Activity Report 2014

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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Yuliya Tarabalka [Junior Researcher, Inria]

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Qiyin Fang [McMaster University, Canada, one week in May 2014]
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Zoltan Kato [Szeged University, Hungary, one month from mid-July till mid-August 2014]
Vladimir Krylov [Genoa University, Italy, one week in September 2014]
Zhao Liu [University of Manchester, one week in Dec 2014]
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Samir Sahli [McMaster University, Canada, one week in September 2014]
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Other

Emmanuel Maggiori [Masters Internship, Inria, from May 2014 until Nov 2014]

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-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.

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 spectral and spatio-temporal structures. 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 apply our new methodologies to the analysis of SAR, multi- and hyper-spectral remote sensing images and temporal sequences. In particular, we 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. New Results

5.1. Highlights of the Year

- Yuliya Tarabalka was nominated CR1 since 1 January 2015.
- Josiane Zerubia was elected for a duration of 6 years at the board of directors of the French Society of Photogrammetry and Remote Sensing (SFPT, http://www.sfpt.fr/).
- Josiane Zerubia was invited by Technion to give a plenary talk at SIMA'14 in Ein Gedi, Israel organized for the 60th birthday of Prof. Alfred Bruckstein in May, http://www.cs.technion.ac.il/SIMA14/.

5.2. Markov Random Fields

5.2.1. *Fusion of multitemporal and multiresolution remote sensing data and application to natural disasters*

Participants: Ihsen Hedhli, Josiane Zerubia [contact].

This work was carried out in collaboration with Prof. Gabriele Moser and Prof. Sebastiano Serpico from DITEN departement, University of Genoa, Italy.

Multitemporal data, Multiresolution data, Supervised classification, Hierarchical Markov random fields.

The capabilities to monitor the Earth surface, and especially urban and built-up areas, from environmental disasters such as floods or earthquakes, and to assess the ground impact and damage of such events play primary roles from multiple social, economic, and human viewpoints. In this framework, accurate and time-efficient classification methods are especially important tools to support rapid and reliable assessment of the ground changes and damages induced by a disaster, in particular when an extensive area has been affected. Given the huge amount and variety of data available currently from last-generation very-high resolution (VHR) satellite missions, (such as Pléiades, COSMO-SkyMed, or WorldView-2), the main difficulty is to develop a classifier that can take benefit of multiband, multiresolution, multidate, and possibly multisensor input imagery. In such a context, Markov random field (MRF) models are widely used to solve classification problems as they permit one to integrate contextual information into the classification scheme. Due to their non-causal nature, these models generally lead to iterative inference algorithms that are computationally demanding (e.g., optimization via simulated annealing), thereby justifying the choice of a hierarchical structure, with good methodological and application-oriented properties such as: (i) the causality in scale, under Markovian assumption, which allows the use of a non-iterative algorithm with acceptable computational time and (ii) the possibility to incorporate images acquired at multiple resolutions in the hierarchy for multiresolution and multisensor fusion purposes [10]. In the proposed method, multidate and multiresolution fusion is based on explicit statistical modeling through hierarchical Markov random field modeling. The model allows both input data collected at multiple resolutions and additional multiscale features derived through wavelets to be fused. The proposed approach consists of a supervised Bayesian classifier that combines: (i) a joint class-conditional statistical model for pixelwise information and (ii) a hierarchical MRF for spatio-temporal and multiresolution contextual information. Step (i) deals, first, with the modeling of the marginal statistics of the spectral channels acquired at each resolution and conditioned to each class. Step (ii) consists in the integration of this statistical modeling in a hierarchical Markov random field for each date. An especially novel element of the proposed approach is the use of multiple quad-trees in cascade (see Figure 1), each associated with each new available image at different dates, with the aim to characterize the temporal correlations associated with distinct images in the input time series and to support the joint analysis of multitemporal, multiresolution, and possibly multisensor imagery. The transition probabilities between scales and between different dates determine the hierarchical MRF since they formalize the causality of the statistical interactions involved [11].

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

Participant: 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/], and Praveer Singh from Institut Mines-Telecom.

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

In the proposed approach developed last year, 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 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

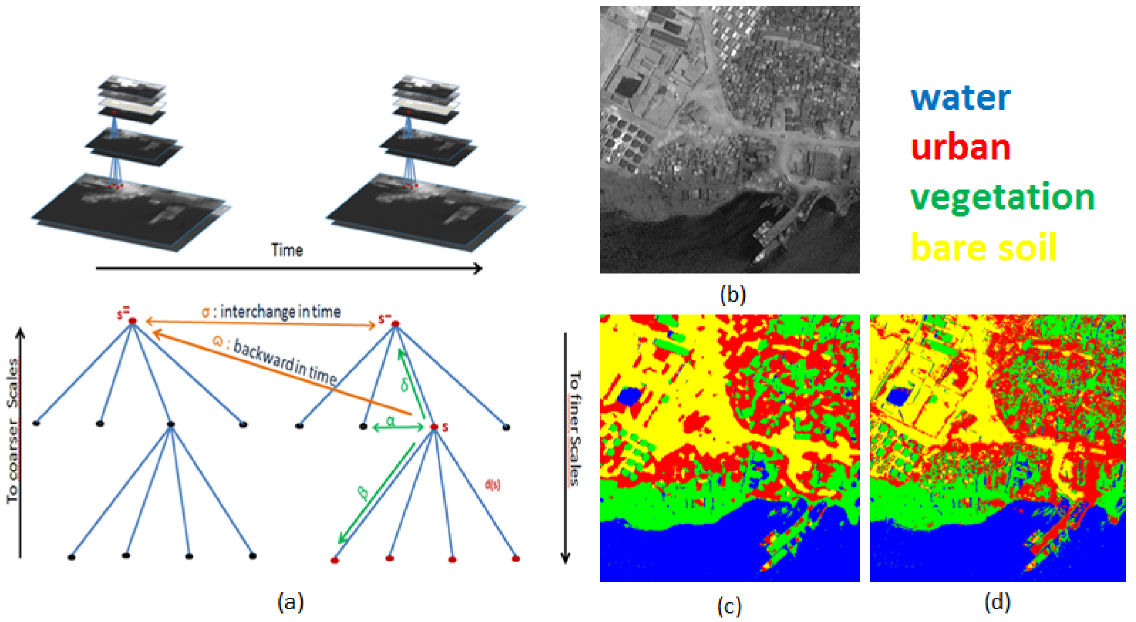


Figure 1. a) Multitemporal hierarchical structure; b) Panchromatic image of Port au Prince (Pléiades, ©CNES distribution Airbus DS, 2013); c) Classification map using single date hierarchical structure; d) Classification map obtained through the proposed multitemporal method.

and (d) is a combination of the hierarchical MRF based change detection (in red), ground truth (in green) and changes detected correctly (in yellow). This year, we have made a comparison of this method with two other multilayer MRFs for change detection developed at MTA-SZTAKI in Budapest, Hungary.

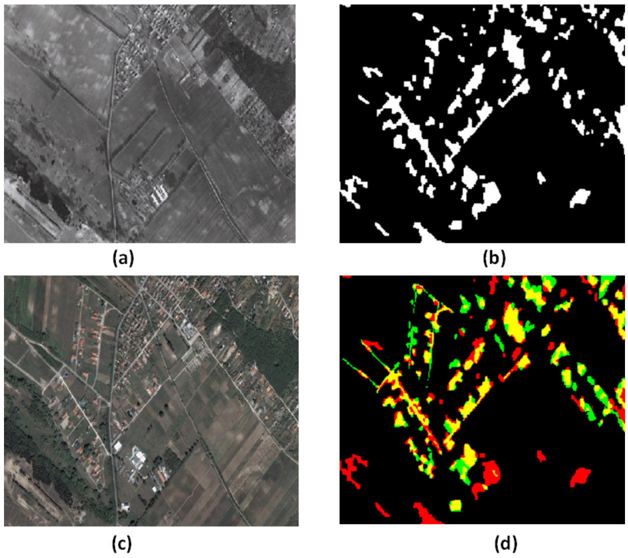


Figure 2. Change detection in an aerial image pair using a hierarchical MRF. a) Aerial image captured in 1984 by ©FOMI; b) Ground truth; c) Aerial image captured by ©GoogleEarth in 2007; d) Combination of the hierarchical MRF based change detection (in red), ground truth (in green), and changes detected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

5.2.3. *Graph-cut-based model for spectral-spatial classification of hyperspectral images*

Participant: Yuliya Tarabalka [contact].

This work has been done in collaboration with Aakanksha Rana (Institut Mines-Telecom/EURECOM).

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 [15]. 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.

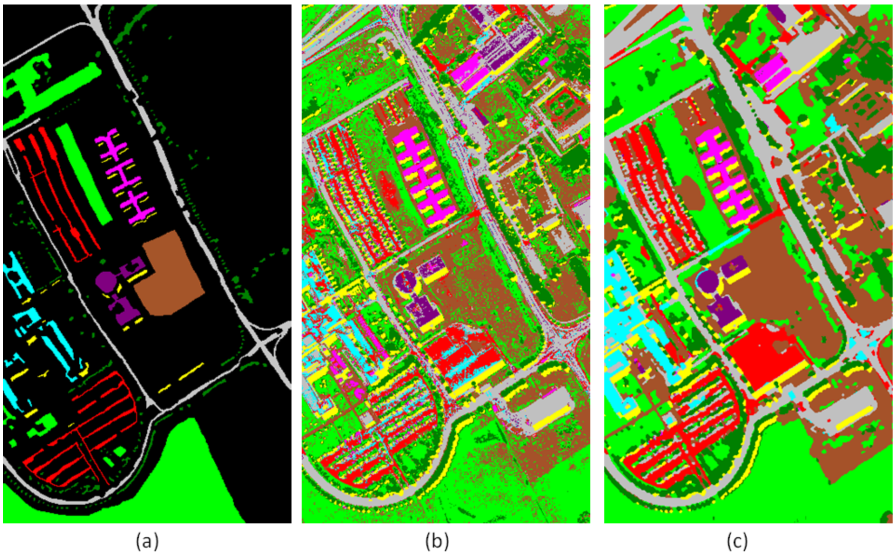


Figure 3. Hyperspectral image of the University of Pavia. (a) Ground-truth (b) Support vector machines classification map. (c) Graph-cut classification map.

5.3. Marked point processes

5.3.1. Multiple target tracking using spatio-temporal marked point processes

Participants: Paula Craciun, Josiane Zerubia [contact].

This work has been done in collaboration with Mathias Ortner from Airbus D&S (http://www.space-airbusds.com/fr/)

Multiple target tracking, stochastic geometry, point processes, remote sensing

Tracking can be defined as the problem of estimating the trajectories of objects in the image plane, as they move around the scene. Hence, a tracker assigns consistent labels to the objects in different frames of a sequence of images and can additionally provide information about the orientation, shape or size of the objects. Multi-target tracking has been historically achieved using sequential techniques, the major drawback of such methods residing in the impossibility to modify past results in the light of new data. However, applications such as offline video processing or information retrieval are not sequential in nature. Batch processing methods are preferred in this case since they do not suffer from the limitations of sequential methods. Nevertheless, these techniques remain poorly explored and highly underused.

We propose a novel approach based on spatio-temporal marked point processes to detect and track moving objects in a batch of high resolution images [17]. We develop a new, intuitive energy based model consisting of several terms that take into account both the image evidence and physical constraints such as target dynamics, track persistence and mutual exclusion. We construct a suitable optimization scheme that allows us to find strong local minima of the proposed highly non-convex energy [9]. The model has been validated on two types of data: remotely sensed satellite image sequences, characterized by high resolution, high signal to noise ratio and low temporal frequency; and biological image sequences, characterized by high resolution, low signal to noise ratio and high temporal frequency.

Tracking results are shown in Figure 4, which shows the detection (dots) and tracking (lines) results of boats in a sequence of 14 high resolution remotely sensed images. The images are captured with a low temporal frequency at different acquisition angles.

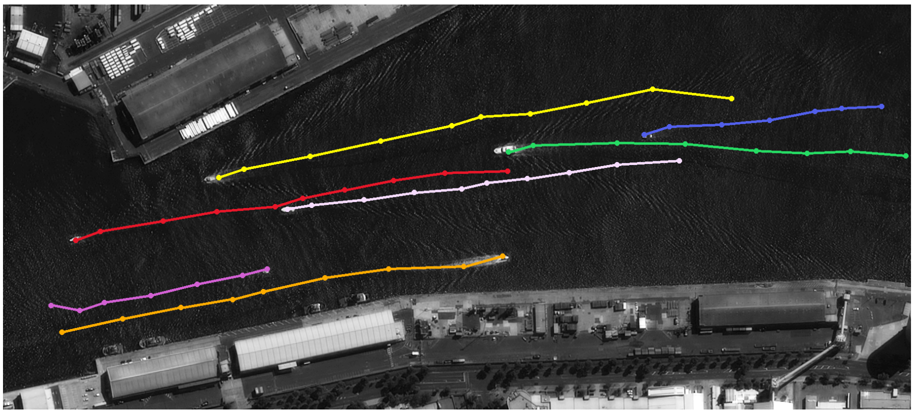


Figure 4. Detection and tracking results on a sequence of satellite images taken at different angles ©Inria/AYIN.

5.3.2. Initialization and estimation of parameters for marked point processes applied to automatic object detection on satellite images

Participants: Aurélie Boisbunon, Josiane Zerubia [contact].

This work has been done in collaboration with Rémi Flamary (Université de Nice Sophia Antipolis), Alain Rakotomamonjy (Université de Rouen) et Alain Giros (CNES). It was partially funded by the French Spatial Agency CNES [http://www.cnes.fr].

Sparse representations, large scale, stochastic algorithms, machine learning, image processing

Marked point processes (MPP) strongly rely on parameters, whose estimation affects both computation time and performances. In this work, we proposed two approaches: the first one consists in initializing MPPs with a first coarse solution obtained very quickly from sparse regularization methods [7], while the second one estimates the parameters by the Stochastic Approximation Expectation-Maximization (SAEM) algorithm [8]. We give details on both approaches below.

The first coarse solution is obtained from a deterministic sparse regularization method. This method is based on the representation of an image with objects as a sum of convolutions between atoms of a dictionary and matrices of positions of the objects in the image. Such a representation is displayed on Figure 5. The atoms of the dictionary are fixed in advance and correspond to different instances of the objects (scales, angles, shapes, etc). This way, we transform the problem of object detection into the problem of estimating extremely sparse matrices. The algorithm we derived for solving the associated optimization problem is both parallelized and very efficient.

Up to recently, the parameters of MPPs were estimated by the Stochastic Expectation-Maximization (SEM) algorithm developed by Celeux & Diebolt (1985). This algorithm consists in alternatively estimating the expected pseudo-likelihood based on a random configuration and updating the parameter value by maximum of pseudo-likelihood. However, since it does not have a pointwise convergence, Ben Hadj et al. (2010) considered running a simulated annealing scheme after few iterations of SEM in order to reach convergence, at the cost of a higher computational time. Instead, we proposed to adapt the Stochastic Approximation Expectation-Maximization (SAEM) algorithm, developed by Delyon et al. (1999), to MPPs. Indeed, it both offers pointwise convergence and a similar computational time as SEM by efficiently taking into account past configurations in the update of the expected pseudo-likelihood.

Using both approaches resulted in the division of the computational time of the estimation of MPPs parameters by 2 and in an increase in performance of detection.

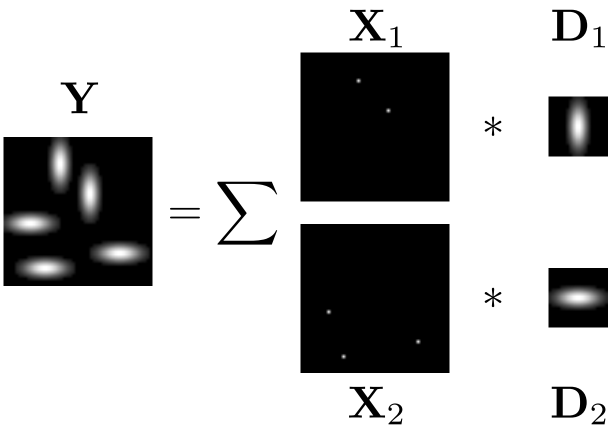


Figure 5. Representation of an image as a sum of convolutions between atoms of a dictionary and matrices of positions.

5.3.3. Generic curvilinear structure modeling via marked point process theory

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

Curvilinear structure extraction, object detection, marked point process, stochastic inference

We proposed a marked point process model to analyze underlying curvilinear structure for wide ranges of input data, for instance, wrinkles, DNA filaments, road cracks, and blood vessels [12], [13]. It is based on sampling technique so that the model represents an arbitrary shape of the line network with a set of small line segments. The line segments should be fit into the given image data, and be harmonic with those of neighborhoods. To take these issues into consideration, we formulate a maximum a posteriori (MAP) estimation as an energy minimization problem. The energy function for given line configuration $\mathbf{s}$ can be decomposed into data likelihood term E_{data} and prior term E_{prior}:

$$E(\mathbf{s}) = \sum_{i}^{\#(\mathbf{s})} E_{\text{data}}(s_i) + \lambda \sum_{i \sim j} E_{\text{prior}}(s_i, s_j),$$

where $\#(\mathbf{s})$ denotes the total number of line segments in the current configuration, $i \sim j$ represents symmetric neighborhood system, and λ controls the relative importance of two terms. For the data term, we exploit oriented gradient information and homogeneity of the pixel intensities corresponding to line segment on the image site. The prior energy defines topology of the line configuration in that penalizes overlapping and attracts smooth connections. Another contribution of the work is to reduce parameter dependencies of the marked point process model using aggregation approach. We repeated to perform Markov chain Monte Carlo (MCMC) sampling with different parameter vectors to obtain multiple line hypotheses. Then, we combine line hypotheses to maximize the consensus among detection results.

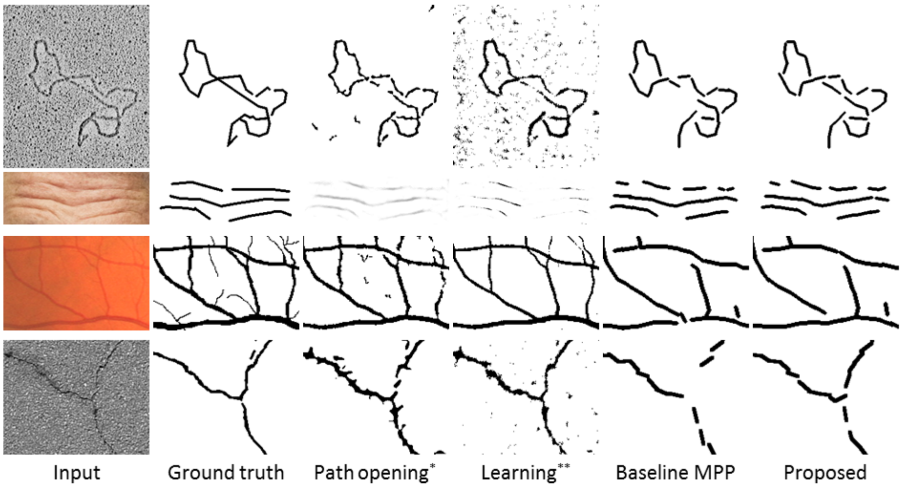


Figure 6. Comparison of the line detection results on DNA filaments, wrinkles, retina, and road cracks (top to bottom).

In figure 6, we have compared line detection results of manually labeled image, morphological filtering (path opening), supervised feature learning, an MPP model using single parameter vector, and the proposed algorithm. The proposed algorithm extracts the most salient line structures for all datasets without any parameter estimation procedure.

5.4. Shapes and contours

5.4.1. Riemannian metrics on spaces of curves and surfaces

Participant: Ian Jermyn [contact].

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

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

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 induced on ‘shape space’ by Riemannian metrics on the space of embeddings. Current work is focused on generalizing to surfaces the elastic metric used for curve embeddings, and in finding surface representations that simplify computations in the same way that the square root velocity representation simplifies computations in the case of curves. The notion of a ‘square-root normal field’ (SRNF), which leads to a reduced version of the full elastic metric, is a promising possibility in this direction.

The most recent work [16] has focused on estimating the inverse of the SRNF map. If this can be done even approximately, a very efficient framework results: the surfaces, represented by their SRNFs, can be efficiently analyzed using standard Euclidean tools, and only the final results need to be mapped back to the surface space. In this work, we developed a procedure for inverting SRNF maps of star-shaped surfaces, a special case for which analytic results can be obtained. We tested our method via the classification of 34 cases of ADHD (Attention Deficit Hyperactivity Disorder), plus controls, in the Detroit Fetal Alcohol and Drug Exposure Cohort study. We obtained state-of-the-art results.

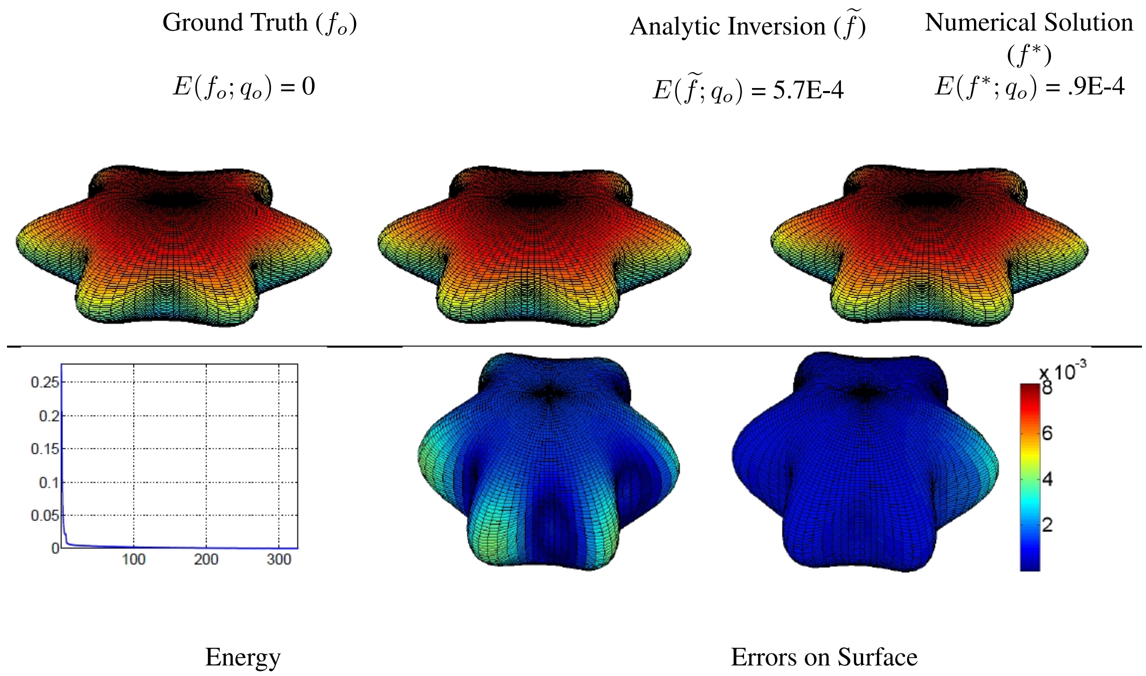


Figure 7. Reconstructing a surface from its SRNF. A target surface (f_o) is numerically reconstructed as f^* with initialization as the unit sphere. The energy plot shows the evolution of energy against iterations with initialization as a unit sphere. The analytically inverted surface $\widetilde{f}$ is shown for comparison. The corresponding energies $E(\widetilde{f}; q_o)$ and $E(f^*; q_o)$ are also shown. The errors between the reconstructed surfaces and the ground truth are shown on the ground truth surface with colours representing the magnitudes, i.e. $|f^*(s) - f_o(s)|$ for all $s \in S^2$.

5.4.2. 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 (Technische Universität München, Germany and Asclepios team, 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 [3]. 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; 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 8 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.

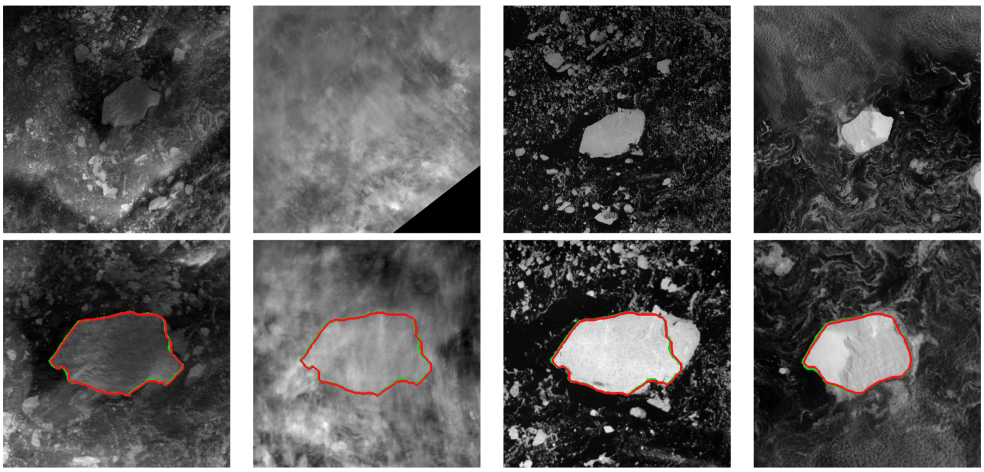


Figure 8. Top: MODIS images for four time moments (days 230, 233, 235 and 267 of 2008, respectively). Bottom: corresponding aligned images with segmentation contours (in red). Manual segmentation is shown in green.

5.4.3. Multi-label image segmentation with partition trees and shape prior

Participants: Emmanuel Maggiori, Yuliya Tarabalka [contact].

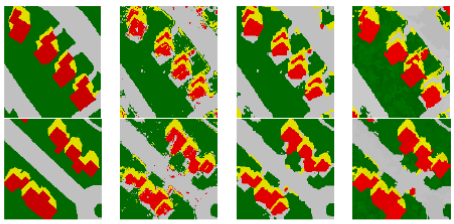
This work has been done in collaboration with Dr. Guillaume Charpiat (STARS team, Inria-SAM).

Partition trees, multi-class segmentation, shape priors, graph cut

The multi-label segmentation of images is one of the great challenges in computer vision. It consists in the simultaneous partitioning of an image into regions and the assignment of labels to each of the segments. The problem can be posed as the minimization of an energy with respect to a set of variables which can take one of multiple labels. Throughout the years, several efforts have been done in the design of algorithms that minimize such energies.

We proposed a new framework for multi-label image segmentation with shape priors using a binary partition tree [19]. In the literature, such trees are used to represent hierarchical partitions of images, and are usually computed in a bottom-up manner based on color similarities, then processed to detect objects with a known shape prior. However, not considering shape priors during the construction phase induces mistakes in the later segmentation. This paper proposes a method which uses both color distribution and shape priors to optimize the trees for image segmentation. The method consists in pruning and regrafting tree branches in order to minimize the energy of the best segmentation that can be extracted from the tree. Theoretical guarantees help reducing the search space and make the optimization efficient (see Figure 9(i)) and [19]. Our experiments (see Figure 9) show that the optimization approach succeeds in incorporating shape information into multi-label segmentation, outperforming the state-of-the-art.

(a) Color image. (b) Manual segment. (c) BPT optimization.



(d) Manual. (e) SVM. (f) GC. (g) BPT Opt.

	$\mathcal{A}$	$\mathcal{D}$
SVM	0.764	0.50
GC	0.799	0.49
TC	0.804	0.47
Opt.	0.813	0.69

(h) Performance.

Time [s]	Time [s] (Props. 1-2)
214	84

(i) Execution time.

Figure 9. Classification results for the satellite image over Brest. $\mathcal{A}$ denotes overall classification accuracy, and $\mathcal{D}$ denotes average building's overlap. The performance of the proposed binary partition tree (BPT) optimization method is compared with the following methods: 1) support vector machines (SVM) classification; 2) graph cut (GC) with α-expansion; 3) cut on the BPT, regularized by the number of regions without using shape priors (TC).

5.5. Other detection approaches

5.5.1. Image-based evaluation of treatment responses of facial wrinkles using LDDMM registration and Gabor features

Participants: Nazre Batool, Josiane Zerubia [contact].

Face, skin texture, detection of wrinkles, LDDMM registration, response to treatment, Gabor filters, morphological processing

The goal of this work is to evaluate quantitatively the subtle variations in facial wrinkles for the same subject in response to treatment using image-based analysis. The novelty of this application is that a series of images of the same subject over a shorter time period of weeks are analyzed instead of more prevalent inter-person analysis of facial images. To overcome the challenges of detecting and evaluating such subtle changes, we propose a framework to compare image features in key wrinkle sites only while excluding the noise introduced by changes in surrounding skin texture. After initial registration using facial landmarks such as corners of eyes, nose, mouth, we propose a method based on Large Deformation Diffeomorphic Metric Mapping (LDDMM) to achieve finer registration. Fig. 10(1a-1e) shows an example of registration using LDDMM for a pair of images. Then we use N. Batool's previously proposed algorithm (Nazre & Chellappa (2015)) to detect key wrinkle sites. The algorithm is based on 'scaled' maximum Gabor filter responses and the incorporation of geometric constraints via morphological image processing. The binary output from the algorithm is used to create a unique wrinkle template for each subject. Fig. 10(2a-2d) an example of obtaining a unique wrinkle template from an image using Gabor responses and wrinkle detection algorithm in (Nazre & Chellappa (2015)). Gabor responses in this template,in time series images are compared to detect subtle changes for a subject. We do not adopt the direct approach of comparing filter responses in the whole image instead of those in wrinkle template only because such an approach causes intermingling of skin texture variations in non-wrinkle sites with changes in wrinkle sites degrading the overall accuracy.

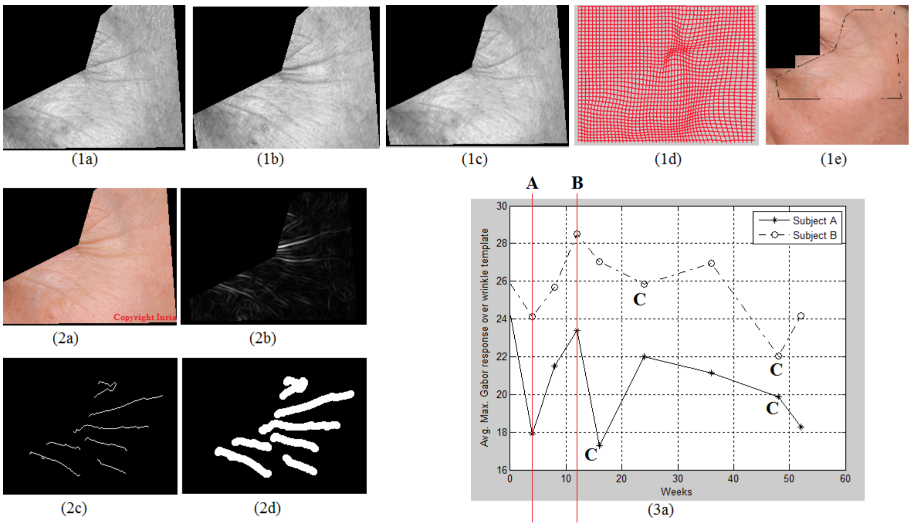


Figure 10. Overview of the evaluation framework. (1a) Week 4 image. (1b) Baseline image. (1c) Week 4 image registered using LDDMM to baseline image. (1d) Deformation of the underlying 2D space. (1e) Deformed week 4 images aligned in the original face image. (2a) Baseline image. (2b) Gabor maximum amplitude response. (2c) Detected wrinkles. (2d) The template for key wrinkle sites. (3) Plot of results for two subjects.

Fig. 10 (3a) shows a plot of results for two subjects where y-axis shows average maximum Gabor amplitude response in key wrinkle sites and x-axis corresponds to the number of weeks after the treatment. For both subjects a significant drop in the average response can been seen 4 weeks after the treatment (event 'A'). An increase in the Gabor response happened at week 12 (event 'B') which coincided with slight darkening/reddening of skin for both subjects. On the other hand, event 'C' represents co-occurrence of skin lightening with a decrease in Gabor response. These preliminary results indicate trends in wrinkle responses to treatment, skin darkening and lightening. In future, these trends will be validated by more rigorous experiments.

5.5.2. SAR data classification using generalized Gamma mixture model

Participant: Josiane Zerubia [contact].

This work has been performed in collaboration with Dr. Vladimir Krylov (University of Genoa, Italy), Prof. Heng-Chao Li, Prof. Ping-Zhi Fan (Southwest Jiaotong University, Chengdu, China) and Prof. William Emery (University of Colorado, Boulder, USA).

SAR images, statistical modeling, generalized Gamma mixture model

The accurate statistical modeling of synthetic aperture radar (SAR) images is a crucial problem in the context of effective SAR image processing, interpretation and application. In this work a semi-parametric approach is designed within the framework of finite mixture models based on the generalized Gamma distribution (GΓD) in view of its flexibility and compact analytical form. Specifically, we have developed a generalized Gamma mixture model (GΓMM) to implement an effective statistical analysis of high-resolution SAR images and proved the identifiability of such mixtures. A low-complexity unsupervised estimation method has been derived by combining the proposed histogram-based expectation-conditional maximization algorithm and the Figueiredo-Jain mixture estimation algorithm. This resulted in a numerical maximum likelihood (ML) estimator that can simultaneously determine the ML estimates of component parameters and the optimal number of mixture components. The state-of-the-art performance of the proposed method has been validated experimentally on a wide range of high-resolution SAR amplitude and intensity images.

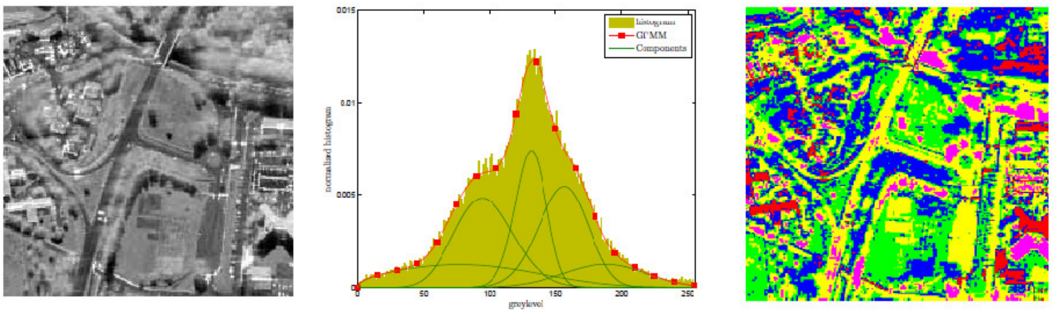


Figure 11. Statistical modeling of a RAMSES (©CNES, ONERA) image (left) by generalized Gamma mixture model (middle) and its visualization by maximum likelihood classification (right).

In Fig. 11 we demonstrate a typical result of the developed statistical modeling technique on a portion of a multilook airborne RAMSES (©CNES, ONERA) sensor acquisition over Toulouse suburbs (single polarization, downsampled to approximately 2m ground resolution). The unsupervised GΓMM estimate contains five components and reports a very accurate result that outperforms the considered benchmark statistical modeling methods. In order to visualize the estimated five statistical components we also report a maximum likelihood classification map.

6. Bilateral Contracts and Grants with Industry

6.1. Bilateral Contracts and Grants with Industry

6.1.1. Airbus D&S

Participants: Paula Craciun, Josiane Zerubia [PI].

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

6.1.2. CNES Toulouse

Participants: Ihsen Hedhli, Josiane Zerubia [PI].

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

6.1.3. CNES Toulouse

Participants: Aurélie Boisbunon, Josiane Zerubia [PI].

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

6.2. Consulting for Industry

Josiane Zerubia is a scientific consultant for the Galderma company.

7. Partnerships and Cooperations

7.1. Regional Initiatives

- Seong-Gyun Jeong, Nazre Batool, Yuliya Tarabalka and Josiane Zerubia have been in contact with Didier Zugaj, image processing expert for early clinical evaluation at Garlderma R&D in Sophia Antipolis http://www.galderma.com/About-Galderma/Worldwide-presence/R-D-Locations to discuss AYIN's research on wrinkle detection.
- Zhao Liu and Josiane Zerubia discussed 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) about Ayin's research on semi-automatic acne detection.

7.2. European Initiatives

7.2.1. 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.

7.3. International Initiatives

7.3.1. Informal International Partners

Qiyin Fang and Samir Sahli.

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

Institution: McMaster University (Canada).

Stuart Jones and Jochen Einbeck.

Subject: Shape modelling applied to subterranean sand bodies.

Institution: Department of Earth Sciences and Department of Mathematical Sciences, Durham University (UK).

Zoltan Kato, Tamas Sziranyi and Csaba Benedek.

Subjects: Multi-layer Markovian models for change detection in aerial and satellite images. Random field models of shape.

Institution: Szeged University and MTA SZTAKI (Hungary).

Gabriele Moser and 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).

7.4. International Research Visitors

7.4.1. Visits of International Scientists

- Csaba Benedek (MTA SZTAKI, Hungary, one week in January 2014).
- Qiyin Fang (McMaster University, Canada, one week in May 2014).
- Joseph Francos (Ben-Gurion University, Israel, one week in July 2014).
- Zoltan Kato (Szeged University, Hungary, one month, from mid-July till mid-August 2014).
- Vladimir Krylov (Genoa University, Italy, one week in September 2014).
- Zhao Liu (University of Manchester, one week in Dec 2014).
- Gabriele Moser (Genoa University, Italy, one week in July 2014).
- Samir Sahli (McMaster University, Canada, one week in September 2014).
- Thomai Tsiftsi (Durham University, UK, one week in March 2014).

7.4.1.1. Internships

Emmanuel Maggiori (from May until November 2014)

Subject: Optimizing partition trees for multi-class segmentation with shape prior.

Institution: Universidad Nacional del Centro de la Provincia de Buenos Aires and Inria.

Shu-Chi Yeh (from May until August 2014)

Subject: Hyperspectral skin image processing.

Institution: McMaster University, Canada.

7.4.2. Visits to International Teams

- Josiane Zerubia was invited in June to visit several laboratories in Israel: Electrical Eng. and Remote Sensing Departements at BGU in Beer Sheva, Computer Science Department at HUJI in Jerusalem, Computer Science Department at Haifa University, Multimedia Department at IDC University in Herzlyia, as well as 2 industrial research centers at Herzlyia (General Motors and Superdimension/Covidian). She also visited 2 start-up companies working in image processing: ORCAM in Jerusalem and GIVIEW in Ramat Gan. Finally she attended the Israel Computer Graphics day 2014 at Weizmann Institute in Rehovot.
- Josiane Zerubia visited in August the Computer Vision and Geometric Modeling lab at the University of Montreal, the Biophotonics lab at the Dept. of Engineering Physics of Mc Master University, as well as the Juravinski cancer research center in Hamilton, and two laboratories working in medical imaging and biological sciences at Sunnybrook Research Institute in Toronto.

- Josiane Zerubia was invited by University of Szeged and the Hungarian Academy of Sciences in December to visit the research group on visual computation at the Informatics Department, as well as the BIOMAG research group of the Synthetic and Systems Biology Unit, located both at Szeged University. She also visited 3 laboratories related to remote sensing, image processing and computer graphics in MTA SZTAKI in Budapest.

8. Dissemination

8.1. Promoting Scientific Activities

8.1.1. Scientific events organisation

8.1.1.1. Member of the organizing committee

- Josiane Zerubia was a part of the organizing committee for the IEEE ICIP conference in Paris in September 2014 (more than 1700 participants) http://icip2014.wp.mines-telecom.fr/. She was also co-chair of the tutorials and chair of a session.

8.1.2. Scientific events selection

8.1.2.1. Member of the conference program committee

- Yuliya Tarabalka was a part of the program committee for the OSA Imaging Systems and Applications conference 2014.
- Josiane Zerubia was a part of the program committee for the EMMCVPR conference in Hong-Kong http://blog.ust.hk/emmcvpr/people/.

8.1.2.2. Reviewer

- Nazre Batool was a reviewer for the conference IEEE ICIP 2014.
- Aurélie Boisbunon was a reviewer for the European Signal Processing Conference (EUSIPCO).
- Ian Jermyn was a reviewer for the conferences EMMCVPR, IEEE ICIP 2014, IDEAL and of proposals for the UK Engineering and Physical Sciences Research Council and the Israel Science Foundation.
- Yuliya Tarabalka was a reviewer for the conferences IEEE ICIP 2014, IEEE IGARSS 2014 and OSA Imaging Systems and Applications 2014.
- Josiane Zerubia was a reviewer for the conferences EMMCVPR, IEEE ICASSP'14, IEEE ISBI'14, IEEE ICIP'2014 and ICPR'14.

8.1.3. Journal

8.1.3.1. Member of the editorial board

- Yuliya Tarabalka was a co-editor of the special issue "Analysis of Remote Sensing Image Data" for the journal Remote Sensing.
- Josiane Zerubia is an Associate Editor of the collection "Foundation and Trends in Signal Processing" [http://www.nowpublishers.com/].
- Josiane Zerubia is a member of the Editorial Board of the "Revue Française de Photogrammétrie et de Télédétection of SFPT".
- Josiane Zerubia is an Associate Editor of the electronic journal Earthzine [http://www.earthzine.org/].

8.1.3.2. Reviewer

- Nazre Batool was a reviewer for IEEE TIP, IET Image Processing journal and International Journal of Image and Graphics.

- Aurélie Boisbunon was a reviewer for the journals Signal Processing and Pattern Recognition.
- Paula Craciun was a reviewer for the IEEE JSTARS journal.
- Seong-Gyun Jeong was a reviewer for the journals IEEE CSVT and ELS JVCIR.
- Ihsen Hedhli was a reviewer for the journals IEEE GRSL, IEEE JSTARS and MDPI remote sensing.
- Ian Jermyn was a reviewer for the Journal of Mathematical Imaging and Vision
- Yuliya Tarabalka was a reviewer for the journals IEEE TIP, IEEE TGRS, IEEE JSTARS and ISPRS Journal of Photogrammetry and Remote Sensing.

8.1.4. Seminars

- Nazre Batool attended a meeting with Galderma R&D in August 2014 at Galderma, Sophia Antipolis and presented research progress on evaluation of temporal changes in facial wrinkles.
- Nazre Batool attended a meeting with Fraunhofer Institutes (Germany) and Philips Research (Netherlands) under LIRA consortium in February 2014 at Inria Sophia Antipolis.
- Aurélie Boisbunon gave the seminar “Détection de bateaux sur images satellitaires de ports”, at BioSP team, INRA Avignon, France, in June.
- Aurélie Boisbunon gave the seminar “Non convex sparse optimization problems in very high dimension and application to object detection”, at the Nonconvex optimization meeting organized by GdR ISIS, Télécom ParisTech, France, in May.
- Paula Craciun gave a seminar about multiple target tracking using marked point processes at Inria Rennes, in December 2014 and enjoyed a large audience from Inria Rennes and IRMAR Institute.
- Ihsen Hedhli, together with Aurélie Boisbunon and Josiane Zerubia presented Ayin research work at a poster session during the Pleiades days organized the French Space Agency in Toulouse in April 2014.
- Seong-Gyun Jeong attended a meeting with Galderma R&D in August 2014 at Galderma, Sophia Antipolis and presented his work on facial wrinkle detection.
- Seong-Gyun Jeong presented his work for regular poster session and Inria booth in IEEE ICIP 2014, Paris, in October.
- Yuliya Tarabalka visited and gave seminars at the University of Surrey and the University of Nice Sophia-Antipolis, on the topic of spatio-temporal video segmentation with shape growth or shrinkage constraint, in January and February 2014, respectively.
- Yuliya Tarabalka, Ian Jermyn and Josiane Zerubia attended a meeting at Institute Mines-Telecom in Paris in March 2014 with Magellium (UK), University of Genoa (Italy), EPFL (Switzerland), University of Szeged (Hungary), University of Tromsø (Norway), University of Iceland and University Ben Gurion (Israel). The meeting was held in regards with a project proposal for the H2020 initiative.
- Josiane Zerubia organized the meeting with 2 Fraunhofer Institutes (Germany), Philips Research (Netherlands), Red Cross Hospital (Netherlands), Galderma R&D (France), CHU Nice/Inserm (France) and Inria-SAM (France). The meeting was held in regards with a project proposal for the H2020 initiative at Inria Sophia Antipolis in February 2014.
- Josiane Zerubia was invited to give in June a series of different seminars related to remote sensing, marked point processes and hierarchical Markov random fields in Israel at Ben Gurion University in Beer Sheva, Hebrew University of Jerusalem, University of Haifa as well as in two industrial R&D centers in Herzlyia (General Motors and Superdimension/Covidian).
- Josiane Zerubia gave in August in Canada a seminar on remote sensing at University of Montreal and two talks on skin image processing at Mc Master University (Biophotonics lab and Juravinski Cancer Center).

- Josiane Zerubia was invited in December to go to Hungary to give a talk on skin image processing at University of Szeged and another one on hierarchical Markov random field for remote sensing at MTA SZTAKI in Budapest.

8.2. Teaching - Supervision - Juries

8.2.1. Teaching

- 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 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).

8.2.2. 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.

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.

8.2.3. Juries

- Yuliya Tarabalka participated in the monitoring committee for the thesis of Amine Bohi, Southern University of Toulon-Var in September 2014.
- Josiane Zerubia was a reviewer for the Master 2 SVS ISAB at UNS.
- Josiane Zerubia participated with another senior researcher of Inria in the monitoring committee for all the PhD theses funded by Airbus Defense and Space at Inria.
- Josiane Zerubia was a reviewer of a joint PhD thesis between ONERA/DOTA in Toulouse and GIPSA lab at ENSE3 in Grenoble (PhD thesis committee).
- Josiane Zerubia was a member of the selection committee to hire junior researchers (CR2) at Inria-SAM in May 2014.

8.3. Popularization

- Aurélie Boisbunon is the representative of PhD students and postdocs at the Mediation and Animation commission (MASTIC) of Inria Sophia Antipolis.
- Aurélie Boisbunon gave talks about machine learning and image processing to high school students and junior high school students for the MathsC2+ training course and for the Fête de la Science 2014.

- Aurélie Boisbunon is participating in a project with junior high school students from Collège Nucéra, in Nice, aiming at giving an introduction to programming and robotics.
- Josiane Zerubia gave a talk on aerial and satellite image processing to high school students in Physics at Valbonne International Center during the “Fête de la Science 2014.”
- Josiane Zerubia presented Inria and Inria-SAM to interested PhD and post-doc students at Inria booth during ICIP'14 in Paris as well as Mc Master University in Canada, University of Szeged and MTA SZTAKI in Hungary.
- Josiane Zerubia is organizing a monthly scientific seminar at Inria-SAM with national and international speakers (see https://team.inria.fr/ayin/ayinseminars/).

9. Bibliography

Publications of the year

Articles in International Peer-Reviewed Journals

[1] H. AGHIGHI, J. TRINDER, Y. TARABALKA, S. LIM. *Dynamic Block-Based Parameter Estimation for MRF Classification of High-Resolution Images*, in "IEEE Geoscience and Remote Sensing Letters", October 2014, vol. 11, n° 10, pp. 1687-1691, https://hal.inria.fr/hal-01016505

[2] P. CRACIUN, J. ZERUBIA. *Unsupervised marked point process model for boat extraction and counting in harbors from high resolution optical remotely sensed images*, in "Revue Francaise de Photogrammétrie et Télédétection", July 2014, n° 207, pp. 33-44, https://hal.inria.fr/hal-01119448

[3] Y. TARABALKA, G. CHARPIAT, L. BRUCKER, B. MENZE. *Spatio-Temporal Video Segmentation with Shape Growth or Shrinkage Constraint*, in "IEEE Transactions on Image Processing", September 2014, vol. 23, n° 9, pp. 3829-3840, https://hal.inria.fr/hal-01052543

[4] 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", June 2014, vol. 52, n° 6, pp. 3346-3358 [*DOI :* 10.1109/TGRS.2013.2272581], https://hal.inria.fr/hal-00841234

International Conferences with Proceedings

[5] H. AGHIGHI, J. TRINDER, K. WANG, Y. TARABALKA, S. LIM. *Smoothing parameter estimation for Markov random field classification of non-Gaussian distribution image*, in "ISPRS TC VII Symposium", Istanbul, Turkey, September 2014, https://hal.inria.fr/hal-01068242

[6] A. BOISBUNON, R. FLAMARY, A. RAKOTOMAMONJY. *Active set strategy for high-dimensional non-convex sparse optimization problems*, in "ICASSP - IEEE International Conference on Acoustics Speech and Signal Processing", Florence, Italy, May 2014, https://hal.inria.fr/hal-01025585

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[9] P. CRACIUN, J. ZERUBIA. *Towards efficient simulation of marked point process models for boat extraction from high resolution optical remotely sensed images*, in "IEEE IGARSS - International Geoscience and Remote Sensing Symposium", Quebec, Canada, July 2014, https://hal.inria.fr/hal-01016874

[10] I. HEDHLI, G. MOSER, J. ZERUBIA, S. B. SERPICO. *Fusion of multitemporal and multiresolution remote sensing data and application to natural disasters*, in "IEEE IGARSS - International Geoscience and Remote Sensing Symposium", Québec, Canada, July 2014, https://hal.inria.fr/hal-01022380

[11] I. HEDHLI, G. MOSER, J. ZERUBIA, S. B. SERPICO. *New cascade model for hierarchical joint classification of multitemporal, multiresolution and multisensor remote sensing data*, in "IEEE ICIP - International Conference on Image Processing", Paris, France, October 2014, https://hal.inria.fr/hal-01071034

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[17] P. CRACIUN, M. ORTNER, J. ZERUBIA. *Joint detection and tracking of moving objects using spatio-temporal marked point processes*, in "IEEE Winter Conference on Applications of Computer Vision", Hawaii, United States, January 2015, https://hal.inria.fr/hal-01104981

Scientific Books (or Scientific Book chapters)

[18] J. TILTON, A. SELIM, Y. TARABALKA. *Image segmentation algorithms for land categorization*, in "Remote Sensing Handbook", P. S. THENKABAIL (editor), Taylor and Francis, September 2015, https://hal.inria.fr/hal-01068167

Research Reports

[19] E. MAGGIORI, Y. TARABALKA, G. CHARPIAT. *Multi-label segmentation of images with partition trees*, Inria Sophia Antipolis, November 2014, https://hal.inria.fr/hal-01084166