Activity Report 2015

Team AYIN

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

Inria teams are typically groups of researchers working on the definition of a common project, and objectives, with the goal to arrive at the creation of a project-team. Such project-teams may include other partners (universities or research institutions).

RESEARCH CENTER
Sophia Antipolis - Méditerranée

THEME
Vision, perception and multimedia interpretation

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Team AYIN

Creation of the Team: 2012 January 01

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1. Members

Research Scientist

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

Engineer

Anthony Jacquemin [Inria, in July and Oct 2015]

PhD Students

Paula Craciun [Inria, until Nov 2015, granted by Airbus DS]
Ihsen Hedhli [cosupervised with the University of Genoa, granted by the Italian government]
Seong-Gyun Jeong [Univ. Nice, until Nov 2015, granted by the French government (MESR)]

Post-Doctoral Fellows

Nazre Batool [Inria, until May 2015]
Aurélie Boisbunon [CNES, until Jan 2015]

Administrative Assistant

Valeria Neglia [Inria, until May 2015]

Others

Ali Madooei [PhD student, Simon Fraser University, Canada, Inria Intern, from Jun 2015 until Aug 2015, granted by MITACS/Inria]
Ganchi Zhang [PhD student, University of Cambridge, UK, one week in March 2015]
Vladimir Krylov [Postdoctoral researcher, University of Genoa, Italy, one week in November 2015]

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 the 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 or marginalized 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. Highlights of the Year

5.1. Highlights of the Year

- Yuliya Tarabalka (Inria junior researcher) and Emmanuel Maggiori (PhD student) moved from AYIN [https://team.inria.fr/ayin/] to TITANE [https://team.inria.fr/titane/] team in January.
- Josiane Zerubia was nominated in November IEEE Signal Processing Society (SPS) Distinguished Lecturer for a duration of 2 years [http://www.signalprocessingsociety.org/newsletter/2015/11/sps-announces-2016-class-of-distinguished-lecturers/].

6. New Software and Platforms

6.1. SAAD

- Participants: Zhao Liu and Josiane Zerubia
- Contact: Josiane Zerubia

The code SAAD (Semi-Automatic Acne Detection) V1.0, related to a new acne detection approach using a Markov random field model and chromophore descriptors extracted by bilateral decomposition, developed by Zhao Liu and Josiane Zerubia and deposited at APP (Agence de Protection des Programmes) in December 2013, has been transferred to L'OREAL company for research tests in February 2015.

6.2. ED

- Participants: Paula Craciun and Josiane Zerubia
- Contact: Josiane Zerubia

The code ED (Ellipses Detection) V1.0, related to a new elliptic object detection approach using Marked Point Process (MPP), developed by Paula Craciun and Josiane Zerubia, has been deposited to APP in December.

6.3. ET

- Participants: Paula Craciun and Josiane Zerubia
- Contact: Josiane Zerubia

The code ET (Ellipses Tracking) V1.0, related to a new elliptic object tracking approach using MPP, developed by Paula Craciun and Josiane Zerubia, has been deposited to APP in December. This code is available in a sequential or in a parallel (multi-core) version and can be applied to image sequences in biology or remote sensing (between 2 and 30 frames/second)

6.4. ETK

- Participants: Paula Craciun and Josiane Zerubia
- Contact: Josiane Zerubia

The code ETK (Ellipses Tracking Kalman) V1.0, which is a variant of of the ET V1.0 code (without the parallel implementation) using a Kalman filter, developed by Paula Craciun and Josiane Zerubia, has been deposited to BNF (Bibliothèque Nationale de France) in December.

6.5. CLESTO

- Participants: Seong-Gyun Jeong, Yuliya Taralka and Josiane Zerubia
- Contact: Josiane Zerubia

The code CLESTO (CurviLinear structure Extraction with STOchastic process) V1.0, related to a new method for the extraction of curvilinear structures based on MPP, developed by Seong-Gyun Jeong, Yuliya Taralka and Josiane Zerubia, has been deposited to BNF in December.

6.6. CLERANK

- Participants: Seong-Gyun Jeong, Yuliya Taralka and Josiane Zerubia
- Contact: Josiane Zerubia

The code CLERANK (CurviLinear structure Extraction with RANKing) V1.0, related to a new method for the extraction of curvilinear structures using ranking, developed by Seong-Gyun Jeong, Yuliya Taralka and Josiane Zerubia, has been deposited to BNF in December.

6.7. Consulting for Industry

Josiane Zerubia is a scientific consultant for the Galderma company [http://www.galderma.com/About-Galderma/Worldwide-presence/R-D-Locations]

7. New Results

7.1. Markov Random Fields

7.1.1. New hierarchical joint classification method of SAR and optical multiresolution remote sensing datas

Participants: Ihsen Hedhli, Josiane Zerubia [contact].

This work was carried out in collaboration with Prof. Gabriele Moser and Prof. Sebastiano Serpico from DITEN departement [www.diten.unige.it/], University of Genoa, Italy.

Nowadays, a wide variety of remote sensing images is available. Therefore, it becomes more and more important to be able to analyze compound data sets consisting of different types of images acquired by different sensors, as they allow a spatially distributed and temporally repetitive view of the monitored area at the desired spatial scales. In particular, the opportunity of joint availability of synthetic aperture radar (SAR) and optical images offers high resolution (HR), all-weather, day/night, short revisit time data, as well as polarimetric and multifrequency acquisition capabilities. Similarly, the strong differences in terms of wavelength range (microwave vs. visible and near infrared), sensitivity to cloud cover and sun illumination (strong for optical imagery vs. almost negligible for SAR), and noise-like properties (speckle in SAR vs. generally low noise variance in current HR optical sensors) make the joint use of HR optical and SAR imagery especially interesting for many applications to environmental monitoring and natural risk management. Within this framework, there is a definite need for classification methods that automatically correlate different sets of images taken on the same area from different sensors and at different resolutions. This year we developed a novel classification approach for multiresolution, multisensor (optical and synthetic aperture radar), and/or multiband images. Accurate and time-efficient classification methods are particularly important tools to support rapid and reliable assessment of the ground changes. Given the huge amount and variety of data available currently from last-generation satellite missions, the main difficulty is to develop a classifier that can benefit from multiband, multiresolution, and multisensor input imagery. As shown in Figure 1, the proposed method addresses the problem of multisensor fusion of SAR with optical data for classification purposes, and allows input data collected at multiple resolutions and additional multiscale features derived through wavelets to be fused. The proposed approach formalizes a supervised Bayesian classifier within a multiple quadtree topology that combines a class-conditional statistical model for pixel-wise information and a hierarchical Markov random field (MRF) for multisensor and multiresolution contextual information.

7.2. Marked point processes

7.2.1. Integrating RJMCMC and Kalman filters for multiple object tracking

Participants: Paula Craciun, Josiane Zerubia [contact].

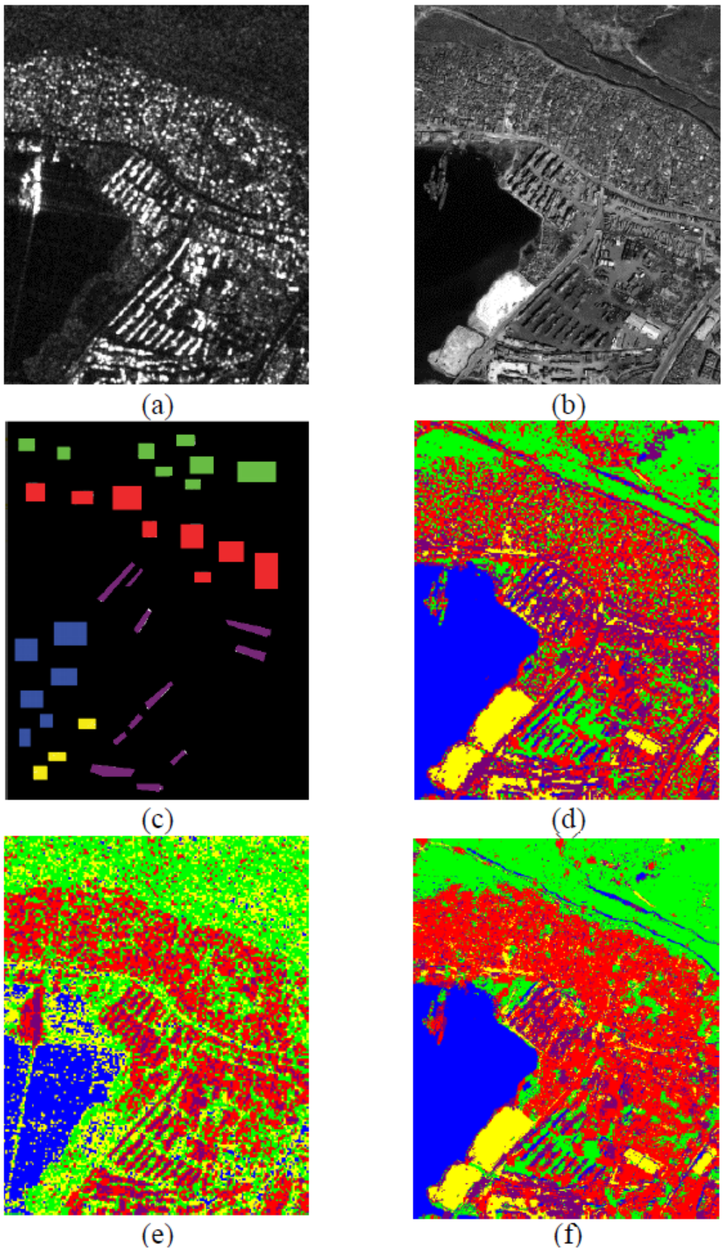


Figure 1. (a) SAR image (© ASI), (b) one channel from the optical image (© GeoEye), (c) the available ground truth, (d) hierarchical MRF-based classification obtained from the optical image, using Laferté method, (e) hierarchical MRF-based classification obtained for the SAR image, using Laferté method, (f) hierarchical MRF-based classification obtained by the proposed method.

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

Recently, we have proposed a new spatio-temporal marked point process model for tracking small, rigid objects in high resolution images. We have shown very good detection and tracking results for synthetic biological data as well as remotely sensed sequences. The model is based on defining a dedicated energy function that is highly non-convex. The solution is found by minimizing this energy function using a suitable batch-optimization scheme based on Reversible Jump Markov Chain Monte Carlo (RJMCMC) sampler. This approach is motivated by the low temporal frequency of the sequences (1Hz).
Sequential filters have proven to provide relatively fast and reliable tracking performances in particular for single target tracking. We have efficiently exploited the properties of sequential filters within the RJMCMC sampling scheme. The filter is used to generate more meaningful perturbation proposals which are then evaluated using an appropriate Green acceptance ratio. Better perturbation proposals increase the acceptance probability of the overall RJMCMC sampling scheme which in turn leads to a faster convergence.
Figure 2 shows the detection and tracking results on two synthetic biological sequences as well as on two sequences of simulated satellite images of Toulon by courtesy of Airbus Defence & Space, France. The evolution of the energy with the number of iterations for the standard RJMCMC sampler and the proposed sampler is also shown. The proposed sampler is depicted blue.

7.2.2. 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 Dr. Rémi Flamary (Université de Nice Sophia Antipolis), Prof. Alain Rakotomamonjy (Université de Rouen) et Alain Giros (CNES). It was partially funded by the French Spatial Agency CNES [http://www.cnes.fr].

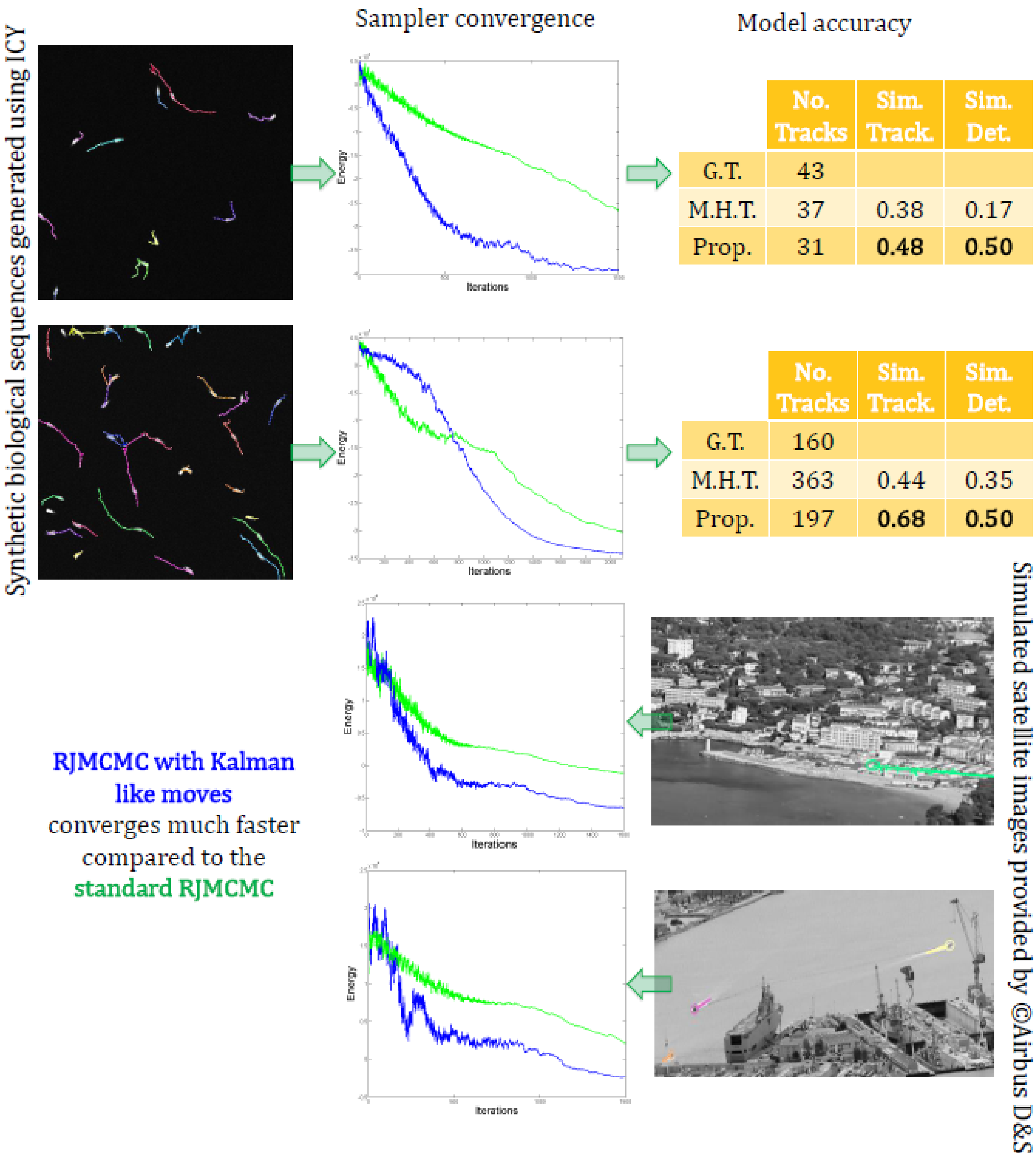
Sparse representations, large scale, stochastic algorithms, machine learning, image processing Marked point processes (MPP) strongly rely on parameters, whose estimation affects both computation time and performances. In this work, we proposed two approaches: the first one consists in initializing MPPs with a first coarse solution obtained very quickly from sparse regularization methods, while the second one estimates the parameters by the Stochastic Approximation Expectation-Maximization (SAEM) algorithm. 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. 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. This work started last year, and continued this year by conducting more tests.

7.2.3. Generic curvilinear structure modeling via marked point process theory

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

This work has been done in collaboration with Dr. Nicolas Nisse (COATI team [https://team.inria.fr/coati/], Inria-SAM) and Dr. Yuliya Tarabalka (Titane team [https://team.inria.fr/titane/team/], Inria-SAM)

We propose a novel curvilinear structure reconstruction algorithm based on ranking learning and graph theory. In this work we reconstruct the curvilinear structure as a set of small line segments (via MPP). Specifically, we infer the structured output ranking of the line segments via Structured Support Vector Machine(SSVM). To predict the existence of the curvilinear structure, we measure oriented image gradient maps and morphological profiles. We propose an orientation-aware curvilinear feature descriptor and a feature grouping operator to improve the structural consistency for learning system. In order to provide topological information, we develop a graph-based curvilinear structure reconstruction algorithm. The proposed algorithm builds a graph based on the output ranking scores and searches the longest geodesic paths which are associated with the latent curvilinear structure. Experimental results (see Figure 3) show that the proposed algorithm faithfully detects the curvilinear structures and preserves topological information compared with the competing algorithms.



	No. Tracks	Sim. Track.	Sim. Det.
G.T.	43		
M.H.T.	37	0.38	0.17
Prop.	31	**0.48**	**0.50**

	No. Tracks	Sim. Track.	Sim. Det.
G.T.	160		
M.H.T.	363	0.44	0.35
Prop.	197	**0.68**	**0.50**

Figure 2. Tracking results and sampler convergence on two synthetic biological sequences (generated using ICY [http://icy.bioimageanalysis.org/], a free software offered by the Quantitative Analysis Unit from the Pasteur Institute, France) as well as two sequences of simulated satellite images of Toulon (by courtesy of Airbus Defence & Space, France). The RJMCMC sampler with Kalman like moves (shown in blue) requires a significantly lower number of iterations until convergence as compared to the standard RJMCMC.

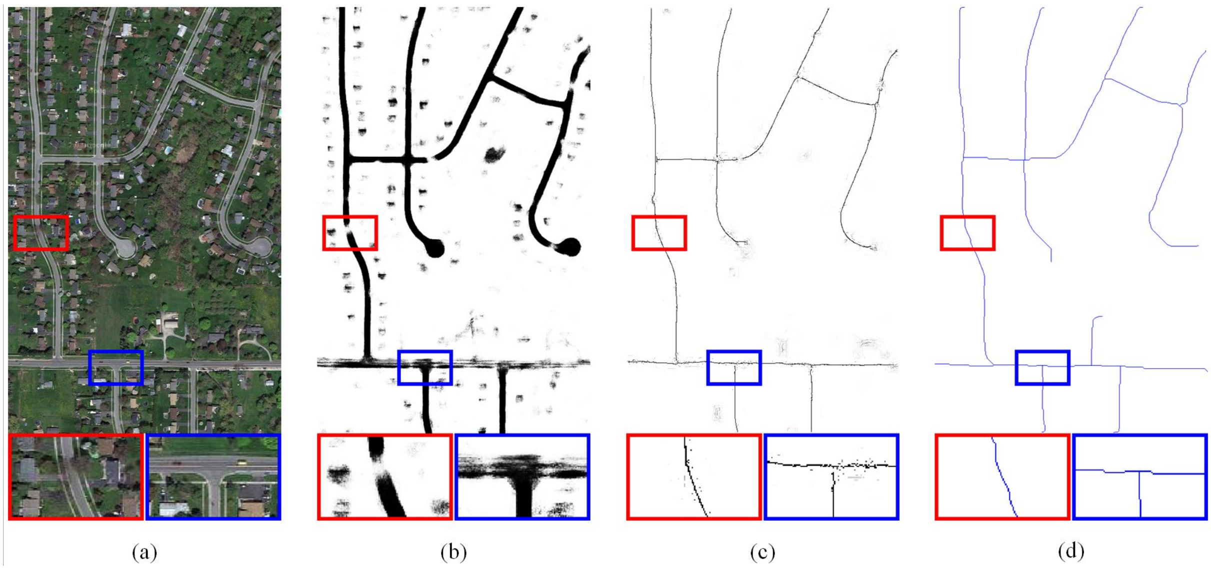


Figure 3. Compared with (b) the segmentation and (c) the centerline detection methods, (d) the proposed algorithm well represents topological features of the curvilinear structure. Setting a threshold value yields to lose correlated information of the pixels on the reconstructed curvilinear structure. In this example, road network is partially occluded by trees or cars, so that the local measure often fails to detect the underlying curvilinear structures. Although the centerline is able to quantify scale (width) of curvilinear structure, it is inaccurate to classify pixels around junctions. In this work we learn spatial patterns of the curvilinear structures with structured output ranking scores. We also propose a graph-based representation algorithm to obtain the topological information.

7.3. Other approaches

7.3.1. Acne detection on polarized or non-polarized images

Participants: Zhao Liu, Josiane Zerubia [contact].

This work is in collaboration with Dr. Queille-Roussel and Prof. Bahadoran in CHU Nice, France. Now Dr. Zhao Liu is a post-doc at Manchester University [www.manchester.ac.uk/], Manchester, UK.

This work is in collaboration with Dr. Queille-Roussel and Prof. Bahadoran in CHU Nice, France.

Acne vulgaris, a highly prevalent skin disease, has a significant life quality impact on patients. It is generally believed that this type of skin disorder results from proliferation of propionibacterium acnes in pilosebaceous units, which can lead to inflammatory lesions due to increase of oxyhemoglobin level. So far there is no golden standard for acne diagnosis in clinics. It entirely depends on dermatologists' experience for acne assessment. But significant variability among individual diagnosis may lead to less trustworthy results, and less reproducibility of human evaluation makes the comparison of acne follow-up difficult. This work, incorporating the knowledge of optical characteristics of human skin, identifies cutaneous chromophore distribution using bilateral decomposition. Then the inflammatory acne lesions are detected by a Markov random field (MRF) model associating the chromophore descriptors. Experimental results (see Figure 4) show that the proposed method is robust to large dynamic range intensity, and the derived automatic segmentation of inflammatory acne appears to be highly consistent to human visual assessment. This research work was started in 2013. This year, more tests have been conducted on polarized and non-polarized images.

Figure 4. Acne detection using proposed method. (Left) Original image provided by CHU Nice. (Right) Acne detection result.

7.3.2. Finer registration of facial wrinkles in time series images

Participants: Nazre Batool, Josiane Zerubia [contact].

Dr. Batool was funded by the Inria-DPEI fellowship for the period Feb. 2014 – May 2015. Currently she is a postdoc researcher at CMIV, Linköping University [www.liu.se/cmiv], Linköping, Sweden.

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. Any image analysis technique for the analysis of such subtle image variations would require high accuracy and precision for good performance. As in other imaging problems geared towards detection of temporal changes, accurate registration of key image features (wrinkles) is mandatory as a first step. We propose to compare image features in key wrinkle sites only while excluding the noise introduced by changes in surrounding skin texture. Therefore, previously we proposed a 2-step registration algorithm where the initial registration was based on the alignment of facial landmarks such as corners of eyes, nose, and mouth. Then a method based on Large Deformation Diffeomorphic Metric Mapping (LDDMM) was used to achieve finer local registration for wrinkles. However, the LDDMM algorithm had the shortcoming of the unavailability of time invariant finer facial landmarks and that the deformations were guided by image intensities which were varying among images as well due to subtle changes in skin texture. The deformation of skin due to underlying movement can be categorized loosely as locally rigid because the local skin texture remains constant but globally non-rigid because of the movement of skin areas due to slight expression and misalignment. Due to this dual nature of deformation, registration schemes such as thin plate spline or affine transformations are not applicable. Our improved approach is to guide the LDDMM registration on skin features with higher intensity gradients only (such as due to moles, wrinkles, rough surface) which have the higher probability of being constant and detected across temporal changes. First we detect key landmarks and landmark correspondences using the Gabor feature images where the phase correlation is used to find estimates of landmark correspondences. The phase correlation is based on the well-known Fourier shift property i.e. a shift in the spatial domain of two images results in a linear phase difference in the frequency domain of their respective Fourier Transforms. Figure 5 shows Gabor features of two images captured 4 weeks apart in (a) and (b). Figure 5 (c) shows key landmarks placed at high Gabor amplitude sites and (d) shows their corresponding landmarks detected using Fourier phase correlation.

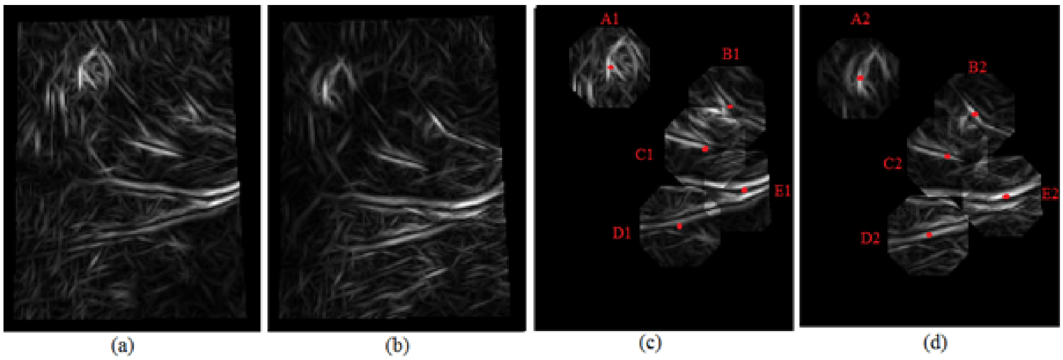


Figure 5. Detection of landmarks and correspondences. (a) Gabor response for source image. (b) Gabor response for target image. (c) 5 landmarks with circular templates in source image. (d) Corresponding detected landmarks with circular templates in target image.

Then, as a next step, the detected key landmarks and their corresponding positions are used in the landmark based LDDMM algorithm to find locally non-rigid deformations between two images. Figure 6 shows an example where the corresponding landmarks are shown as black dots in (a) and (b). Fig. 5 (c) shows the image in (a) wrapped to (b) using LDDMM based on landmark correspondences. In (d) the drifts of landmarks are shown during the LDDMM algorithm and (e) shows the non-rigid deformation of underlying image grid. In the future, the proposed wrinkle registration algorithm will be used to compare wrinkle intensities in time series of images to quantify very minute changes in wrinkles in response to dermatological treatments.

7.3.3. Hyperspectral Image Processing for Detection and Grading of Skin Erythema

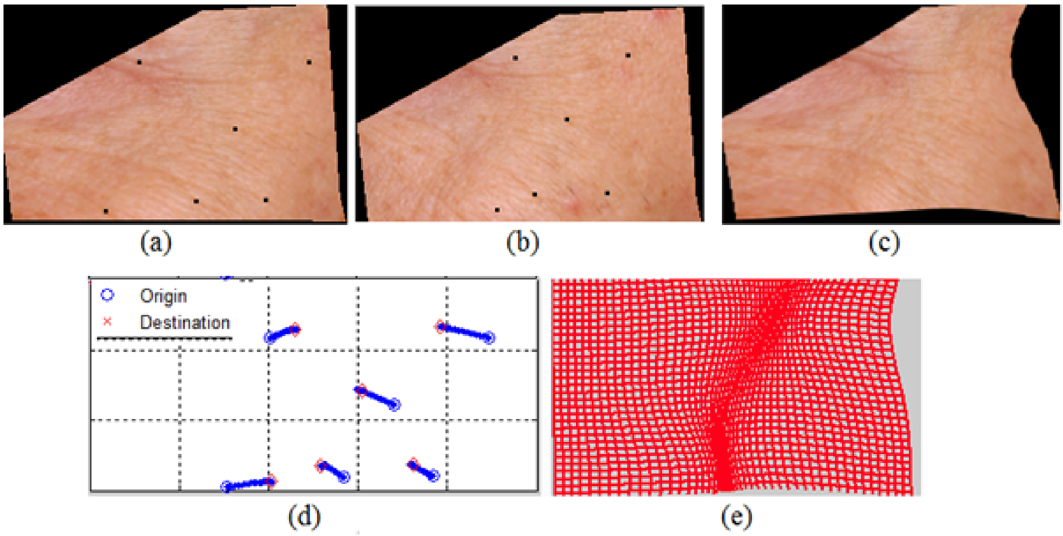


Figure 6. Finer registration of micro features in skin images. (a) Source image with landmarks shown as black dots. (b) Target image with landmarks. (c) Source image wrapped to target image. (d) Path of landmarks during LDDMM registration. (e) Deformation of underlying grid during LDDMM registration.

Participants: Ali Madooei, Josiane Zerubia [contact].

Ali Madooei worked at Inria Sophia Antipolis on an internship funded by the Canadian Mitacs Globalink Research Award & Inria. He is currently in his last year of PhD at Simon Fraser [www.sfu.ca/] University, Canada. This work has been conducted in collaboration with Ramy M. Abdlaty, Lilian Doerwald-Munoz, Dr. Joseph Hayward and Prof. Qiyin Fang from Mc Master university [http://future.mcmaster.ca/]/Juravinsky cancer center [www.jcc.hhsc.ca/], Canada, and Prof. Joseph Hayward from Simon Fraser University, Canada.

Acute skin erythema is a common side effect in patients undergoing radiotherapy treatment. It displays itself as an increase in skin redness and irritation. Erythema has been reported to correlate to individual patient response to radiation and therefore may be useful to guide and modify courses of treatment in a timely manner. Currently, upon visual examination, a qualitative score can be assigned to characterize the severity of erythema, which then may be used for assessing radiation response. Due to the subjective nature of this method, additional non-invasive techniques are needed for more accurate evaluation. Previous studies have mainly focused on tissue reflectance spectroscopy or imaging photography. The former retrieves spectral information from point measurements while the latter is obtained with conventional Red, Green, Blue(RGB) colour cameras. Photography has the advantage of offering spatial information but this comes at the cost of losing much of spectral information. We use hyperspectral imaging (HSI) which provides both spatial and spectral representation of the affected area. A hyperspectral camera effectively divides the spectrum into very many thin image slices (the actual number depending on the camera and application see Fig.7). This fine-grained slicing reveals spectral structure that may not be evident to the eye or to an RGB camera but can provide a rich set of information for image processing. As an emerging imaging modality for medical applications, the combination of HSI devices with adequate image processing techniques offers the perfect landscape for developing new methods for noninvasive disease monitoring and diagnosis.

The purpose of our study was to investigate the possibility of monitoring the degree of erythema using HSI data. To this aim, we proposed an image processing pipeline and conducted controlled experiments to demonstrate the efficacy of the proposed approach for (1) reproducing clinical assessments, and (2)

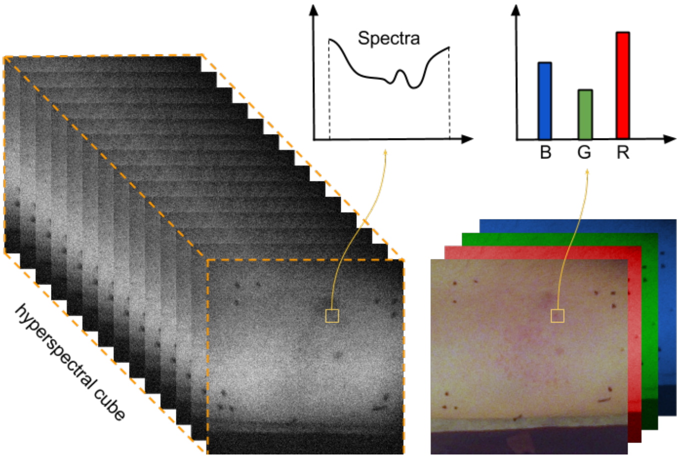


Figure 7. A schematic representation of hyperspectral vs. RGB image data.

outperforming RGB imaging data. We combined the problem of erythema detection and grading into a multi-class classification problem where each pixel is classified as one of the four erythema classes or a non-erythema class. We used a weighted LDA (linear discriminant analysis) classifier to deal with noisy labels. Moreover, we devised pre-processing steps to deal with noisy measurements. We evaluated the system against the clinical assessment of an experienced clinician. We also compared the performance to that of using digital photography (instead of HSI). The results from this preliminary study are encouraging and indicate that hyperspectral image data do contain relevant information, and indeed outperform imaging photography. In the future, we want to extend the technique to further detect other skin responses to radiation (such as dry/moist desquamation, skin necrosis, etc.) and also to experiment with real patients undergoing radiotherapy. Our ultimate objective is to build a system for monitoring radiation response in individuals using HSI technology and image processing.

7.3.4. SAR data classification using generalized Gamma mixture model

Participants: Vladimir Krylov, Josiane Zerubia [contact].

Vladimir Krylov is a former AYIN post-doc, now post-doc at DITEN department, University of Genoa [www.diten.unige.it/], Italy. This work has been performed in collaboration with Prof. Heng-Chao Li, Prof. Ping-Zhi Fan (Southwest Jiaotong University, Chengdu [english.swjtu.edu.cn/], China) and Prof. William Emery (University of Colorado [www.colorado.edu/], Boulder, USA).

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.

In Fig. 8 we demonstrate a typical result of the developed statistical modeling technique on a portion of a 2 meter resolution L-band image acquired by an airborne EMISAR system. The unsupervised GΓMM estimate

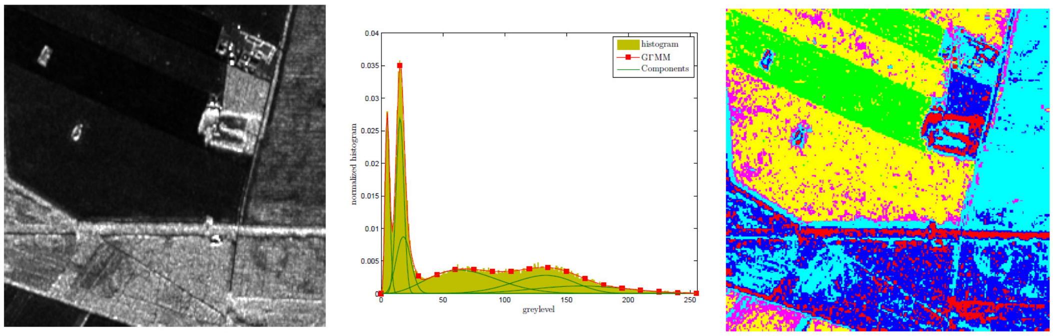


Figure 8. Statistical modeling of a EMISAR (©ESA) image (left) by generalized Gamma mixture model (middle) and its visualization by maximum likelihood classification (right).

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.

7.3.5. Multitemporal image change detection with a False Discovery Rate approach

Participants: Vladimir Krylov, Josiane Zerubia [contact].

This work has been performed in collaboration with Prof. Sebastiano Serpico and Prof. Gabriele Moser, DITEN department, University of Genoa [www.diten.unige.it/], Italy.

Multitemporal change detection is one of the fundamental image processing problems and multiple detection, monitoring and tracking applications rely on its accurate and timely performance. In this work we address the problem of unsupervised change detection on two or more coregistered images of the same object or scene at several time instants. The designed method is appropriate for short image sequences with a relatively small amount of changes. Such analysis is instrumental in various applications where acquisitions are relatively sparse and report limited meaningful changes, in particular, in remote sensing and medical image processing. We develop a novel patch-based hypothesis testing approach which is based on a false discovery rate formulation for statistical significance testing. This alternative error metric allows to adjust the family-wise error rate by imposing control over the proportion of the false positives in the detection. The designed change detector allows the use of various statistical features. The appropriate choice of the latter enables the detector to address application-specific detection problems with a particular set of disturbance factors, like noise, illumination variation, etc. In particular, we demonstrate the use of two rank-based statistics for change detection on image pairs and one multisample statistic for the analysis of image sequences. The experiments with remotely sensed radar, dermatological, and still camera surveillance imagery demonstrate competitive performance and flexibility of the proposed method.

A typical result obtained with the proposed change detection technique is reported in Fig. 9. The proposed approach gives a unified statistical thresholding procedure to perform change detection based on statistical features that have a known distribution under the no-change hypothesis. This approach is essentially non-parametric and is highly parallelizable.

8. Bilateral Contracts and Grants with Industry

8.1. Bilateral Contracts with Industry

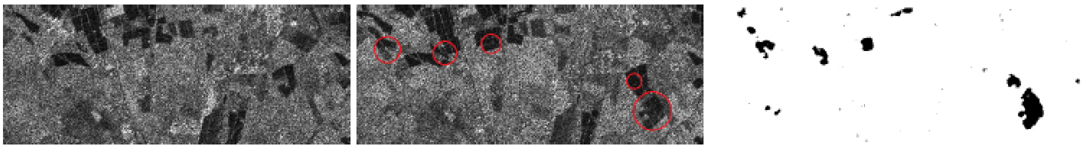


Figure 9. Change detection on a pair of 15 meter resolution XSAR images (first and second) obtained with a false discovery rate error metric based on the Cramer-von Mises statistic. The changes are highlighted with red circles (second), and the unsupervised detection result is reported in black (third).

8.1.1. Airbus D&S

Participants: Paula Craciun, Josiane Zerubia [contact].

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

8.1.2. L'OREAL Cosmétique Active International

Participants: Zhao Liu, Josiane Zerubia [contact].

Acne detection on images using a Markov random field model and chromophore descriptors extracted by bilateral decomposition. Contract #201514035.

8.2. Bilateral Grants with Industry

8.2.1. CNES Toulouse

Participants: Aurélie Boisbunon, Josiane Zerubia [contact].

Parameter estimation for automatic object change detection in a sequence of very high resolution optical images. Full post-doctoral grant funded by CNES, given to Aurélie Boisbunon during her 16 month stay in AYIN team.

9. Partnerships and Cooperations

9.1. Regional Initiatives

- Seong-Gyun Jeong, Nazre Batool and Josiane Zerubia have been in contact with image processing experts for early clinical evaluation at Galderma 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 Dr Catherine 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.
- Josiane Zerubia have been in contact with Dr Sandrine Mathieu, image processing quality expert at Thales Alenia Space in Cannes [https://www.thalesgroup.com/en/worldwide/space] to discuss AYIN's research on remote sensing.

9.2. International Initiatives

9.2.1. Inria International Partners

- Josiane Zerubia has been working for more than 20 years with MTA SZTAKI (Hungarian Academy of Sciences) in Budapest, Hungary, and with University of Szeged, Hungary.
- Josiane Zerubia has also a strong collaboration with University of Genoa, Italy, for more than 20 years.
- Finally, another collaboration with Mc Master University, Hamilton, Canada, started in 2012.

9.3. International Research Visitors

9.3.1. Visits of International Scientists

- 2 young researchers visited AYIN team during one week each: Ganchi Zhang, PhD student, working with Prof. Nick Kingsbury at University of Cambridge, UK, in March and Dr. Vladimir Krylov, post-doc researcher, working with Prof. Sebastiano Serpico and Prof. Gabriele Moser at University of Genoa, Italy in Nov.
- several senior researchers visited AYIN team during a few days this year: Prof. Qiyin Fang, Mc Master University, Hamilton, Canada, in June; Prof. Hassan Foroosh, University of Central Florida, Orlando, USA, in July; Prof. Rozen Dayhiot, Trinity College Dublin, Ireland, in October; Prof. Freddy Buckstein, Technion, Haifa, Israel, in November; Prof. Pascal Fua, EPFL, Lausanne, Switzerland, in November; Prof. Daniela Zaharie, West University of Timioara, Romania, in November and Prof. Tamas Sziranyi, MTA Sztaki and Univ. of Technology and Economics Budapest, Hungary in November.

9.3.1.1. Internships

- Ali Madooei, PhD student, supervised by Prof. Joseph Hayward from Simon Fraser University, Burnaby, Canada, got a Mitacs/Inria internship fellowship (Mitacs Globalink Research Award [https://www.mitacs.ca/en/programs/globalink/globalink-research-award-inria]) to work in AYIN team during 3 months (June to August) in collaboration with Josiane Zerubia and the research group of Prof. Qiyin Fang at Mc Master University and Juravinsky Cancer Center, Hamilton, Canada.

9.3.2. Visits to International Teams

- Seong-Gyun Jeong was invited in January to visit the Institute of Space and Earth Information Science (ISEIS, [http://www.iseis.cuhk.edu.hk/eng/]) at the Chinese University of Hong Kong (CUHK), China.
- Josiane Zerubia was invited during a few days in April at Trinity College Dublin, Ireland, to visit the School of Computer Science and Statistics [https://www.cs.tcd.ie/] and the School of Engineering [http://www.tcd.ie/Engineering/].

10. Dissemination

10.1. Promoting Scientific Activities

10.1.1. Scientific events organisation

10.1.1.1. General chair, scientific chair

- Josiane Zerubia was General Chair with Prof. Konrad Schindler (ETH Zurich) of the EARTHVISION workshop at CVPR'15 [http://www.pamitc.org/cvpr15/workshops.php] in Boston, USA, in June.
- Josiane Zerubia was Plenary talks Chair with Prof Sergios Theodoridis (University of Athens) of IEEE/EURASIP EUSIPCO'15 conference [http://www.eusipco2015.org/content/keynotes] in Nice, France, in September.

- Josiane Zerubia was Scientific Chair of the workshop on Stochastic Geometry and Big Data [https://team.inria.fr/ayin/workshop/] in Sophia Antipolis, France, in November.

10.1.1.2. Member of the organizing committees

- Josiane Zerubia was part of the organizing committee of IEEE/EURASIP EUSIPCO'15 conference [http://www.eusipco2015.org/content/organising-committee] in Nice, looking for the sponsoring of Inria (Bronze sponsor + Best Student Award sponsor).
- Josiane Zerubia also organized the workshop on Stochastic Geometry and Big Data [https://team.inria.fr/ayin/workshop/] in Sophia-Antipolis, financially supported by Airbus D&S, CNRS (GdR GeoStoch) and Inria.

10.1.2. Scientific events selection

10.1.2.1. Member of the conference program committees

- Josiane Zerubia was part of the conference program committee of EMMCVPR'15 [http://blog.ust.hk/emmcvpr/people/] in Hong Kong, China, in January.
- Josiane Zerubia was part of the conference program committee of ISPRS/SPIE Remote Sensing'15 [http://spie.org/spieremotesensing] and [http://eventegg.com/spie-2015-toulouse/] in Toulouse, France, in September.

10.1.2.2. Reviewer

- Nazre Batool was a reviewer for the conference IEEE ICIP'15
- Josiane Zerubia was a reviewer for the conferences EMMCVPR'15, IEEE ICASSP'15, IEEE ICIP'15, IEEE EMBS'15, IEEE-EURASIP EUSIPCO'15, ISPRS-SPIE Remote Sensing'15, TAIMA'15 and GRETSI'15.

10.1.3. Journal

10.1.3.1. Member of the editorial boards

- 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" [http://www.sfpt.fr/rfpt/].
- Josiane Zerubia is an Associate Editor of the electronic journal Earthzine [http://www.earthzine.org/].

10.1.3.2. Reviewer - Reviewing activities

- Seong-Gyun Jeong was a reviewer for the journals APSIPA TSIP, IEEE TCSVT and ELS JVCIR.
- Paula Craciun was a reviewer for IEEE JSTARS journal.
- Ihsen Hedhli was a reviewer for IEEE TGRS, TGRL and TIP journals.
- Nazre Batool was a reviewer for IEEE TIP and JSTARS, and Elsevier Expert Systems with Applications journals.
- Josiane Zerubia was part of SFPT/RFPT Best Paper Award committee in 2015 to evaluate the papers from the year 2014 [http://www.sfpt.fr/revue/prix-etudiant-sfpt/].

10.1.4. Invited talks

- Paula Craciun gave a seminar at the Center for Vision, Cognition, Learning and Autonomy, at University of California Los Angeles, USA (invited by Prof. Song-Chun Zhu [http://vcla.stat.ucla.edu/people.html]) and the Computer Vision Group, University of California Berkeley, USA (invited by Prof. Jitendra Malik [http://www.eecs.berkeley.edu/Research/Projects/CS/vision/]) in January 2015 on joint detection and tracking of moving objects using spatio-temporal marked point processes. Paula Craciun also gave a seminar at the University of Lille 1, France (invited by Dr. Radu Stoica [http://math.univ-lille1.fr/~stoica/]) in September 2015 on a similar topic.

- Nazre Batool gave a seminar on modeling and analysis of wrinkles on aging human faces at the Computer Vision Lab, at ETH Zurich, Switzerland (invited by Dr. Orcun Goksel [http://www.vision.ee.ethz.ch/~ogoksel/]), in June 2015. Nazre Batool also gave a seminar on modeling of facial wrinkles in aging human faces, at the Multimedia and Visual Computing Lab, at New York University in Abu Dhabi (NYUAD), UAE (invited by Dr. Yi Fang [http://nyuad.nyu.edu/en/academics/faculty/yi-fang.html]), in April 2015.
- Josiane Zerubia gave a seminar on marked point processes for object detection in high resolution images at the School of Computer Science and Statistics, at Trinity College Dublin, Ireland (invited by Prof. Rozenn Dahyot [https://www.cs.tcd.ie/Rozenn.Dahyot/]), in April 2015. She also gave a seminar on assessing skin lesion evolution from multispectral image sequences at ONERA/DOTA in Toulouse, France (invited by Dr Xavier Briottet [http://www.onera.fr/dota]), in January 2015.

10.1.5. Leadership within the scientific community

- Josiane Zerubia is IEEE Fellow since 2003 and IEEE SPS Distinguished Lecturer since November 2015. ([http://www.ieee.org/membership_services/membership/fellows/index.html], [http://www.signalprocessingsociety.org/community/lectures/]).

10.1.6. Scientific expertise

- Nazre Batool was a reviewer for the Austrian Science Fund, FWF, Austria in 2015 [https://www.fwf.ac.at/en/research-funding/fwf-programmes/]
- Josiane Zerubia was a reviewer for the Natural Sciences and Engineering Research Council of Canada, NSERC, Canada in 2015 [http://www.nserc-crsng.gc.ca].
- Josiane Zerubia also worked as a remote sensing expert for the preparation of the Thales Alenia Space/Inria Chile Symposium in collaboration with Claude Puech and Hervé Coulomb (see [http://inria.cl/] and [http://www.inria.fr/actualite/actualites-inria/inria-chile-acteur-de-l-innovation]), and prepared in collaboration with Vladimir Krylov a presentation entitled "the Use of Remotely Sensed Optical Imagery for Civil Applications at Inria" given at this symposium on April 29, 2015, in Chile.
- Josiane Zerubia was a reviewer for the IRD Post-Doctoral Fellowship Program, France, in 2015 [https://www.ird.fr/nous-rejoindre/l-ird-recrute/accueil-de-post-doctorants-campagne-2015-resultats-disponibles].
- Josiane Zerubia is part of the Scientific Council of Academy 3 of UCA-Jedi [http://univ-cotedazur.fr/english] dedicated to "Space, Environment, Risks and Resilience".
- Josiane Zerubia was member of the working group for the creation of the GraphDeco team [https://team.inria.fr/graphdeco/] at Inria-SAM.

10.1.7. Research administration

- Josiane Zerubia is part of the Board of Directors of the French Photogrammetry and Remote Sensing Society [http://www.sfpt.fr/sfpt/bureau/].

10.2. Teaching - Supervision - Juries

10.2.1. Teaching

- Masters: Ihsen Hedhli, Introduction to Image Processing,TP & TD in Matlab, 10h eq. TD, M2 SVS ISAB, Université de Nice Sophia-Antipolis, France.
- 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 M2 of Applied Mathematics at the University Toulouse III Paul Sabatier, 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, 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).
- Doctoral School (PhD level): Josiane Zerubia, Hierarchical Markovian Models and MCMC Optimisation Techniques, 9h eq. TD (6h of lectures), SUPCOM Tunis Doctoral School, Tunisia. This course was also validated by ENSI Tunis and EP Tunis Doctoral Schools, Tunisia.
- Summer Shool (PhD and Post-doc level): Josiane Zerubia, Image Deconvolution and Denoising for Confocal Microscopy, 6h eq. TD (4h of lectures) at SSMIA'15, Sinaia, Romania. The courses of SSMIA'15 were validated by University Politehnica of Bucharest and Titu Maiorescu University, Bucharest, Romania, and by Technion-Israel Institute of Technology, Israel. See [http://imag.pub.ro/ssima/?page_id=44] and [https://www.youtube.com/watch?v=1wnmL8P8arQ].

10.2.2. Supervision

PhD (defended): Paula Craciun, Stochastic geometry for automatic object detection and tracking in remotely sensed image sequences, University of Nice-Sophia Antipolis, started in December 2012, defended in November 2015, Josiane Zerubia.

PhD (defended): Seong-Gyun Jeong, Curvilinear structure modeling and its applications in computer vision, University of Nice-Sophia Antipolis, started in December 2012, defended in November 2015, Josiane Zerubia and Yuliya Tarabalka.

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

10.2.3. Juries

- Josiane Zerubia was a member of the Jury for the Masters BioComp defenses at University of Nice Sophia-Antipolis in August 2015.
- Josiane Zerubia was a reviewer of a PhD thesis at SUPCOM Tunis, Tunisia, and a member of the PhD defense committee in Tunis, in April 2015.
- Josiane Zerubia was a member of a PhD defense committee (joint PhD thesis between Paris-Saclay University, CentraleSupelec and ENSEEIHT) in Toulouse, in October 2015.
- Josiane Zerubia was a member of two PhD defense committees at University of Nice Sophia-Antipolis/Inria, in Sophia-Antipolis, in November 2015.
- Josiane Zerubia was a reviewer of a joint PhD thesis (cotutelle) between University of Bordeaux, France, and University of Rabat, Morocco, and a member of the PhD defense committee in Bordeaux, in December 2015.

10.3. Popularization

- Paula Craciun and Josiane Zerubia wrote a brief scientific popularization article entitled "high resolution satellite imaging" for the book "Mathematics of Planet Earth" published by SIAM in 2015.
- Ihsen Hedhli and Josiane Zerubia hosted in AYIN team during one full day, a schoolboy from "Collège l'Archet", Nice, and a schoolgirl from "collège l'Eganaude", Biot, France. Furthermore, Josiane Zerubia was in charge of the schoolboy internship at Inria-SAM during one week in December 2015.

- Josiane Zerubia provided Hachette publisher with a land cover classification image obtained by an energy minimization based method to make the front cover of a text book of Physics in Ivory Coast.
- Josiane Zerubia participated in the Women in Computer Vision workshop at CVPR'15 in Boston, in June [https://sites.google.com/site/wicv2015/home]. She was the mentor of 4 female PhD students from USA, Taiwan, PR China and Sri Lanka, during the dinner organized afterwards.
- Josiane Zerubia presented Inria and Inria-SAM to interested PhD and post-doc students at both SUPCOM Tunis in Tunisia and Trinity College Dublin, Ireland.
- Josiane Zerubia is organizing a monthly scientific seminar at Inria-SAM with national and international speakers (see [https://team.inria.fr/ayin/ayinseminars/]).

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Publications of the year

Doctoral Dissertations and Habilitation Theses

[1] P. CRACIUN. *Stochastic geometry for automatic object detection and tracking in remotely sensed image sequences*, Université de Nice-Sophia Antipolis, November 2015, https://hal.inria.fr/tel-01235255

[2] S.-G. JEONG. *Curvilinear Structure Modeling and Its Applications in Computer Vision*, Université de Nice-Sophia Antipolis, November 2015, The full thesis will be available at the end of Januray 2016 at the same address (HAL-Inria), https://hal.inria.fr/tel-01243028

Articles in International Peer-Reviewed Journals

[3] H. AGHIGHI, J. TRINDER, S. LIM, Y. TARABALKA. *Fully spatially adaptive smoothing parameter estimation for Markov random field super-resolution mapping of remotely sensed images*, in "International Journal of Remote Sensing,", June 2015, vol. 36, n^o 11, pp. 2851-2879 [*DOI :* 10.1080/01431161.2015.1049381], https://hal.inria.fr/hal-01159037

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[7] Z. LIU, J. ZERUBIA. *Skin image illumination modeling and chromophore identication for melanoma diagnosis*, in "Physics in Medicine and Biology", 2015, vol. 60, n^o 9, pp. 3415-3431 [*DOI :* 10.1088/0031-9155/60/9/3415], https://hal.inria.fr/hal-01164805

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[11] I. HEDHLI, G. MOSER, S. B. SERPICO, J. ZERUBIA. *New cascade model for hierarchical joint classification of multisensor and multiresolution remote sensing data*, in "IEEE International Geoscience and Remote Sensing Symposium", Milan, Italy, July 2015, https://hal.inria.fr/hal-01161817

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Scientific Popularization

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