Activity Report 2013

Team AYIN

Models of spatio-temporal structure for high-resolution image processing

RESEARCH CENTER
Sophia Antipolis - Méditerranée

THEME
Vision, perception and multimedia interpretation

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Team AYIN

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

Creation of the Team: 2012 January 01.

1. Members

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Marc Berthod [Emeritus Senior Researcher, Inria, HdR]
Ian Jermyn [Junior Researcher, Inria, from Oct 2013]
Yuliya Tarabalka [Junior Researcher, Inria]

PhD Students

Paula Craciun [Inria, Inria-ASTRIUM EADS grant]
Ihsen Hedhli [Genoa University/Inria, Italian Government - CNES grant, from Jan 2013]
Seong-Gyun Jeong [UNS/Inria]

Post-Doctoral Fellows

Ikhlef Bechar [EADS Foundation/Inria, until Mar 2013]
Aurélie Boisbunon [CNES/Inria, from Oct 2013]
Zhao Liu [DPE Inria, until Dec 2013]

Visiting Scientists

Qiyin Fang [McMaster University, Canada, one week in May 2013]
Zoltan Kato [Szeged University, Hungary, from Jul 2013 until Aug 2013]
Gregoire Mercier [Telecom Bretagne, Brest, one week in June 2013 and one week in December 2013]
Gabriele Moser [Genoa University, Italy, one week in July 2013]

Others

Claudio Price González [Masters Internship, Inria Chile, from Jan 2013 until Mar 2013]
Aakanksha Rana [Masters Internship, Inria/EURECOM, from Jul 2013 until Sep 2013]
Praveer Singh [Masters Internship, Inria/EURECOM, from Jul 2013 until Sep 2013]

2. Overall Objectives

2.1. Overall Objectives

The Ayin team is devoted to the modeling of spatio-temporal structures, for use in the analysis of high-resolution image data, with particular application to images arising in remote sensing, broadly interpreted, and skin care.

The latest and upcoming generations of imaging sensors, for example, in remote sensing (Pleiades, EnMAP, Sentinel) and medicine (Philips, Christie Medical), result in large volumes of heterogeneous data with high spatial, spectral, and temporal resolution. High resolution imagery (this may refer to spatial, spectral, or temporal resolutions) is a rich source of information about the imaged scene, information that is unavailable in lower resolution data. In particular, spatial and spatio-temporal structures abound, and frequently constitute the information of greatest interest in practice. As a result, such imagery is vital to advances in a range of applications (urban monitoring, precision agriculture, skin disease diagnosis, *etc.*). The high resolution and high volume of the imagery presents new challenges, however, that must be overcome if the potential of the data is to be realized. Extracting the available information requires the development of new modeling techniques adapted to the nature and profusion of structures, and the design of corresponding algorithms, which must in turn be implemented in a time- and space-efficient way if the techniques are to be made operational.

The overall scientific objective of the Ayin team is precisely to advance the state of theory and practice in this area by the development of such modeling techniques and the design of such algorithms. We make use of a variety of methodologies in order to achieve this goal, taking a broadly Bayesian point of view. This point of view suggests dividing the modeling task into two parts: modeling of the scene, *i.e.* describing the scenes to be expected in any given application; and modeling of the image, *i.e.* describing the images to be expected from any given scene. Ayin focuses on spatio-, spatio-temporal, and spectral structure, leading to the modeling of geometrical properties on the one hand, and large, coherent structures in images and image sequences on the other. The new models also require new algorithms, for dealing with the nuisance parameters they contain, and for extracting the desired information. This forms a third major component of Ayin's research. The models and algorithms are developed in parallel with their application to information extraction from very high resolution images, in particular data arising in remote sensing and skin care.

2.2. Highlights of the Year

- Ian Jermyn rejoined Inria as a CR1 in the Ayin team in October 2013.
- Yuliya Tarabalka was invited to present the work of the Ayin team at the India-France Technology Summit in New Delhi, India in October.
- Josiane Zerubia was invited to present Ayin's research on remote sensing at the Institute of Mathematics and its Applications, University of Minnesota, USA, in September.

3. Research Program

3.1. Geometric and shape modeling

One of the grand challenges of computer vision and image processing is the expression and use of prior geometric information via the construction of appropriate models. For very high resolution imagery, this problem becomes critically important, as the increasing resolution of the data results in the appearance of a great deal of complex geometric structure hitherto invisible. Ayin studies various approaches to the construction of models of geometry and shape.

3.1.1. Stochastic geometry

One of the most promising approaches to the inclusion of this type of information is stochastic geometry, which is an important research direction 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 distributions are called 'marked point processes'. New models are being developed both for remote sensing applications, and for skin care problems, such as wrinkle and acne detection.

3.1.2. Contours, phase fields, and MRFs with long-range interactions

An alternative approach to shape modeling starts with generic 'regions' in the image, and adds constraints in order to model specific shapes and objects. Ayin investigates contour, phase field, and binary field representations of regions, incorporating shape information via highly-structured long-range interactions that constrain the set of high-probability regions to those with specific geometric properties. This class of models can represent infinite-dimensional families of shapes and families with unbounded topology, as well as families consisting of an arbitrary number of object instances, at no extra computational cost. Key sub-problems include the development of models of more complex shapes and shape configurations; the development of models in more than two spatial dimensions; and understanding the equivalences between models in different representations and approaches.

3.1.3. Shapes in time

Ayin is concerned with spatio- and spatio-temporal structure. To deal with the latter, the above scene modeling approaches are extended into the time dimension, either by modeling time dependence directly, or, in the field-based approaches, by modeling spacetime structures, or, in the stochastic geometry approach, by including the time t in the mark. An example is a spatio-temporal graph-cut-based method that introduces directed infinite links connecting pixels in successive image frames in order to impose constraints on shape change.

3.2. Image modeling

The key issue that arises in modeling the high-resolution image data generated in Ayin's applications, is how to include large-scale spatial, temporal, and spectral dependencies. Ayin investigates approaches to the construction of image models including such dependencies. A central question in teh use of such models is how to deal with the large data volumes arising both from the large size of the images involved, and the existence of large image collections. Fortunately, high dimensionality typically implies data redundancy, and so Ayin investigates methods for reducing the dimensionality of the data and describing the spatial, temporal, and spectral dependencies in ways that allow efficient data processing.

3.2.1. Markov random fields with long-range and higher-order interactions

One way to achieve large-scale dependencies is via explicit long-range interactions. MRFs with long-range interactions are also used in Ayin to model geometric spatial and temporal structure, and the techniques and algorithms developed there will also be applied to image modeling. In modeling image structures, however, other important properties, such as control of the relative phase of Fourier components, and spontaneous symmetry breaking, may also be required. These properties can only be achieved by higher-order interactions. These require specific techniques and algorithms, which are developed in parallel with the models.

3.2.2. Hierarchical models

Another way to achieve long-range dependencies is via shorter range interactions in a hierarchical structure. Ayin works on the development of models defined as a set of hierarchical image partitions represented by a binary forest structure. Key sub-problems include the development of multi-feature models of image regions as an ensemble of spectral, texture, geometrical, and classification features, where we search to optimize the ratio between discrimination capacity of the feature space and dimensionality of this space; and the development of similarity criteria between image regions, which would compute distances between regions in the designed feature space and would be data-driven and scale-independent. One way to proceed in the latter case consists in developing a composite kernel method, which would seek to project multi-feature data into a new space, where regions from different thematic categories become linearly or almost linearly separable. This involves developing kernel functions as a combination of basis kernels, and estimating kernel-based support vector machine parameters.

3.3. Algorithms

Computational techniques are necessary in order to extract the information of interest from the models. In addition, most models contain 'nuisance parameters', including the structure of the models themselves, that must be dealt with in some way. Ayin is interested in adapting and developing methods for solving these problems in cases where existing methods are inadequate.

3.3.1. Nuisance parameters and parameter estimation

In order to render the models operational, it is crucial to find some way to deal with nuisance parameters. In a Bayesian framework, the parameters must be integrated out. Unfortunately, this is usually very difficult. Fortunately, Laplace's method often provides a good approximation, in many cases being equivalent to classical maximum likelihood parameter estimation. Even these problems are not easy to solve, however, when dealing with complex, structured models. This is particularly true when it is necessary to estimate simultaneously both the information of interest and the parameters. Ayin is developing a number of different methods for dealing with nuisance parameters, corresponding to the diversity of modeling approaches.

3.3.2. Information extraction

Extracting the information of interest from any model involves making estimates based on various criteria, for example MAP, MPM, or MMSE. Computing these estimates often requires the solution of hard optimization problems. The complexity of many of the models to be developed within Ayin means that off-the-shelf algorithms and current techniques are often not capable of solving these problems. Ayin develops a diversity of algorithmic approaches adapted to the particular models developed.

4. Application Domains

4.1. Remote sensing

With the development and launch of new instruments (for instance, GeoEye, Ikonos, Pleiades, COSMO-SkyMed, TerraSAR-X, and future missions EnMAP, PRISMA, HYPXIM, ...) capturing Earth images at very high spatial, spectral, and temporal resolutions, numerous new applications arise, such as precision agriculture, natural disaster management, monitoring of urban environments, and mineralogy. We will apply our new methodologies to the analysis of SAR, multi- and hyper-spectral remote sensing images and temporal sequences. In particular, we will address image segmentation and classification, change detection, the extraction of structures, and object tracking.

4.2. Skin care

The most recent sensors used in dermatology and cosmetology produce images with very high spatial, spectral, and temporal resolutions. As with remote sensing, numerous applications then arise that can make use of the new information. In the application to dermatology, we are particularly interested in hyperpigmentation detection and the evaluation of the severity of various disorders (for instance, for melasma, vitiligo, acne, melanoma, etc.). In the application to cosmetology, our main goals are the analysis, modeling, and characterization of the condition of human skin, especially as applied to the evaluation of methods designed to influence that condition.

5. Software and Platforms

5.1. Deposits

- The software SAMD (Semi-Automatic Melanoma Detection) V1.0 was deposited with the APP in December 2013. It has been tested on public databases.
- The software SAAD (Semi-Automatic Acne Detection) V1.0 was deposited with the APP in December 2013. It has been tested on public databases as well as on data sets provided by CHU Nice and Galderma.

6. New Results

6.1. Markov Random Fields

6.1.1. Hierarchical multitemporal and multiresolution classification in remote sensing imagery

Participants: Ihsen Hedhli, Josiane Zerubia [contact].

This activity was conducted in collaboration with Dr. Gabriele Moser and Prof. Sebastiano B. Serpico (Department of Electrical, Electronic, and Telecommunications Engineering and Naval Architecture, DITEN, University of Genoa) [http://www.unige.it] with partial financial support from CNES [http://www.cnes.fr].

Markov random field (MRF), hierarchical classification, satellite image time series

The capability to monitor the Earth's surface, and especially urban and built-up areas, for environmental disasters such as floods or earthquakes, and to assess the ground impact and damage caused by such events, play important roles from multiple social, economic, and human viewpoints. Current and forthcoming satellite missions for Earth observation (EO; e.g., Pleiades, COSMO-SkyMed, TerraSAR-X, Sentinel) possess huge potential for such applications, as they allow a spatially distributed and temporally repetitive view of the monitored area at the desired spatial scales. In this framework, accurate and time-efficient classification methods using time series are especially important tools for supporting rapid and reliable assessment of the ground changes and damage induced by a disaster, in particular when an extensive area has been affected. Given the huge amount and variety of data available, the main difficulty is to find a classifier that takes into account multi-band, multi-resolution, multi-date, and possibly multi-sensor data.

This research addresses the problem of supervised classification at multiple spatial resolutions for multiple dates. The approach is based on the extension of recent methods proposed by DITEN and/or AYIN [4], [5], [6]. These methods focus on a supervised Bayesian classifier that combines joint class-conditional statistical modeling and a hierarchical Markov random field. The key idea of the proposed method is to combine the multiresolution modeling capabilities of this previous technique with a model for the temporal correlation among distinct images in a time series. For this purpose, a hierarchical spatio-temporal Markov random field model has been proposed that is aimed at fusing the pixel-wise, neighborhood, multiresolution, and temporal information associated with the input time series. Pixel-wise information is characterized through separate statistical modeling for each target class (e.g., vegetation, urban, etc.) by using a finite mixture model, estimated using a modified stochastic expectation maximization algorithm. Such a model is well suited to dealing with heterogeneous classes, and each mixture component may reflect the contribution of the different materials contained in a given class. At each considered resolution, the different input bands are statistically combined by using multivariate copulas, and the resulting statistical pixel-wise model is integrated in a hierarchical Markov random field based on a quad-tree structure. Among the different algorithms employed in the literature, we chose to use an exact estimator based on the marginal posterior mode (MPM). Specifically, a new formulation of MPM is developed to formalize, within the aforementioned hierarchical model, a 'cascade' multi-date decision rule. Such a classifier is sufficiently flexible to take into account different types of data (e.g., multispectral, panchromatic, synthetic aperture radar). The method is being experimentally validated with data acquired over a given area at different resolutions (e.g., multiresolution Pleiades images), directly integrated at the different levels of the cascade hierarchical model. An example of a classification result is illustrated in Fig. 1. Here, Pleiades multiresolution images (panchromatic resolution: 50 centimeters and multispectral resolution: 2 meters) acquired over Port-au-Prince quay (Haiti) on two different dates are considered. Spatially disjoint training areas were manually annotated. The classification has been performed with respect to 5 main classes: urban areas, natural landscape, sand, containers, and wet areas. A visual analysis of the resulting map suggests that the proposed approach achieves remarkable accuracy.

6.1.2. A multi-layer Markov model for change detection in temporally separated aerial image pairs

Participants: Praveer Singh, Josiane Zerubia [contact].

This work was carried out in collaboration with Prof. Zoltan Kato from Institute of Informatics, University of Szeged, Hungary. [http://www.inf.u-szeged.hu/~kato/].

Multilayer Markov Random Fields (MRF), Histogram of Gradients (HOG), change detection, graph-cut optimization, aerial / satellite images.

In the proposed approach, we have tried to include both texture as well as pixel level information to build a three layer Markov model using the *Histogram of Oriented Gradients (HOG)* and the *Gray Level Difference* features on the topmost and bottommost layer respectively. Using a ground truth (GT) mask defined manually by an expert for each of the image pairs in the data set (obtained from the Hungarian Institute of Geodesy, Cartography and Remote Sensing), we employ a supervised technique to mark the initial set of pixels / sites as foreground or background. On the basis of the *HOG difference* and the *Gray level difference* feature vector

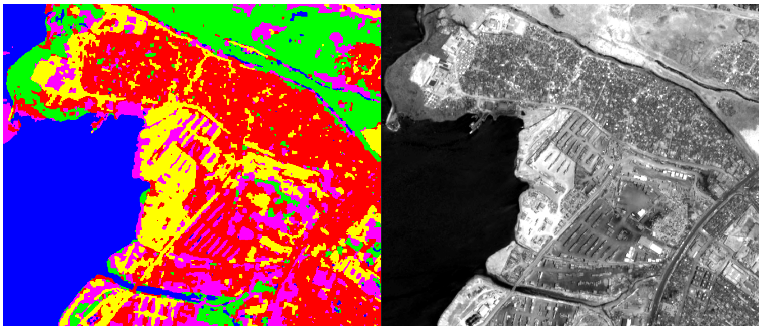


Figure 1. Right: Initial optical image of Port-au-Prince (Haiti) (©CNES, 2013). Left: Classification map obtained with the proposed multi-temporal hierarchical method for the 5 classes (blue: wet areas; green: vegetation; red: urban areas; yellow: sand; purple: containers).

corresponding to all the pixels in the image pair, a probability density function is fitted individually for the binary label set comprising of foreground and background labels using the GT. The probabilistic estimate is calculated using one training image pair for each data set. Using this probabilistic measure, a negative log likelihood is computed for each pixel (for both the features as well as the binary label set) which is then passed to the energy function of the proposed 3-layer MRF model. The final segmentation is obtained by minimizing the energy using a graph-cut algorithm, and subsequently a final foreground and background labelling is obtained over the combined layer. Figure 2, shows aerial image pairs, one of them captured in 1984 by FOMI, Hungary (a) and the other one by GoogleEarth in 2007 (c). (b) is the ground truth and (d) is a combination of the hierarchical MRF based change detection (in red), ground truth (in green) and changes detected correctly (in yellow).

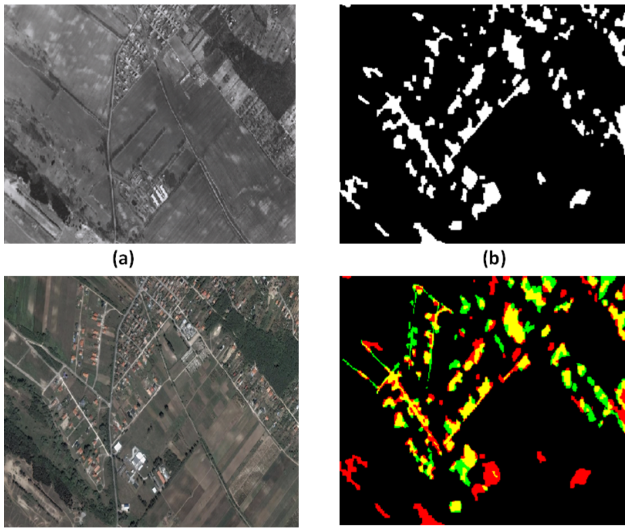
6.1.3. Graph-cut model for spectral-spatial classification of hyperspectral images

Participants: Aakanksha Rana, Yuliya Tarabalka [contact].

Hyperspectral images, graph cut, multi-label alpha expansion, contextual information, energy minimization

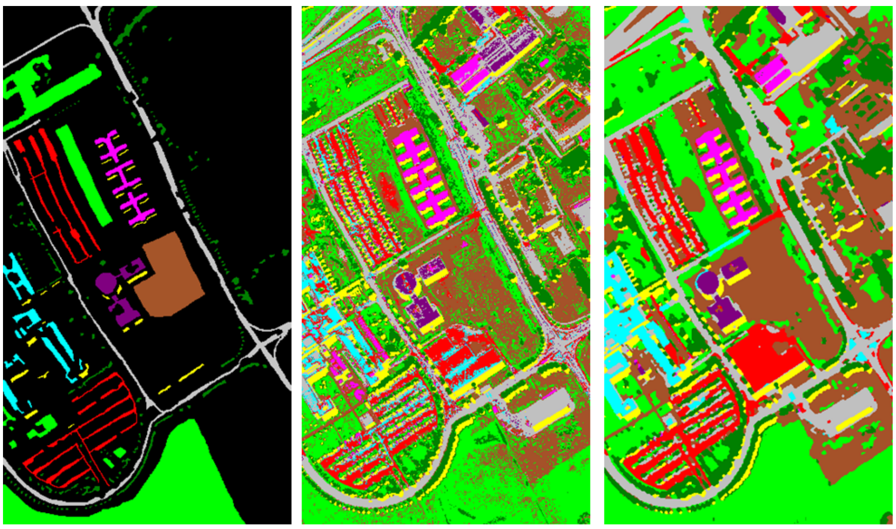
The very high spatial and spectral resolution of the last generation of remote sensors provides rich information about every pixel in an image scene, hence opening new perspectives in classification, but also presenting the challenge of analysing high data volumes. While pixel-wise classification methods analyze each pixel independently, classification results can be significantly improved by including spatial information in a classifier.

In this work, we proposed a spectral-spatial method for hyperspectral image classification based on a graph cut. The classification task is expressed as an energy minimization problem on the spatio-temporal graph of image pixels, and is solved by using the graph-cut α-expansion approach. The energy to optimize is computed as a sum of data and interaction energy terms, respectively. The data energy term is computed using the outputs of the probabilistic support vector machines classification. The second energy term, which expresses the interaction between spatially adjacent pixels in the eight-neighborhood, is computed by using dissimilarity measures between spectral vectors, such as vector norms, spectral angle map, or spectral information divergence. The performance of the proposed method was validated on hyperspectral images captured by the ROSIS and the AVIRIS sensors. Figure 3 compares classification results obtained by applying support vector machines and the proposed approach for the ROSIS hyperspectral image acquired over the University of Pavia. The new method yields higher classification accuracies when compared to the recent state-of-the-art approaches.



(a) (b) (c) (d)

Figure 2. Change detection in an aerial image pair using a hierarchical MRF. a) Aerial image captured in 1984 by ©FOMI; b) Ground truth; c) Aerial image captured by ©GoogleEarth in 2007; d) Combination of the hierarchical MRF based change detection (in red), ground truth (in green), and changes detected correctly (in yellow).



(a) (b) (c)

Figure 3. Hyperspectral image of the University of Pavia. (a) Ground-truth (b) Support vector machines classification map. (c) Graph-cut classification map.

6.2. Marked point processes

6.2.1. Marked point process models for boat extraction from high resolution remotely sensed optical images

Participants: Paula Craciun, Josiane Zerubia [contact].

This work was done in collaboration with Dr. Mathias Ortner (ASTRIUM EADS) [http://www.astrium.eads.net] and Prof. Pierre del Moral (ALEA team, Inria Bordeaux).

Stochastic geometry, Markov model, detection, parallel algorithm

Marked point process models have been successfully applied to object extraction problems in high resolution optical images, ranging from tree crown or road extraction to flamingo or crowd counting. We try to model the problem of boat detection and counting in harbors. The difficulty of this problem resides in the particular distribution of the objects. The model consists of two energy terms: a data term, which reflects the model's fidelity to the input image, and a prior term containing knowledge about the objects to be extracted. The model relies on a high number of parameters and is computationally intensive. The purpose of this research is to extend a previously developed marked point process model of ellipses and make it more computationally manageable. In particular, we add a preprocessing step in which we determine the global and local direction of the objects [8], [17]. Additionally, segmentation of land and water areas is implemented as a preprocessing step. Boat extraction results are shown in Figure 4. Finally, we implement an improved parallel sampler, thereby drastically improving computation times.

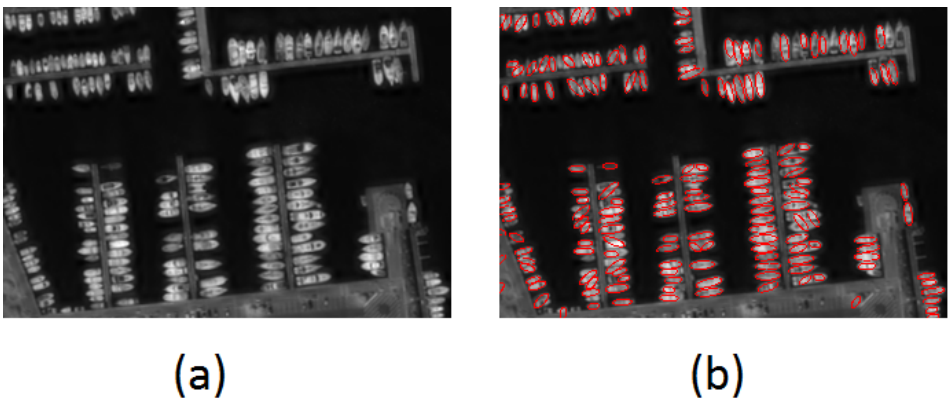


Figure 4. Boat extraction in a harbor using a marked point process model (a) harbor image ©CNES; (b) extraction results.

6.2.2. Parameter estimation for automatic object detection in very high resolution optical images

Participants: Aurélie Boisbunon, Josiane Zerubia [contact].

This work was partially funded by the French Space Agency CNES [http://www.cnes.fr].

Markov model, Monte Carlo method, evolutionary algorithm, optimization, image processing, detection

The main goal of this work is to study parameter estimation for several marked point processes. Currently, the parameters of such models are estimated by a Stochastic Expectation and Minimization (SEM) algorithm, which is computationally expensive. We will investigate and propose new parameter estimation techniques, based on Randomized Quasi-Likelihood and evolutionary algorithms, for the parameters of the probability density of a marked point process. The goal is to improve computation times with respect to SEM while maintaining similar accuracy. The first application envisioned is boat detection for harbor activity monitoring (see Figure 5).

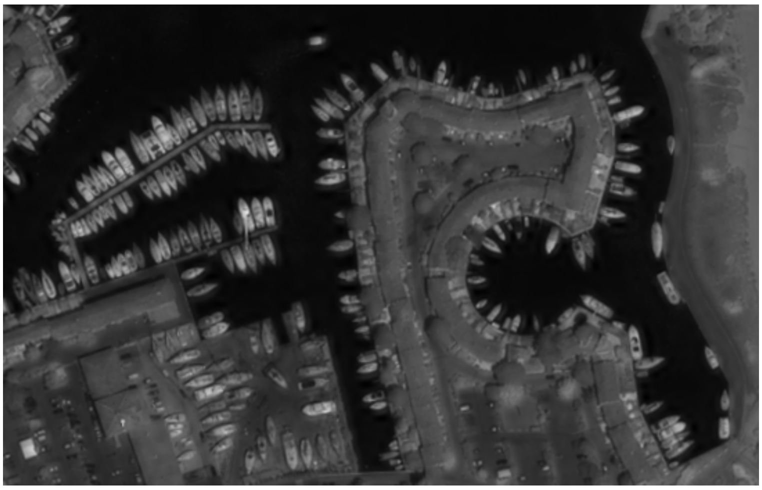


Figure 5. Harbor activity monitoring. ©CNES

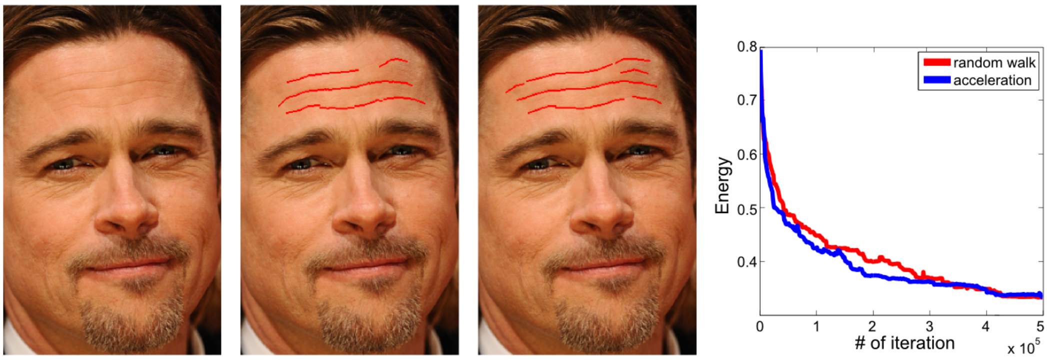
6.2.3. Wrinkle detection using a marked point process

Participants: Seong-Gyun Jeong, Yuliya Tarabalka, Josiane Zerubia [contact].

Skin image processing, wrinkle detection, line detection, marked point process, RJMCMC

We developed a novel wrinkle detection algorithm using a marked point process (MPP). Since wrinkles are the most important visual features of aging, automatic wrinkle detection algorithm can have many applications, such as the evaluation of cosmetic products, age estimation, and aging synthesis. In order to detect wrinkles of arbitrary shape, we represent wrinkles as a set of small line segments. Note that each line segment consists of a length and an orientation. A stochastic wrinkle model density exploits the local edge profile and constrains the spatial placement of adjacent lines. To maximize the model density, we employ a reversible jump Markov chain Monte Carlo (RJMCMC) sampler. A state of the Markov chain corresponds to a wrinkle configuration, and it is updated according to the acceptance ratio of sub-transition kernels: line segment births and deaths, and an affine transformation kernel. The transition kernels perturb the Markov chain by adding, removing, or modifying a wrinkle segment in the current configuration. In addition, an acceleration scheme has been developed for the RJMCMC sampler that enforces the connectivity of line segments. RJMCMC with acceleration reduces mixing time and improves detection accuracy as well.

Figure 6 compares wrinkle detection results simulated by random walk and the proposed acceleration scheme. The proposed algorithm faithfully detects wrinkles as smoothly connected lines. In addition, Figure 6 (d) plots the energy as a function of the number of iterations. It shows that the proposed acceleration method reaches a lower energy more rapidly than the random walk method.



(a) (b) (c) (d)

Figure 6. Comparison of wrinkle detection results using different simulation procedures: (b) random walk and (c) the proposed acceleration scheme. Energy as a function of the number of iterations is plotted in (d).

6.3. Shapes and contours

6.3.1. Shape reconstruction from lidar data

Participant: Ian Jermyn [contact].

This work is being done in collaboration with Dr. Stuart Jones, Dr. Jochen Einbeck, and PhD student Thomai Tsiftsi of Durham University, UK [https://www.dur.ac.uk].

sand body, petroleum, shape, submanifold,

The cross-sectional shapes of 'sand bodies', ancient underground river channels filled with sediment, are of great interest in geology, and to the petroleum industry, because the shape is strongly correlated with the nature of the sediment, and in particular with its porosity, which in turn helps determine the volume fraction of crude oil contained in the sand body. The geological literature, however, only discusses simple characterizations of these shapes, and there is much room for improvement. This project aims to build probabilistic models of the cross-sectional shapes of sand bodies based on lidar point cloud data gathered from surface-projecting sand bodies by geologists in the field. Such models, when built, can be used to test the current geological classification of sand bodies, to generate new and geologically relevant classes, and to build functional models of the connection between sand body shape and oil yield.

Current work is focused on extracting reliable cross-sectional shapes from the lidar data (see Figure 7), a difficult task in itself since the sand bodies are frequently occluded or otherwise incomplete. Bayesian inference based on parameterized models of shape suggested by the current geological classification are used for this purpose. Since sand body shapes are concentrated near a low-dimensional submanifold of shape space, these models will later be extended using techniques such as mixtures built on principal curves, adapted to curved manifolds, in order to find and characterize this submanifold.

6.3.2. Riemannian metrics on spaces of curves and surfaces

Participant: Ian Jermyn [contact].

This work is being done in collaboration with Prof. Anuj Srivastava of Florida State University [http://www.fsu.edu].

Shape, Riemannian metric, elastic, curve, surface, functional data, alignment

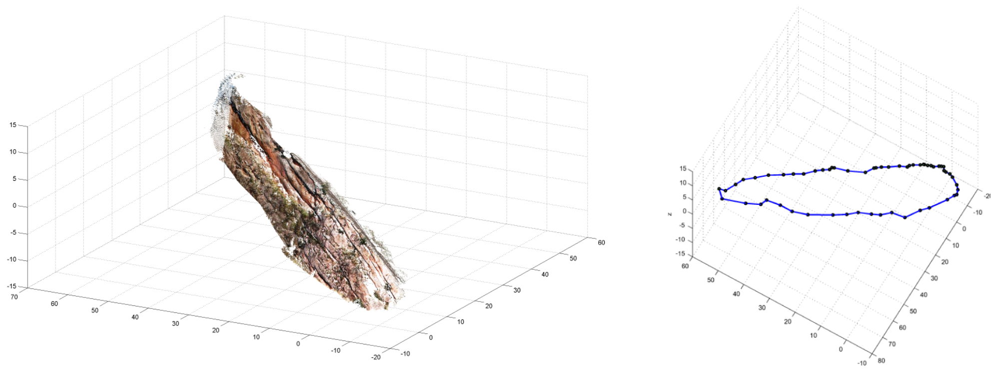


Figure 7. Left: a point cloud containing a sand body extracted from a larger cloud. Right: cross-sectional shape derived from the point cloud.

Statistical shape modelling has many applications in image processing and beyond. One of the key problems in this area is to develop and understand measures of shape similarity. One approach uses Riemannian metrics defined on 'shape space', the quotient of spaces of sphere or disc embeddings by similarities or other geometric group, and the diffeomorphism group of the sphere or disc. These metrics are defined by Riemannian metrics on the space of embeddings on which the transformation groups act by isometries, and so attention is focused on understanding such metrics and their properties.

Current work is focused on two areas. The first is on classifying and describing the diffeomorphism-invariant metrics on function spaces (shapes in one dimension) that satisfy additional desiderata useful in different applications, with particular application to function alignment. The second is on generalizing to surfaces the elastic metric much used in the case of curves, and in finding surface representations that permit analytic results to be derived, or that simplify computations, in the same way that the square root velocity representation simplifies computations involving the elastic metric on curves (see Figure 8).

6.3.3. Sampling methods for random field models of shape

Participant: Ian Jermyn [contact].

Part of this work is being done in collaboration with Prof. Zoltan Kato and PhD student Csaba Molnar of the University of Szeged, Hungary [http://www.inf.u-szeged.hu/~kato/], and part in collaboration with PhD student Michael Racovitan of Durham University, UK [https://www.dur.ac.uk].

Shape, long range interaction, Markov random field, phase field, contour, learning, wavelet

The detection and segmentation of objects from images is a problem with innumerable applications in many domains. Probabilistic models of shape, used as prior distributions in the inference process, are a necessity in solving any nontrivial instance of this problem. In many cases of importance, the shapes to be modelled cannot be treated efficiently, or at all, with current techniques, for example when multiple instances of an object must be segmented. The overall goal of this project is to develop a general shape modelling methodology capable of dealing with these difficult cases, as well as more traditional instances of the problem.

Recent algorithmic work has focused on developing efficient sampling methods for the models, for use in parameter and model learning. The models, whether expressed in terms of shape boundaries, phase fields, or binary fields, contain many long-range frustrated interactions, and hence are not amenable to standard techniques. Simplifications of the interaction structure using adapted wavelet bases, and re-expressions of the models using varieties of Hubbard-Stratanovich transformation are two directions being explored.

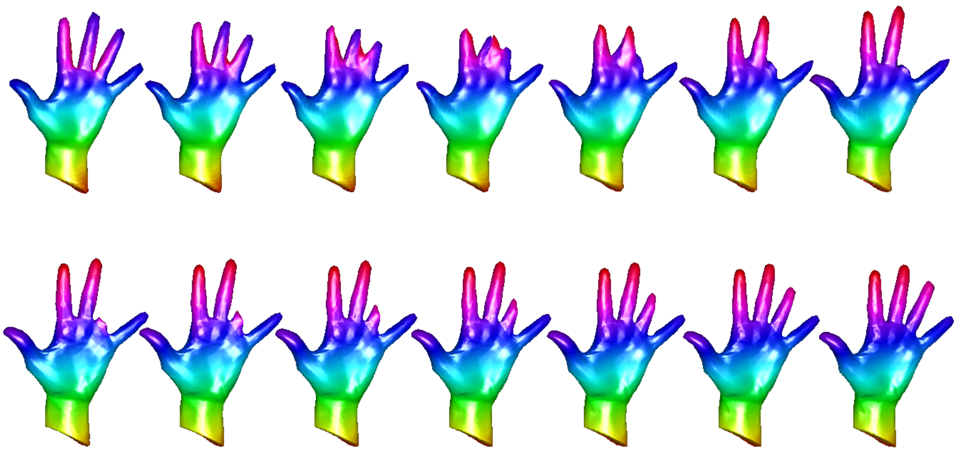


Figure 8. Top: interpolating surfaces based on a previous Riemannian metric. Bottom: interploating shapes based on the generalized elastic metric.

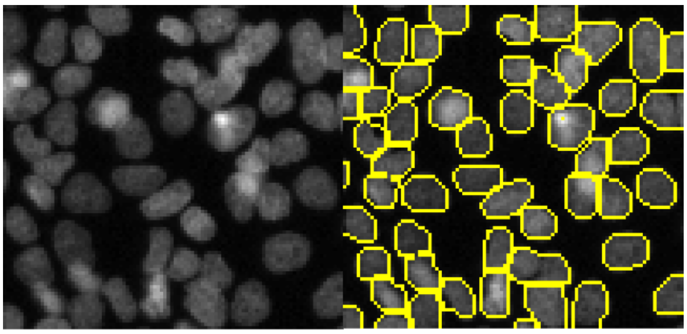


Figure 9. A typical result on an image of lipid cells.

6.3.4. *Multiple-instance object detection via a third-order active contour shape model*

Participants: Ikhlef Bechar, Ian Jermyn, Josiane Zerubia [contact].

This work was funded by the EADS Foundation [http://www.fondation.eads.com].

Object detection, multiple objects, shape, invariance, prior, higher-order active contour (HOAC), energy minimization

Recent modelling work has focused on generalizing the higher-active contour methodology to families of shapes whose members consist of an arbitrary number of object instances, each of which is similar to a given reference shape. This means finding energies on the space of regions that possess low-energy local minima corresponding to an arbitrary number of instances of the reference shape. To this end, we have studied a family of fourth-order energy functionals on regions based on a kernel given in closed form as a function of the reference region. The energy has, amongst its global minima, regions consisting of an arbitrary number of well-separated instances of the reference shape, each under an arbitrary Euclidean transformation, thereby eliminating the need to estimate group-valued 'pose' parameters. It may be combined with a likelihood energy, and the result minimized using gradient descent, speeded up by use of the Fourier domain. Although problems still remain, a series of experiments on both synthetic and real images has demonstrated the feasibility of the approach (see Figure 10).

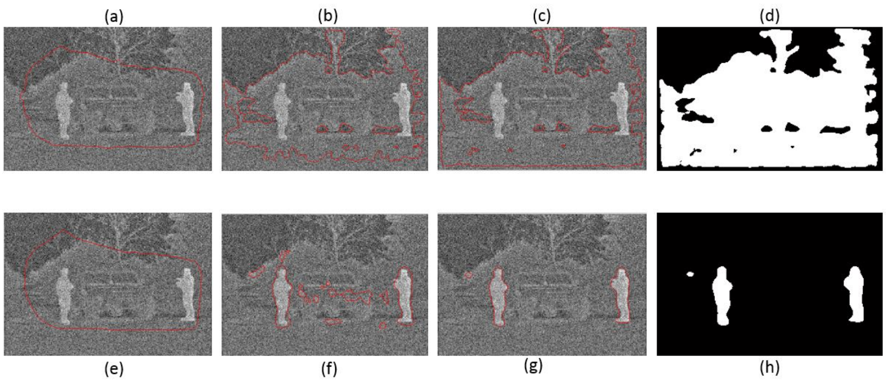


Figure 10. Detection of a shape in a noisy infrared image (SNR = 5dB): (top row) without using prior shape knowledge, and (bottom row) using the proposed fourth-order prior shape model. First column: initialization; second column: intermediate contour; third column: final contour; fourth column: segmentation.

6.4. Shapes in time

6.4.1. *Graph-based model for multitemporal segmentation of sea ice floes from satellite data*

Participants: Claudio Price González, Yuliya Tarabalka [contact].

This work has been done in collaboration with Dr. Ludovic Brucker (NASA GSFC, USA) [http://www.nasa.gov].

Multitemporal segmentation, region growing, MODIS, sea ice floes

Automated segmentation of the evolution of sea ice from satellite images would allow scientists studying climate change to build accurate models of the sea ice meltdown process, which is a sensitive climate indicator. In this work, we proposed a new method which uses shape analysis and graph-based optimization to segment a multiyear ice floe from time series of satellite images [13]. The new approach combines data from two instruments onboard the NASA Aqua satellite, enabling several measurements per day over the Earth's polar regions: Advanced Microwave Scanning Radiometer - Earth Observing System (AMSR-E); and Moderate-Resolution Imaging Spectroradiometer (MODIS). The method performs best merge region growing, followed by energy minimization on the image graph, where the energy consists of two terms describing the floe shape (shape term) and the gradient between the floe and the background (data term), respectively. We validated the performance of the proposed method for segmentation of a shrinking ice floe from a sequence of AMSR-E and MODIS images acquired in August–October 2008 (see Figure 11). The results obtained showed both the effectiveness of the proposed approach and its robustness to low-contrast data.

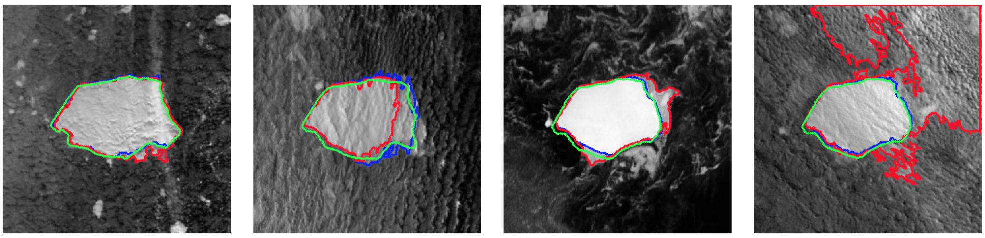


Figure 11. Comparison of results for the MODIS image sequence acquired in August-October 2008. Manual segmentation of the ice floe contour is shown in green, hierarchical step-wise optimization result in red, and the new graph-based approach in blue.

6.4.2. Enforcing monotonous shape growth or shrinkage in video segmentation

Participant: Yuliya Tarabalka [contact].

This work has been done in collaboration with Dr. Guillaume Charpiat (STARS team, Inria-SAM), Dr. Bjoern Menze (Computer Vision Laboratory at ETH Zurich and Asclepios team at Inria-SAM), and Dr. Ludovic Brucker (NASA GSFC, USA) [http://www.nasa.gov].

Video segmentation, graph cut, shape analysis, shape growth

Automatic segmentation of objects from video data is a difficult task, especially when image sequences are subject to low signal-to-noise ratio or low contrast between the intensities of neighboring structures. Such challenging data are acquired routinely, for example, in medical imaging or satellite remote sensing. While individual frames can be analyzed independently, temporal coherence in image sequences provides a lot of information not available for a single image. In this work, we focused on segmenting shapes that grow or shrink monotonically in time, from sequences of extremely noisy images.

We proposed a new method for the joint segmentation of monotonically growing or shrinking shapes in a time sequence of images with low signal-to-noise ratio [15]. The task of segmenting the image time series is expressed as an optimization problem using the spatio-temporal graph of pixels, in which we are able to impose the constraint of shape growth or shrinkage by introducing unidirectional infinite-weight links connecting pixels at the same spatial locations in successive image frames. The globally-optimal solution is computed with a graph-cut algorithm. The performance of the proposed method was validated on three applications: segmentation of melting sea ice floes; of growing burned areas from time series of 2D satellite images [16]; and of a growing brain tumor from sequences of 3D medical scans. In the latter application, we imposed an additional inter-sequences inclusion constraint by adding directed infinite-weight links between pixels of dependent image structures. Figure 12 shows a multi-year sea ice floe segmentation result. The proposed method proved to be robust to high noise and low contrast, and to cope well with missing data. Moreover, it showed linear complexity in practice.

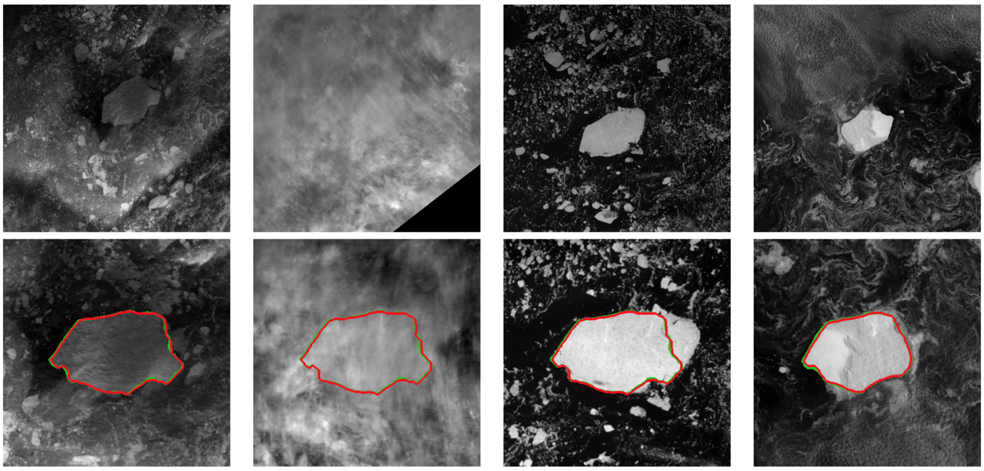


Figure 12. Top: MODIS images for four time moments (days 230, 233, 235 and 267 of 2008, respectively). Bottom: corresponding aligned images with segmentation contours (in red). Manual segmentation is shown in green.

6.5. Other detection approaches

6.5.1. Illumination modeling and chromophore identification in dermatological images for skin disease analysis

Participants: Zhao Liu, Josiane Zerubia [contact].

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

Chromophore identification, illumination modeling, skin disease analysis, dermatology

Skin color is an important characteristic for the accurate diagnosis and grading of cutaneous lesions by experienced dermatologists in clinical practice. However, the visual perception of skin color is not only a function of the major chromophores (melanin and hemoglobin) underneath the skin surface, but is also affected by external illumination and the spectral responses of imaging detectors. Skin color representation in a specific color space (e.g. RGB and its transformations) is not a genuine physical quantity. It sometimes fails to provide precise information about the concentrations of cutaneous chromophores, and is easily influenced by external imaging factors. As a result, conventional colorimetry may not properly describe the underlying histological content of skin, and hence tends to yield less trustworthy results when applied directly for skin disease analysis.

Building on a previous study that considered human skin as a diffuse reflectance surface, our work models human skin as having specular and diffuse reflectance, leading to a novel illumination correction method. Based on this method, we have developed a new scheme for chromophore identification from dermatological photographs. The algorithm has three steps. First, specular reflectance is separated from diffuse reflectance in the original skin images through specular pixel localization and image interpolation using a nonlinear weighted averaging process. Second, the resultant diffuse reflectance component is decomposed into a base layer and a detail layer. The base layer, representing low-frequency illumination and shading effects, is approximated by polynomial curve fitting using an initial illumination map using an adaptive bilateral filter as a prior. The detail layer, primarily containing high-frequency chromophore reflectance, can then be calculated by subtracting the base layer from the corresponding diffuse spectral band in logarithmic form. Finally, by incorporating knowledge of chromophore absorption characteristics, melanin and hemoglobin densities are identified using the detail layers from different spectral channels [11].

For algorithm evaluation, the method was applied to two skin disease analysis problems: computer-aided melanoma diagnosis [11] and automatic acne detection [12]. For melanoma diagnosis, 201 conventional RGB skin lesion images (62MMs, 139 benign nevi (BN)) were collected from free public databases (http://www.dermquest.com/, http://www.dermis.net/) to form an experimental data set. Figure 13-(I) shows an example of a superficial spreading melanoma with obvious horizontal shading effects, and the corresponding experimental results. It is clear that the proposed algorithm successfully removed the imaging artifacts from the original skin lesion photographs.

For acne detection, a set of 50 challenging images were tested as a qualitative evaluation to demonstrate the usefulness of the proposed method. Automatic acne segmentation is performed using an MRF model based on chromophore descriptors. Figure 13-(II) shows one acne example captured in an uncontrolled environment from a free public database (http://www.dermnetnz.org/). The detected acne areas are highly consistent under visual inspection, and the inflammatory acne can be distinguished from hyperpigmentation by comparing the average values of the melanin and hemoglobin indices.

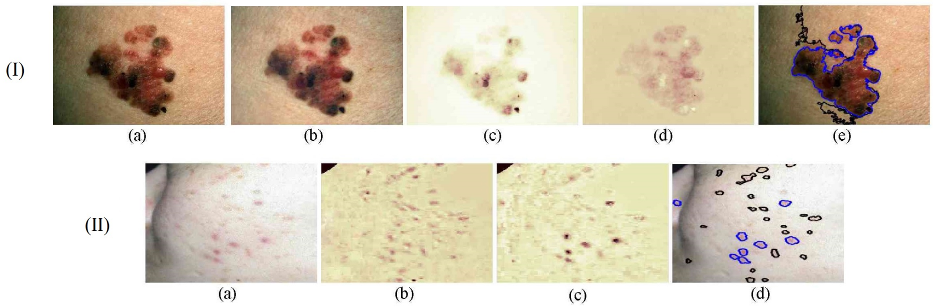


Figure 13. Examples of different types of skin disease requiring shading removal and chromophore identification: (I-a) Original melanoma image; (I-b) Corrected melanoma image; (I-c) Melanin index map of image (I-a); (I-d) Hemoglobin index map of image (I-a); (I-e) Two-class segmentation results from Otsu's method on the original melanoma image (black line) and the corrected melanoma image (blue line), respectively; (II-a) Original acne image; (II-b) Melanin index map of image (II-a); (II-c) Hemoglobin index map of image (II-a); (II-d) Acne segmentation result using an MRF model, highlighting inflammatory acne (blue line) and hyperpigmentation (black line), respectively.

7. Bilateral Contracts and Grants with Industry

7.1. Bilateral Contracts and Grants with Industry

7.1.1. EADS foundation Paris

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). This contract finished at the end of March 2013. Contract #4643.

7.1.2. ASTRIUM EADS Toulouse

Participants: Paula Craciun, Josiane Zerubia [PI].

Automatic object tracking on a sequence of images taken from a geostationary satellite. Contract #7363.

7.1.3. CNES Toulouse

Participants: Ihsen Hedhli, Josiane Zerubia [PI].

Multi-sensor change detection. Application to risk management after the Haiti earthquake. Contract #8361.

7.1.4. CNES Toulouse

Participants: Aurélie Boisbunon, Josiane Zerubia [PI].

Parameter estimation for automatic object change detection in a sequence of very high resolution optical images.

8. Partnerships and Cooperations

8.1. Regional Initiatives

- Paula Craciun and Josiane Zerubia have been in contact with Antoine Mangin, Scientific Director at ACRI-ST (http://www.acri-st.fr/English/index.html), in Sophia Antipolis to discuss Paula Craciun's research on boat detection and counting in Mediterranean harbors using marked point processes.
- Zhao Liu and Josiane Zerubia met several times with Prof. Bahadoran from CHU Nice/Inserm (Faculty of Medicine, Dermatology department, at l'Archet 2 hospital in Nice) and Dr Queille-Roussel, CPCAD managing director at CHU Nice (Faculty of Medicine, Dermatology department, at l'Archet 2 hospital in Nice) to discuss Ayin's research on semi-automatic acne detection.

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. Informal International Partners

Qiyin Fang.

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

Institution: McMaster University (Canada).

Zoltan Kato.

Subject: Multi-layer Markovian models for change detection in aerial and satellite images.

Institution: Szeged University (Hungary).

Gabriele Moser, Sebastiano Serpico.

Subject: Hierarchical Markov random fields for multi-temporal and multi-resolution classification in remote sensing.

Institution: Genoa University (Italy).

Anuj Srivastava.

Subject: Statistical shape analysis of functions, curves, and surfaces.

Institution: Florida State University (USA).

Zoltan Kato.

Subject: Random field models of shape.

Institution: Szeged University (Hungary).

Jochen Einbeck, Stuart Jones.

Subject: Statistical shape modelling for geology.

Institution: Durham University (UK).

8.4. International Research Visitors

8.4.1. Visits of International Scientists

- Qiyin Fang (McMaster University, Canada, one week in May 2013).
- Zoltan Kato (Szeged University, Hungary, from Jul 2013 until Aug 2013).
- Gregoire Mercier (Telecom Bretagne, Brest, one week in June 2013 and one week in December 2013).
- Gabriele Moser (Genoa University, Italy, one week in July 2013).

8.4.2. Internships

Claudio Price González (from January 2013 until March 2013)

Subject: Graph-based model for multitemporal segmentation of sea ice floes from satellite data.

Institution: Federico Santa Maria Technical University and Inria Chile.

9. Dissemination

9.1. Scientific Animation

- Ikhlef Bechar participated in "Journées Envol-Recherche EADS" in Paris on 14/02/2013.
- Aurélie Boisbunon, Seong-Gyun Jeong, and Yuliya Tarabalka attended the "Methodological Aspects of Hyperspectral Imaging" (MAHI) workshop in Nice (France) in October.
- Paula Craciun gave a seminar at ASTRIUM EADS in Toulouse, in January. She gave a seminar at the West University of Timisoara, Romania, in February. She gave a presentation at Inria in Bordeaux, in May. Also in May, she obtained a grant from the Centre for Stochastic Geometry and Advanced Bioimaging (CSGB), Denmark, to attend a summer school on "Topics on space-time modeling and inference", in Aalborg, Denmark. She presented a paper at ICIP'13 in Melbourne, Australia, in September. Paula Craciun visited Dr. Ba-Ngu Vo at Curtin University, Perth, Australia, from 20/09/2013 to 25/09/2013. She attended meetings with ASTRIUM EADS in Paris and Toulouse in December.
- Seong-Gyun Jeong attended the workshop GeoStoch'13 in Grenoble in April. He was a reviewer for the journal JVCI (Journal of Visual Communication and Image Representation).

- Zhao Liu presented a paper at EUSIPCO'13 in Marrakech, Morocco, in September, and another paper at ACPR'13 in Okinawa, Japan, in November. She gave talks to the LIRA Consortium during the LIRA workshop in Sophia Antipolis in February, and at the workshop in Berlin in May. She presented her work to CHU Nice at the hospital l'Archet 2 in May, and to Galderma R&D in Sophia Antipolis in July.
- Claudio Price presented a paper at the LARS conference in Santiago, Chile in October.
- Yuliya Tarabalka presented a paper at the IEEE IGARSS conference in Melbourne, Australia, and a paper at the BMVC conference in Bristol, UK. She also presented a paper of A. Gamal Eldin *et al.* at the SPIE Computational Imaging Conference in Burlingame, USA. In June, she presented the Ayin team and her work to students visiting Inria from SupCom-Tunis. She presented the Ayin team at the India-France Technology Summit in New Delhi, India in October. She visited and gave a seminar at the Indian Institute of Space Science and Technology in Trivandrum, India in October. She gave a seminar at the MAP5 laboratory of the University Paris Descartes in Paris in December. Yuliya Tarabalka is a co-editor of the special issue "Analysis of Remote Sensing Image Data" for the journal Remote Sensing. She was a reviewer for the journals IEEE TIP, IEEE TGRS, IEEE GRSL, IEEE Trans. on Neural Networks and Learning Systems, Computer Vision and Image Understanding, Remote Sensing, IEEE JSTARS, Journal of Applied Remote Sensing, and for the conferences GRETSI'2013, IEEE ICIP'2013, IEEE ICASSP'2013, IEEE IGARSS'2013 and OSA Imaging Systems and Applications'2013. She was a part of the program committee for the OSA Imaging Systems and Applications conference. She chaired a session at the conference IEEE IGARSS'2013.
- Ian Jermyn was a reviewer for the conferences EMMCVPR, ICIP, IDEAL; for the Journal of Mathematical Imaging and Vision; and of proposals for the UK Engineering and Physical Sciences Research Council and the Israel Science Foundation.
- Josiane Zerubia is an IEEE Fellow. She was a reference proposal reviewer for CRC Press. She was a reviewer for SFPT (Revue Française de Photogrammétrie et de Télédétection). She was a reviewer (and also a program committee member for some of these conferences) for ICASSP'13, ISBI'13, ICIP'13, and for EMMCVPR'13, MICCAI'13, TAIMA'13, SPIE-ISPRS'13 ("Image and Signal Processing for Remote Sensing"), ICPRAM'13 and GRETSI'13. She was a member of the Image, Video and Multidimensional Signal Processing (IVMSP) Technical Committee of the IEEE Signal Processing Society until December 2013. She was a member of the Editorial Board of IJCV until March 2013. 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 Board of the "Revue Française de Photogrammétrie et de Télédétection of SFPT". She is an Associate Editor of the electronic journal Earthzine [http://www.earthzine.org/].

  Josiane Zerubia visited Astrium EADS Toulouse in January. She participated in the CNES Research and Technology day in Toulouse in February. In February, she also organized at Inria-SAM the LIRA skincare workshop. In April, she attended a dermoscopy workshop organized by CHU Nice (Faculty of Medicine), and presented the work of Ayin in dermato/cosmetology at the L'Oreal R&D center in Aulnay. She also attended the IGN Research Days in Marne la Vallee in April. She was a member of the CR2 selection committee at Inria-SAM in May. In May, she gave a talk at l'Archet 2 hospital, CHU Nice (Dept of Dermatology), a talk in Berlin at the Fraunhofer Institute during a LIRA skincare workshop, and a third talk at the international KAL'Haiti meeting organized by CNES at the Ministry of Foreign Affairs in Paris. Finally, in May she took part in a one-day meeting with EPI Alea and Astrium EADS at Inria Bordeaux. In June she presented Ayin's research in dermatology at Galderma R&D and gave a talk on Ayin's research in remote sensing at the University of Tunis El Manar. She also presented the activities of Inria-SAM and of the international Masters UBINET and BIOCOMP of UNS to Tunisian Masters students. In September, she gave an invited talk at the "Imaging in Geospatial Applications" workshop at the Institute of Mathematics and Applications (IMA) at University of Minneapolis, and presented a paper at GRETSI in Brest. In November she gave an invited talk at the Remote Sensing Days organized by the University of Bordeaux I. In

December, she went to Toulouse for meetings with Astrium EADS and with CNES. In December, she also attended the annual meeting of the Astrium/Inria PhD committee organized at EADS in Suresnes.

Josiane Zerubia is a deputy of Frederic Alexandre on the Executive Committee of the LIRA Consortium (Philips, CWI, Fraunhofer, Inria). She is a member of the ORFEO group (CNES). She is a consultant for Galderma R&D in Sophia-Antipolis. She is also a member of the Program Committee of the 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

- Masters: Yuliya Tarabalka, Spaceborne sensors and their applications, 4.5h eq. TD (3h of lectures), Master PPMD, École Nationale des Sciences Géographiques, France.
- Masters: Yuliya Tarabalka, Digital imaging, 15h eq. TD (2h of lectures + 12h of TD), M2 SVS ISAB, Université de Nice Sophia-Antipolis, France.
- Masters: Josiane Zerubia, Deconvolution and denoising in confocal microscopy, 18h eq. TD (12h of lectures), M2 IFI BCC, Université de Nice Sophia-Antipolis, France. Josiane Zerubia is also director of this course (total: 24h of lectures).
- Masters: Josiane Zerubia, Advanced techniques in signal and image processing, 30h eq. TD (20h of lectures), ISAE/SUPAERO, France. Josiane Zerubia is also director of this course (total: 30h of lectures and 10h of TD). This course was given to third-year students at ISAE/SUPAERO and was also validated by the Master 2 of Applied Mathematics at the University Paul Sabatier in Toulouse.
- Masters: Josiane Zerubia, Introduction to image processing, 4.5h eq. TD (3h of lectures), M2 SVS ISAB, Université de Nice Sophia-Antipolis, France. Josiane Zerubia is also director of the course "Digital imaging" at UNS, Master 2 SVS ISAB, UE3 (total: 25h of lectures and 25h of TD).

9.2.2. Supervision

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.

PhD in progress: Ihsen Hedhli, Change detection methods for multisensor and multiresolution remote sensing images for applications to environmental disaster management, University of Genova and University of Nice-Sophia Antipolis, started in January 2013, Gabriele Moser 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.

9.2.3. Juries

- Yuliya Tarabalka was a reviewer of one PhD thesis for the AFIA prize.
- Josiane Zerubia was a member of two PhD committees in April and October 2013. She was a reviewer of one PhD thesis at the University of Tunis El Manar in Tunisia, in July 2013.

9.3. Popularization

- Paula Craciun and Josiane Zerubia have published an article in ERCIM News'95 [19]. They have also written a blog article for MPT2013 in French [http://mpt2013.fr/les-ports-vus-du-ciel/] and MPE2013 in English [http://mpe2013.org/2013/10/29/boat-extraction-in-harbors-from-high-resolution-satellite-images/].

- Yuliya Tarabalka gave an interview to the LISA journal in January 2013 [https://lisa.sophia.inria.fr/yuliya-tarabalka-888.html]. She participated in the conference of the Young Academy of Science in Ukraine, presenting the Ayin team and her research work to the 12-16 year-old attendees of the Academy.
- Yuliya Tarabalka and Guillaume Charpiat (STARS EPI) published an article in the Earthzine journal “Exploiting Temporal Coherence for Fire Mapping from MODIS Spaceborne Observations” in September 2013 [20].
- Josiane Zerubia took part in a debate on the topic “Les TIC, une révolution pour les femmes?” organized at the SKEMA Business School in Sophia-Antipolis by three associations (Femmes & Sciences, Femmes 3000 and Telecom Valley) on November 26, 2013 (for more detail see http://www.femmesetsciences.fr/actualites/les-tic-une-revolution-pour-les-femmes-conference-debat-261113-sophia-antipolis/)

10. Bibliography

Publications of the year

Doctoral Dissertations and Habilitation Theses

[1] Y. Verdie. , *Modélisation de scènes urbaines à partir de données aeriennes*, Université Nice Sophia Antipolis, October 2013, Version éditée après soutenance (Novembre 2013), http://hal.inria.fr/tel-00881242

Articles in International Peer-Reviewed Journals

[2] M. Fauvel, Y. Tarabalka, J. A. Benediktsson, J. Chanussot, J. Tilton. *Advances in Spectral-Spatial Classification of Hyperspectral Images*, in "Proceedings of the IEEE", March 2013, vol. 101, n^{o} 3, pp. 652-675 [*DOI :* 10.1109/JPROC.2012.2197589], http://hal.inria.fr/hal-00737075

[3] K. Kayabol, J. Zerubia. *Unsupervised amplitude and texture classification of SAR images with multinomial latent model*, in "IEEE Transactions on Image Processing", February 2013, vol. 22, n^{o} 2, pp. 561-572 [*DOI :* 10.1109/TIP.2012.2219545], http://hal.inria.fr/hal-00745387

[4] V. Krylov, G. Moser, S. B. Serpico, J. Zerubia. *On the Method of Logarithmic Cumulants for Parametric Probability Density Function Estimation*, in "IEEE Transactions on Image Processing", October 2013, vol. 22, n^{o} 10, pp. 3791-3806, http://hal.inria.fr/hal-00820782

[5] A. Voisin, V. Krylov, G. Moser, S. B. Serpico, J. Zerubia. *Supervised Classification of Multi-sensor and Multi-resolution Remote Sensing Images with a Hierarchical Copula-based Approach*, in "IEEE Transactions on Geoscience and Remote Sensing", July 2013 [*DOI :* 10.1109/TGRS.2013.2272581], http://hal.inria.fr/hal-00841234

[6] A. Voisin, V. Krylov, G. Moser, S. B. Serpico, J. Zerubia. *Classification of Very High Resolution SAR Images of Urban Areas Using Copulas and Texture in a Hierarchical Markov Random Field Model*, in "IEEE Geoscience and Remote Sensing Letters", 2013, vol. 10, n^{o} 1, pp. 96-100 [*DOI :* 10.1109/LGRS.2012.2193869], http://hal.inria.fr/hal-00723280

[7] J. Zhou, C. Proisy, X. Descombes, G. Le Maire, Y. Nouvellon, J.-L. Stape, G. Viennois, J. Zerubia, P. Couteron. *Mapping local density of young Eucalyptus plantations by individual tree detection in high spatial resolution satellite images*, in "Forest Ecology and Management", 2013, vol. 301, pp. 129-141 [*DOI :* 10.1016/j.foreco.2012.10.007], http://hal.inria.fr/hal-00741010

International Conferences with Proceedings

[8] P. CRACIUN, J. ZERUBIA. *Unsupervised marked point process model for boat extraction in harbors from high resolution optical remotely sensed images*, in "IEEE ICIP - International Conference on Image Processing", Melbourne, Australia, September 2013, http://hal.inria.fr/hal-00867585

[9] A. GAMAL ELDIN, G. CHARPIAT, X. DESCOMBES, J. ZERUBIA. *An efficient optimizer for simple point process models*, in "SPIE, Computational Imaging XI", Burlingame, California, United States, C. A. BOUMAN, I. POLLAK, P. J. WOLFE (editors), SPIE Proceedings, SPIE, February 2013, vol. 8657 [*DOI :* 10.1117/12.2009238], http://hal.inria.fr/hal-00801448

[10] V. KRYLOV, G. MOSER, S. SERPICO, J. ZERUBIA. *False discovery rate approach to image change detection*, in "IEEE International Conf. on Image Processing (ICIP)", Melbourne, Australia, September 2013, http://hal.inria.fr/hal-00841236

[11] Z. LIU, J. ZERUBIA. *Melanin and Hemoglobin Identification for Skin Disease Analysis*, in "Asian Conference on Pattern Recognition (ACPR)", Okinawa, Japan, IEEE, November 2013, http://hal.inria.fr/hal-00872331

[12] Z. LIU, J. ZERUBIA. *Towards Automatic Acne Detection Using a MRF Model with Chromophore Descriptors*, in "European Signal Processing Conference (EUSIPCO)", Marrakech, Morocco, IEEE, September 2013, http://hal.inria.fr/hal-00863046

[13] C. PRICE, Y. TARABALKA, L. BRUCKER. *Graph-Based Method for Multitemporal Segmentation of Sea Ice Floes from Satellite Data*, in "Latin American Remote Sensing Week", Santiago, Chile, October 2013, http://hal.inria.fr/hal-00874537

[14] S. PRIGENT, X. DESCOMBES, D. ZUGAJ, L. PETIT, J. ZERUBIA. *Multi-scale analysis of skin hyper-pigmentation evolution*, in "ICIP - International Conf. on Image Processing", Melbourne, Australia, IEEE, September 2013, http://hal.inria.fr/hal-00841460

[15] Y. TARABALKA, G. CHARPIAT, L. BRUCKER, B. MENZE. *Enforcing Monotonous Shape Growth or Shrinkage in Video Segmentation*, in "BMVC - British Machine Vision Conference", Bristol, United Kingdom, September 2013, http://hal.inria.fr/hal-00856634

[16] Y. TARABALKA, G. CHARPIAT. *A Graph-Cut-Based Method for Spatio-Temporal Segmentation of Fire from Satellite Observations*, in "IEEE IGARSS - International Geoscience and Remote Sensing Symposium", Melbourne, Australia, July 2013, http://hal.inria.fr/hal-00845691

National Conferences with Proceedings

[17] P. CRACIUN, J. ZERUBIA. *Boat extraction in harbors from high resolution satellite images using mathematical morphology and marked point processes*, in "GRETSI - Traitement du Signal et des Images", Brest, France, September 2013, http://hal.inria.fr/hal-00867592

Scientific Books (or Scientific Book chapters)

[18] P. PANKAJAKSHAN, G. ENGLER, L. BLANC-FERAUD, J. ZERUBIA. *Deconvolution and denoising for computational microscopy*, in "Modeling in Computational Biology and Biomedecine. A Multidisciplinary Endeavor", F. CAZALS, P. KORNPROBST (editors), Springer, 2013, vol. XXVI, pp. 117-164, http://hal.inria.fr/hal-00766226

Scientific Popularization

[19] P. CRACIUN, J. ZERUBIA. *Boat Extraction in Harbours From High Resolution Satellite Images Using Marked Point Processes*, in "ERCIM News", October 2013, http://hal.inria.fr/hal-00939160

[20] Y. TARABALKA, G. CHARPIAT. *Exploiting Temporal Coherence for Fire Mapping from MODIS Spaceborne Observations*, in "Earthzine", September 2013, http://hal.inria.fr/hal-00915245