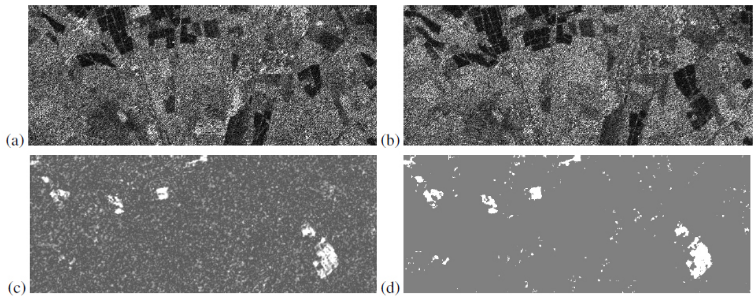


Figure 7. Coregistered XSAR images (©Univ. of Pavia) acquired on (a) April 16, 1994 and (b) April 18, 1994 and the detection results: (c) 5×5 *window-based image ratio, (d) proposed method with* 5×5 *window.*

We proposed a methodology to estimate the efficacy a treatment by calculating three differential criteria: the darkness, the area and the homogeneity. The darkness measures the average intensity of the disease on a gray scaled image I obtained by a linear combination of the spectral bands of the original multi-spectral image. A differential darkness is then obtained by measuring the deviation between the initial measurement at time t_0, and the measurement at time t_k. The differential area criterion is calculated by analyzing the histogram of $I_{diff} = I_{t_0} - I_{t_k}$ a difference gray scale image between two measurements in a time series. The differential homogeneity criterion is obtained with a multi-scale analysis of I_{diff} adapted from the Statistical Parametric Mapping (SPM) methodology. Indeed, statistical inferences allow to assign a probability of change to each region of I_{diff} above a set of thresholds. These probabilities are calculated with respect to the maximum intensity and the spatial extend of each region. An integration of the obtained statistical map denoted SM, allows to get a homogeneity criterion.
The Fig. 8 illustrates the differential score calculated on a patient whose pathology decreases during the clinical trial. The proposed differential score has been tested in a full clinical study and provided results that agreed with the clinical analysis. This work have been patented, submitted to ISBI'13 conference and to the IEEE TMI journal, and published in Inria research reports [26], [27].

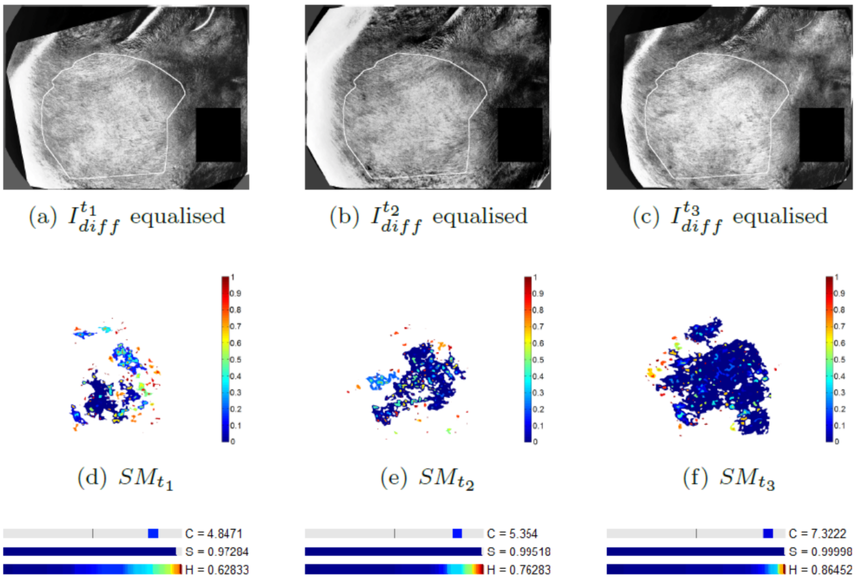
6.3. Hierarchical models

6.3.1. Hierarchical and graph cut-based models for multiyear sea ice floe segmentation

Participant: Yuliya Tarabalka [contact].

This work has been done in collaboration with Dr. Guillaume Charpiat (STARS team, Inria-SAM), Dr. Ludovic Brucker (NASA GSFC, USA) and Dr. James Tilton (NASA GSFC, USA).

The melting of sea ice is correlated to increases in sea surface temperature and associated climatic changes. Therefore, it is important to investigate how rapidly sea ice floes melt. We proposed two methods for segmentation of a time series of a melting sea ice floe. The first method employs hierarchical model for ice floe segmentation. Image features are extracted using morphological operators, and the floe of interest is marked based on AMSR-E satellite measurements. Then, hierarchical step-wise optimization segmentation is performed, by iteratively merging adjacent regions with the smallest dissimilarity criterion. We proposed to use area and shape parameters of the floe at two previous time moments as priors for computing a segmentation map at the next time moment.



(a) I^{t1}_{diff} equalised (b) I^{t2}_{diff} equalised (c) I^{t3}_{diff} equalised

(d) SM_{t_1} (e) SM_{t_2} (f) SM_{t_3}

(g) score t_1 (h) score t_2 (i) score t_3

Figure 8. I_{diff}, SM and differential score for the three measurements t_1, t_2, t_3 calculated for a patient whose disease decrease.

Fig. 9 (a) depicts a graph of the multiyear ice floe area as a function of time, computed by applying the proposed hierarchical model to the summer series of Moderate-Resolution Imaging Spectroradiometer (MODIS) images. While a multiyear ice floe can only melt in the summer period, peaks on the graph correspond to segmentation errors, which are a consequence of either a cloud cover or weakness of contrast between the multiyear ice and the surrounding young ice floes. These segmentation imprecisions can be avoided by simultaneously optimizing all segmentation maps in a time series. For this purpose, we developed a new method based on graph cuts for joint segmentation of monotonously shrinking (or growing) shapes. We impose shape shrinkage (or growth, respectively) constraint in graph cuts, and minimization of energy computed on the resulting graph of the image sequence yields globally optimal segmentation. Fig. 9 (c-d) show examples of floe segmentations using the new approach. Fig. 9 (b) presents a graph of the floe area as a function of time computed by performing the proposed graph cut-based method. The results are compared to those obtained by applying graph cut segmentation to each single image in the considered time series. It can be seen that the new approach yields results with continuous shrinkage of the shape size.

6.3.2. *Hierarchical model for spectral-spatial classification of hyperspectral images*

Participant: Yuliya Tarabalka [contact].

This work has been done in collaboration with Dr. James Tilton (NASA GSFC, USA).

The recent advances in hyperspectral remote sensor technology makes it possible to acquire data with a very high spectral (hundreds of spectral channels) and spatial (order of a meter) resolution. The rich spectral information of the hyperspectral data leads to the potential of a more accurate classification, but also presents challenges of high-dimensional data analysis.

We developed a new method for spectral-spatial classification of hyperspectral images. The method is based on the integration of probabilistic classification and shape analysis within the hierarchical step-wise optimization algorithm. First, probabilistic support vector machines classification is applied. Then, at each iteration two

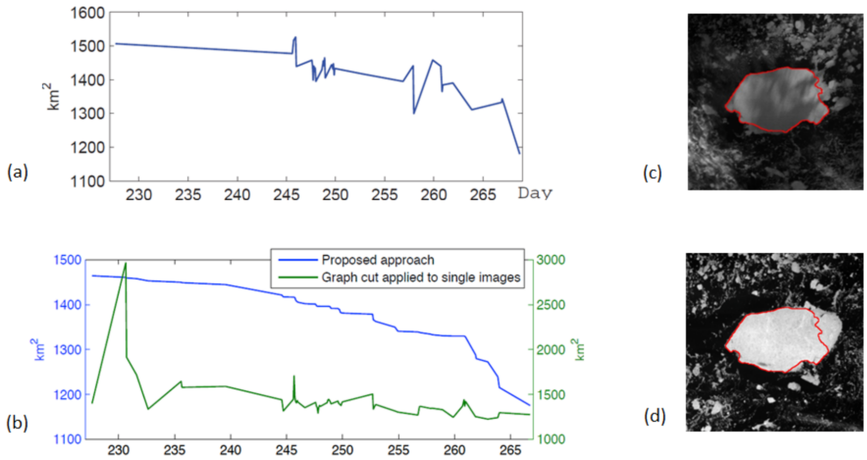


Figure 9. (a) Area of a multiyear ice floe as a function of time, computed by applying the proposed hierarchical model. (b) Area of the floe as a function of time (days), computed by using the proposed graph cut-based model (blue) and by applying graph cut segmentation to each single image in a time series. (c-d) Examples of floe segmentations using the proposed graph cut-based model.

neighboring regions with the smallest dissimilarity criterion are merged, and classification probabilities are recomputed. We proposed to estimate a dissimilarity criterion between regions as a function of statistical, classification and geometrical (area and rectangularity) features. Fig. 10 shows the obtained classification results on a 102-band ROSIS image of the Center of Pavia, Italy, which are compared with Support Vector Machines (SVM) classification results. These results did show that the proposed method succeeded in taking advantage of both spatial and spectral information for accurate hyperspectral image classification.

Figure 10. Center of Pavia image. (Left) Three-band color composite. (Middle) SVM classification map, overall classification accuracy = 94.9%. (Right) Classification map obtained using the proposed hierarchical approach, overall classification accuracy = 97.1%.

6.3.3. Classification of combined hyperspectral and panchromatic data using spectral-spatial approaches

Participants: Yuliya Tarabalka [contact], Josiane Zerubia.

This work has been conducted in collaboration with the French Space Agency CNES (http://www.cnes.fr/), with Dr. Marie-José Lefèvre, Dr. Hélène DeBoissezon and Mr. Manuel Grizonnet.

Hyperspectral imaging records a detailed spectrum for each pixel, opening new perspectives in classification. Currently, several hyperspectral satellite missions such as EnMAP (210 bands, GSR 30m) are under development. The future hyperspectral satellite missions PRISMA and HYPXIM also include a panchromatic channel with better spatial resolution. We explored if a panchromatic channel at a higher spatial resolution (factor 4) contributes for more accurate classification of hyperspectral images in space conditions.

We adapted and compared several classification methods for combined hyperspectral and panchromatic images, and conducted experiments on the simulated HYPXIM data provided by CNES. We fused both data sources using principal component and Gram-Schmidt fusion methods, as well as the vector stacking approach. We then applied Support Vector Machines (SVM) classification on the resulting feature sets. Furthermore, we considered spatial information for more accurate classification by: (1) including Haralick's texture features in the feature set; (2) segmenting an image into homogeneous regions using a Hierarchical Step-Wise Optimization (HSWO) technique, and assigning each segmented region to the dominant class within this region.

Classification results are illustrated in Fig. 11. We concluded that classification accuracies of the HYPXIM simulated data have been improved when including a panchromatic channel at a higher spatial resolution into a classification system. These results are close to hyperspectral aerial data classifications. For the image containing one-pixel regions and mixed pixels, standard spectral-spatial classification methods are not well adapted and thus do not improve accuracies when compared to pixelwise classification. In the future, we plan to develop methods which would use both spatial information and a spectral unmixing concept for efficient fusion of hyperspectral and panchromatic data.

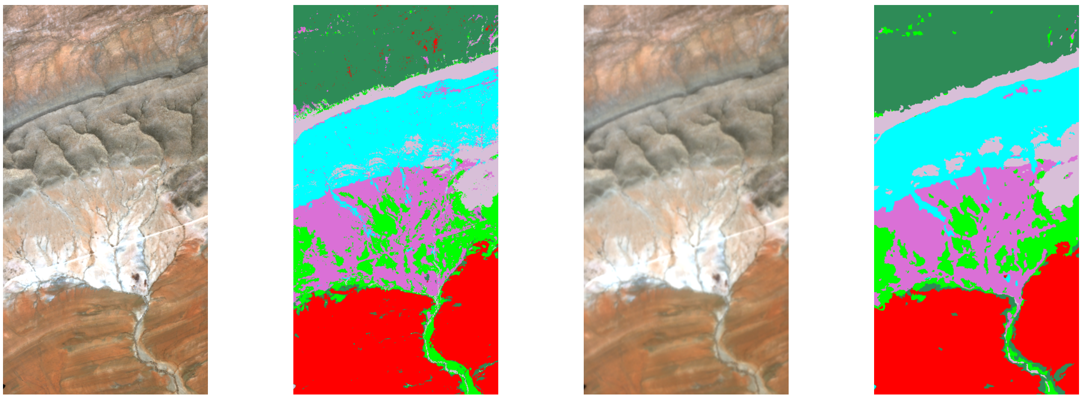


Figure 11. From left to right (a-d): (a) The false-color HYMAP aerial image (126 bands, GSR 4.8m). (b) SVM classification map for the HYMAP image, overall classification accuracy $= 83\%$. (c) Simulated HYPXIM image (126 bands, GSR 14.4m). (d) Classification map of the fused by vector stacking hyperspectral image (c) and panchromatic image at GSR 4.8m, using HSWO-based spatial regularization, overall classification accuracy $= 80.7\%$.

6.4. Other detection approaches

6.4.1. Multiple-instance object detection using a higher-order active shape prior

Participants: Ikhlef Bechar, Josiane Zerubia [contact].

This work is done in collaboration with Dr. Ian Jermyn of Durham University (United Kingdom, https://www.dur.ac.uk/mathematical.sciences/) and was funded by a contract with the EADS foundation (http://www.fondation.eads.com/).

The problem under consideration is the multiple-instance object detection from imagery using prior shape knowledge. As mathematical and algorithmic framework, we have used the higher-order active contour (HOAC) model framework in order to incoporate prior shape knowledge about a class of objects of interest. On top of its robustness and its computational attractiveness (due to its parameter-estimation free method), the HOAC object-detection framework allows to incorporate shape knowledge about multiple occurrences of an object of interest in an image and to carry out object detection in a single algorithmic framework via the minimization of energy of the form:

$$\min_{\text{over all shapes}\gamma} E(\gamma) = E_{image}(\gamma) + E_{prior}(\gamma) \tag{1}$$

where γ stands for the contour an image object, $E_{image}(\gamma)$ stands for its image-based energy and $E_{prior}(\gamma)$ stands for a prior energy which is only a function of an objet's shape (and not of image data). The goal of this project is thus to model $E_{prior}(\gamma)$ using the HOAC methodology.

In this work, we have developed a fourth-order active contour (FOAC) framework for incorporating prior shape knowledge about target shapes. Typically, we express a FOAC energy model as

$$E_{foac}(\gamma) = \lambda_C L(\gamma) + \alpha_C A(\gamma) + \beta_C \int\int\int\int \langle \dot{\gamma}_p, \dot{\gamma}_q \rangle \, \mathbf{K}_C \left(|\gamma_p - \gamma_q|, |\gamma_s - \gamma_t| \right) \langle \dot{\gamma}_s, \dot{\gamma}_t \rangle \; dp\, dq\, ds\, dt \tag{2}$$

where $L(\gamma)$ and $A(\gamma)$ stand respectively for the length and the area of a contour γ and $\int\int\int\int \langle \dot{\gamma}_p, \dot{\gamma}_q \rangle \, \mathbf{K}_C \left(|\gamma_p - \gamma_q|, |\gamma_s - \gamma_t| \right) \langle \dot{\gamma}_s, \dot{\gamma}_t \rangle \; dp\, dq\, ds\, dt$ models fourth-order interactions between quadruples of contour points, and λ_C, α_C and β_C stand for some tradeoff parameters that control the contribution of each term of the FOAC energy. Note that the parameters of the method include both the real coefficients λ_C, α_C and β_C and the bivariate kernel $\mathbf{K}_C(u,v)$; $\forall\, u, v \in \mathbf{R}^+$. These parameters need to be tuned optimally for a given target shape γ^*. Thus we have developed a direct method for the optimal estimation of the FOAC parameters.

We have then shown that shapes with arbitrary geometric complexity can be modeled using such the FOAC framework 2, and we have developed a direct method for the estimation of the parameters for a given class of shapes. In order to be able to detect multiple occurrences of a target object in an image, one needs to re-express such an originally contour-based energy 2 by replacing appropriately in formula 2 the one-dimensional contour quantity γ with an equivalent two-dimensional quantity (ie. with respect to the image domain) such as the characteristic function of γ and to minimize with respect to it the resulting energy functional. This allows topological changes of an evolving contour and hence the detection of possible multiple instances of a target object in an image. We have shown that such a new formalism is a third-order Markov Random Field (MRF) which practical optimization was a challenging question. Therefore, we have also developed a method for the exact minimization of the energy of the resulting MRF model (using a equivalent convex-relaxation approach, see Fig. 12).

6.4.2. Image analysis for automatic facial acne detection and evaluation

Participants: Zhao Liu, Josiane Zerubia [contact].

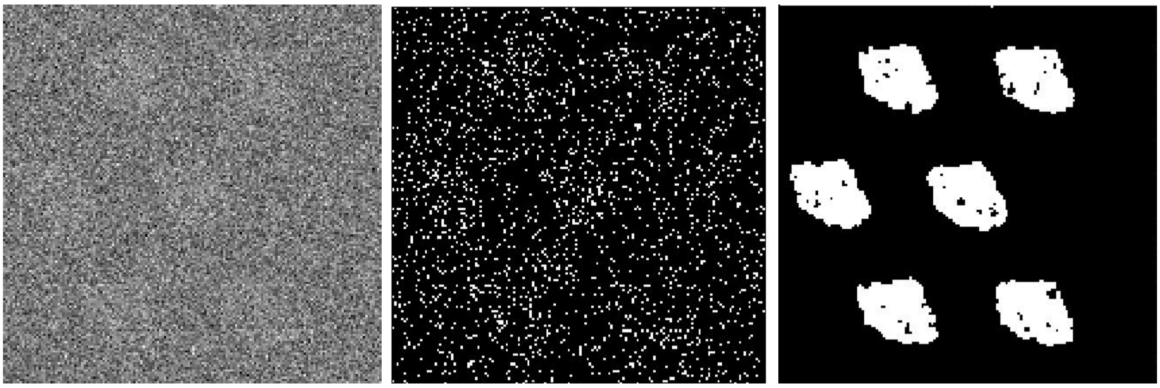


Figure 12. (Left) A very noisy input image; Multiple-instance object detection using: (Middle) a traditional segmentation method (Mumford-Shah model with a TV-based regularization) alone; (Right) with a FOAC shape prior.

This work is part of LIRA Skin Care Project, which includes four key partners: Philips R&D (Netherlands, http://www.philips.nl), CWI (Netherlands, http://www.cwi.nl/), Fraunhofer Institutes (Germany, http://www.fraunhofer.de/en.html) and Inria (France).

Acne vulgaris is a highly prevalent skin disease, which has a significant life quality impact on sufferers. Although acne severity is readily observed by the human eye, it is an extremely challenging task to relate this visual inspection to measurable quantities of various skin tones and types. So far there is no golden standard for acne diagnosis in clinics, and it entirely depends on dermatologists' experience for evaluation of acne severity. But significant inter-rater variability among individual assessment may lead to less trustworthy diagnosis when several clinicians get involved in the study. In addition, less reproducibility of human evaluation makes comparison of acne changes over time difficult. Therefore, the long-term objective of this study is to construct an automatic acne grading system through applying spectroscopy imaging techniques and image processing methods, to objectively evaluate severity of skin disorder. Such a computer-based tool would also significantly benefit the development of better skin care products, if it can reliably characterize treatment effects of products in individual skin layers in agreement with physiological understanding.

Acne segmentation is normally considered as the first significant step in an automatic acne grading system, because segmentation accuracy directly influences the definition of acne pigmentation level, what has an impact on the goodness of acne severity evaluation. An initial unsupervised segmentation method is proposed for conventional RGB images, whose process is demonstrated in Fig. 13 (a). After several pre-processing steps (background and skin hair removal, illumination corrections), nine pigmentation descriptors were extracted from three RGB channels based on colorimetric transformations and absorption spectroscopy of major chromophores. It has been proved that the derived hemoglobin, normalized red, and normalized green descriptors can properly characterize pigmentation distributions of acne, and they are used as segmentation features. Finally, an iterative unsupervised segmentation was performed to maximize pigmentation distributions between acne and normal skin. Fig. 13 (b) shows an example of acne image on human face captured by a conventional RGB camera, while experimental result in Fig. 13 (f) illustrates that suspicious acne areas and healthy human skin can be automatically discriminated by applying the proposed method. Moreover, it only takes 90.8 seconds to segment the example image with the size of 640×428 pixels, which demonstrates the computation efficiency of the algorithm.

It should be noted that the segmentation method stated above is an initial approach. Shadows around non-flatten areas on human face (e.g. areas around nose) have a large influence on accuracy of automatic acne detection. However, based on the initial experimental results, it is difficult to entirely get rid of these effects using RGB channels only. Our finding is actually consistent with the existing studies, where researchers divided human face into several sub-regions and worked on these sub-regions individually to avoid shadow influence. Therefore, the next step study will compare acne segmentation results derived from RGB images and multi- or hyperspectral images, to investigate the most effective bands for describing acne pigmentation, as well as whether the introduction of multi- or hyperspectral analysis to the automatic acne detection and evaluation is necessary.

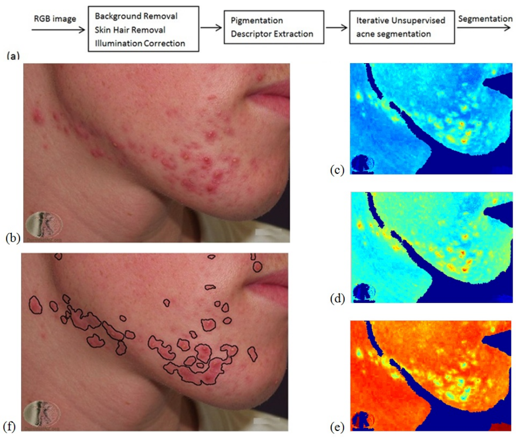


Figure 13. An initial method and result of automatic acne detection. (a) Specific steps in the acne segmentation method. (b) An example of acne disorder on human face (640 × 428 *pixels) from DermnetNZ (http://www.dermnetnz.org/). (c)-(e) pigmentation descriptors: hemoglobin, normalized red, and normalized green, respectively. (f) Segmentation result outlined with black borders on original image.*

7. Bilateral Contracts and Grants with Industry

7.1. Bilateral Contracts and Grants with Industry

7.1.1. Galderma Sophia-Antipolis

Participants: Sylvain Prigent, Xavier Descombes [Morpheme PI], Josiane Zerubia [AYIN PI].

Contribution of multi and hyperspectral imaging to skin pigmentation evaluation. Contract #4383.

7.1.2. ISA/DITEN

Participants: Aurélie Voisin, Vladimir Krylov, Josiane Zerubia [AYIN PI].

Development and validation of multitemporal image analysis methodologies for multirisk monitoring of critical structures and infrastructures. In collaboration with Gabriele Moser and Sebastiano Serpico[PI], from the University of Genoa (DITEN) and the Italian Space Agency (ISA).

7.1.3. EADS foundation

Participants: Ikhlef Bechar, Josiane Zerubia [PI].

Detection of objects in infrared imagery using phase field higher-order active contours. In collaboration with Ian Jermyn from the University of Durham (Dept of Mathematical Sciences).

7.1.4. Astrium/EADS

Participants: Paula Craciun, Josiane Zerubia [PI].

Automatic object tracking on a sequence of images taken from a geostationary satellite. In collaboration with Pierre Del Moral from Inria Bordeaux (ALEA team) and Ecole Polytechnique (CMAPX) Palaiseau.

8. Partnerships and Cooperations

8.1. Regional Initiatives

- Paula Craciun and Josiane Zerubia met Antoine Mangin, Scientific Director at ACRI-ST (http://www.acri-st.fr/English/index.html), in Sophia Antipolis to discuss about Paula Craciun's Master research work on boats detection and counting in Mediterranean harbors using marked point processes.

8.2. European Initiatives

8.2.1. Collaborations with Major European Organizations

LIRA consortium

Partners: Philips R&D (Eindhoven), CWI (Amsterdam), Fraunhofer Institutes (Berlin, Stuttgart, Darmstadt), Inria-SAM

Skincare image and signal processing: Analysis, modeling and characterization of the condition of human skin

8.3. International Initiatives

8.3.1. Participation In International Programs

- In July, during the visit of Prof. Qiyin Fang from Mc Master University (http://www.mcmaster.ca/), Hamilton, Canada, we identified a research project of mutual interests related to new optical sensors for skin imaging and their biomedical applications. the visit of Prof. Fang was supported by the French Embassy in Canada and in November we jointly applied to the France-Canada Research Fund to be able to collaborate during the next 2 years.

8.4. International Research Visitors

8.4.1. Visits of International Scientists

8.4.1.1. Internships

Siddharth Buddhiraju (from May 2012 until July 2012)

Subject: Satellite image classification using Bootstrap EM

Institution: IIT Bombay (India)

Paula Craciun (from March 2012 until August 2012)

Subject: Boats detection and counting in Mediterranean harbors

Institution: West University of Timisoara, Romania

8.4.1.2. Visiting professors

Qiyin Fang (One week in September 2012)

Subject: New optical sensors for skin imaging and their biomedical applications

Institution: McMaster University (Canada)

Joseph Francos (One week in March and one week in July 2012)

Subject: Manifold embedding for geometric deformations estimation. Application to both remote sensing and skin imaging

Institution: Ben-Gurion University (Israel)

Ian Jermyn (One week in July 2012)

Subject: Object shape detection in images using prior shape information and higher order active contours

Institution: Durham University (UK)

Zoltan Kato (One week in July 2012)

Subject: Markov random fields for image segmentation

Institution: Sveged University (Hungary)

Nataliya Zagorodna (One month in July 2012)

Subject: Use of periodic or cyclic random processes for image processing, with application to both remote sensing and skin imaging

Institution: Ternopil Ivan Pul'uj Technical University (Ukraine)

8.4.2. Visits to International Teams

- Ikhlef Bechar was visiting Dr. Ian Jermyn at Durham University, UK from October 21, 2012 until November 19, 2012.
- Yannick Verdie visited National Institute of Informatics (Nii) in Tokyo, Japan from February 15, 2012 to June 15, 2012, funded by Nii internship exchange program. He worked there on the topic of exact sub graph matching by mixed-integer linear problem.

9. Dissemination

9.1. Scientific Animation

- Ikhlef Bechar and Yuliya Tarabalka presented on June 15, 2012 their work for visiting students from SupCom-Tunis to Inria.
- Ikhlef Bechar presented his work at Astrium/EADS in Toulouse in January and at "ENVOL de la Recherche" day organized by the EADS foundation in March in Paris.
- Vladimir Krylov presented a paper at the conference IEEE ICIP in September in Orlando, USA. He was a reviewer for the journals IEEE TIP, IEEE TGRS, IEEE GRSL, IEEE JSATRS, DSP and PRL.
- Yuliya Tarabalka presented 2 papers at the conference IEEE IGARSS'2012 and a paper at the conference UkrObraz'2012. She also presented a poster at the Journées CNES Jeunes Chercheurs in Toulouse in October. She gave 4 seminars at Inria-SAM, CESBIO in Toulouse, University of Orleans and Télécom ParisTech in Paris (France). She was a reviewer for the journals IEEE TIP, IEEE TGRS, IEEE GRSL, Remote Sensing, IEEE JSTARS, and for the conferences ISPRS'2012, IEEE IGARSS'2012 and ICPRAM'2012. She was a part of the program committee for the conferences ISPRS'2012 and ICPRAM'2012. She chaired a session at the conference IEEE IGARSS'2012.
- Yannick Verdie presented a paper at the conference ECCV'12 in Florence, Italy in October. He also presented his work at the National Institute of Informatics (Nii) in Tokyo, Japan.
- Aurélie Voisin presented 2 papers at the conferences IS&T/SPIE Electronic Imaging'12 in San Francisco (USA) in January, and EUSIPCO'12 in Bucharest (Romania) in August. She presented a poster at Pleiades days organized by CNES in Toulouse in January. She was also invited to present her work by the Centre de Recherche en Automatique de Nancy (France) in June.

- Josiane Zerubia chaired a session at IEEE ICIP in September in Orlando, USA, and attended the IVMSP-TC meeting there. She was a reviewer for TS (Traitement du Signal) and SFPT (Revue Française de Photogrammétrie et de Télédétection). She also was a reviewer and/or a program committee member for ICASSP'12, ISBI'12 and ICIP'12, as member of the IEEE BISP TC and IEEE IVMSP TC, and for SPIE-ISPRS'12 ('Image and Signal Processing for Remote Sensing') and ICPRAM'12. She is an IEEE Fellow. She was a member of the Biological Image and Signal Processing (BISP) Technical Committee till April 2012 and is a member of the Image, Video and Multidimensional Signal Processing (IVMSP) Technical Committee of the IEEE Signal Processing Society. She is an Associate Editor of the collection 'Foundation and Trends in Signal Processing' [http://www.nowpublishers.com/]. She is a member of the Editorial Boards of IJCV, the Revue Française de Photogrammétrie et de Télédétection of SFPT and the journal 'Traitement du Signal'. She is an Associate Editor of the electronic journal Earthzine [http://www.earthzine.org/]. Josiane Zerubia visited Astrium EADS Toulouse in January. She also participated in the CNES Pleiades days and CNES Research and Technology day both in Toulouse in January. In March, she presented Inria-SAM activities and the research work of AYIN at BASF-France Headquarters at Levallois Perret, attended the IGN Research days in St Mande and participated to the Editorial Board meeting of SFPT at CNES in Paris. In April she visited ACRI ST in Sophia Antipolis. In June she attended the KAL'Haiti day at CNES in Paris. She participated to the LIRA Consortium workshop at Inria-SAM in September and to a LIRA meeting with Philips R&D in December. As a PI, she regularly organized and attended meetings with Galderma in Sophia-Antipolis. As a Co-PI, she also organized and participated to several meetings with IRD at UMR AMAP in Montpellier and at Inria-SAM. She is a deputy of Frederic Alexandre at the Executive Committee of LIRA Consortium (Philips, CWI, Fraunhofer, Inria), and a Co-PI of an Inria/DITEN/ISA project. She is a member of the ORFEO group (CNES). She is a consultant for Galderma R&D in Sophia-Antipolis. Finally, she is a member of the program committee of Master 2 in Computational Biology and Biomedicine (CBB) at the University of Nice Sophia Antipolis in charge of sponsoring.

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

Master: Yuliya Tarabalka, Digital imaging, 15h eq. TD (2h of lectures + 12h of TD), M2 SVS ISAB, Université de Nice Sophia-Antipolis, France

Master et PhD: Yuliya Tarabalka, Computer vision, 8h of lectures = 12h eq. TD, M1 and M2, Ternopil Ivan Pul'uj National Technical University, Ukraine

Licence: Yuliya Tarabalka, Techniques for statistical data analysis, 39h eq. TD, L1, École Polytechnique de l'Université de Nice Sophia-Antipolis, France

Master: Josiane Zerubia, Deconvolution and denoising in confocal microscopy, 18h eq. TD (12h of lectures), M2 IFI BCC, Université de Nice Sophia-Antipolis, France. Furthermore she is also director of this course (total: 24h of lectures).

Master: Josiane Zerubia, Advanced techniques in signal and image processing, 30h eq. TD (20h of lectures), ISAE/SUPAERO, France. Furthermore she is also director of this course (total: 30h of lectures and 12.5h of TD). This course has been given to the third-year students of ISAE/SUPAERO and was also validated by Master 2 of Applied Mathematics of University Paul Sabatier of Toulouse.

Master: Josiane Zerubia, Introduction to image processing, 4.5h eq. TD (3h of lectures), M2 SVS ISAB, Université de Nice Sophia-Antipolis, France. Furthermore she is also director of the course "Digital imaging" at UNS, Master2 SVS ISAB, UE3 (total: 25h of lectures and 25h of TD).

Licence: Jia Zhou, Mathematics, 60h eq. TD, L2, IUT Montpellier, France.

9.2.2. Supervision

9.2.2.1. Ph.D. theses

PhD: Aurélie Voisin, Supervised classification of high-resolution remote sensing images including urban areas by using Markovian models, University of Nice-Sophia Antipolis, Defended on October 17th, 2012, Josiane Zerubia.

PhD: Sylvain Prigent, Contribution of multi and hyperspectral imaging to skin pigmentation evaluation, University of Nice-Sophia Antipolis, Defended on November 30th, 2012, Xavier Descombes and Josiane Zerubia.

PhD: Jia Zhou, Object identification on remote sensing images of tropical forest canopies - applications to the study of Eucalyptus plantation and mangrove forest, University of Montpellier 2, Defended on November 16th, 2012, Pierre Couteron and Josiane Zerubia.

PhD in progress: Yannick Verdié, Urban scene analysis from unstructured point data, University of Nice-Sophia Antipolis, started in November 2010, Florent Lafarge and Josiane Zerubia.

PhD in progress: Seong-Gyun Jeong, New image processing methods for skin condition evaluation, University of Nice-Sophia Antipolis, started in December 2012, Josiane Zerubia and Yuliya Tarabalka.

PhD in progress: Paula Craciun, Automatic object tracking on a sequence of images taken from a geostationary satellite, University of Nice-Sophia Antipolis, started in December 2012, Josiane Zerubia and Pierre Del Moral.

9.2.3. Juries

- Josiane Zerubia was a reviewer of one HdR and of one PhD thesis, and member of 3 PhD committees.

9.3. Popularization

- Josiane Zerubia attended a meeting at ICIP'12 in Orlando organized by IEEE women in engineering (http://www.ieee.org/membership_services/membership/women/women_about.html). She met several female PhD students, postdocs and junior researchers to exchange views on women scientific careers in the world.

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Publications of the year

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[2] A. VOISIN. *Classification supervisée d'images d'observation de la Terre à haute résolution par utilisation de méthodes markoviennes*, Université de Nice Sophia-Antipolis, October 2012, http://hal.inria.fr/tel-00747906.

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