Part IV

Detailed activities: Signal and Image Processing

Chapter 13

Audio, Acoustics and Waves (AAO)

13.1 Executive Summary

Team Leader G. Richard

Initial Staff 7 Professors; 1 Research Scientist;

Staff who Left 3 Permanent Staff (89 months) ; 16 PhD Students (450 months) ; 5 Postdocs (103 months) ; 1 Engineer (24 months).

Permanent Staff who Were Hired A. Gramfort (09/2012), (PostDoc, CEA)

Scientific Highlights

- *International Projects:* Participation in 5 European projects including 2 Networks of excellence: IST Kspace (*Knowledge Space of Semantic Inference for Automatic Annotation and Retrieval of Multimedia Content*) and 3DLife (*Bringing the Media Internet to Life*)); Obtention of a 3 years Marie Curie Grant for a research fellow exchange between AAO and Columbia University (Prof. D. Ellis).
- *Publications:* 224 publications (56 journals, 141 conferences, 11 book chapters, 17 PhD thesis) for a global H-number of the group for this period of 25 (e.g. 25 papers published in [2008-2013] are cited at least 25 times). The ten most cited papers gather an average of 89 citations (source: Googlescholar).
- *Patents:* 3 new patents were filed and one previous patent was transfered to the SME Invoxia. (Patent transfer and scientific support for the development of a hands-free IP telephone, including microphone array and loudspeaker array).
- *Open source software:* Lead participation in Scikit-Learn (the corresponding journal paper published in 2011 is cited 265 times) and full development and distribution of YAAFE (*Yet Another Audio Features Extractor*) with a growing impact with over 2300 downloads since March 2010 (463 downloads in 01-03/2013) from 79 different countries.
- *Award:* PhD prize in 2010 (jointly awarded by EEA club, GRETSI and ISIS) (N. Bertin, who is now a permanent CNRS researcher);

Scientific Production 56 Journals; 11 Book chapters; 141 Articles in Proceedings; 17 PhD thesis ; 32 Talks

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Major Publications

- G. Richard, S. Sundaram and S. Narayanan, "An overview on Perceptually Motivated Audio Indexing and Classification", Proceedings of the IEEE, Vol. 101, n°9, September 2013.
- A. Gramfort, D. Strohmeier, J. Haueisen, M. Hämäläinen, M. Kowalski, Time-frequency mixed-norm estimates: Sparse M/EEG imaging with non-stationary source activations, Neuroimage, 15;70:410-22, April 2013

- V. Emiya, R. Badeau and B. David, "Multipitch estimation of piano sounds using a new probabilistic spectral smoothness principle", IEEE Transactions on Audio, Speech and Language Processing, vol. 18, n° 6, pp. 1643 1654, 2010.
- S. Essid and C. Févotte. Smooth nonnegative matrix factorization for unsupervised audiovisual document structuring. IEEE Transactions on Multimedia, 15(2):415–425, Mar. 2013.
- R. Badeau, N. Bertin et E. Vincent, "Stability analysis of multiplicative update algorithms and application to non negative matrix factorization", IEEE Transactions on Neural Networks, vol. 21, n° 12, pp. 1869 1881, 2010.

Major Documents

- S. Essid et al. A multi-modal dance corpus for research into interaction between humans in virtual environments. Journal on Multimodal User Interfaces, pages 1–14, Aug. 2012.;
- A. Gramfort is one of the lead developer of *scikit-learn* which is a widely used machine learning toolbox and of the *MNE-python* toolbox for M/EEG data analysis. These two projects are open to students in the framework of the Google Summer of Code program.
- Database production and public release which includes 3 databases for music separation and transcription (MAPS, ENST-Drums, QUASI), 1 for robot audition (ROMEO-HRTF) and 1 for multimodal scenes analysis (ACM Grand Challenge).

Impact and Attractivity

- *Editing activities:* Editor and Associate editors of journals (A. Gramfort for *Jour. FBMIM*; G. Richard for IEEE Trans. on ASLP (2007–2011) and R. Badeau for EURASIP Jour. on AMSP (since 2012)); Guest editors of special issues in journals (B. David, Lead Guest Editor - IEEE Trans. on ASLP 2010; G. Richard, Guest Editor - IEEE JSTSP 2011 ; G. Richard Lead Guest Editor of EURASIP JASP 2013).
- *Organization of International conferences and workshops :* 14th edition of the International Workshop on Image and Audio Analysis for Multimedia Interactive Services (WIAMIS) 2013 (S. Essid, G. Richard : General Co-chairs); IEEE MMSP (Y. Grenier: Technical Co-chair); CFA 2010 (B. David, Technical co-chair); Acoustics08 (B. David, Technical Co-chair)
- Participation to technical committees of Scientific bodies (G. Richard, IEEE AASP TC), Major conferences (A. Gramfort, PRNI; G. Richard, ICASSP, Interspeech; S. Essid ACM MM, ICME; Y. Grenier, IWAENC; R. Badeau, ISSPA) and International PhD committees (G. Richard in 7 European countries).
- *National and International collaborations:* 65 % of published journal papers are co-authored with external collaborators; 5 European projects ; Collaboration with other research groups of LTCI in projects(OSEO-Quaero, FP7-VERVE, FP7-REVERIE, FP7-3Dlife) and PhD thesis supervision (3 joint PhDs with STA including 2 ongoing; 1 starting with MM).
- Invitation of tutorial/Keynotes talks in conferences (A. Gramfort, PRNI'2013, S. Essid and G. Richard at WIAMIS'2012, G. Richard at ACM Multimedia'2011) and in major international research labs.

Interaction with Economic and Social Spheres

- Public scientific conference at "Espace Pierres Gilles de Genes, ESPCI" ("Does the computer has the sense of rythmn ?") by B. David and G. Richard.
- 6 CIFRE PhD theses with Orange (1), INA (2), Arkamys (1), Parrot (1), Audionamix (1)).
- A patent from AAO was transfered to the SME Invoxia (Patent transfer and scientific support for the development of a hands-free IP telephone, including microphone array and loudspeaker array).
- Serving as experts for funding agencies : ANR-CONTINT (G. Richard, member of Programme committee), OSEO (S. Essid), Dutch Technology Foundation STW (S. Essid), European Union (G. Richard)
- Technology transfer to instrument makers: for more than 10 years now, AAO regularly attends the JFIS workshop (ITEMM) with the goal to tackle applied science projects with the stringed instruments luthiers. Leads to the PAFI ANR-project (B. David) where a software and hardware platforms have been developed and used in the today practice of the craftsmen.

Contributions to Higher Education

- Participation in University Masters *Méthodologie en Imagerie Médicale-Paris Descartes* (A. Gramfort), *Informatique-UPMC* (A. Gramfort, Y. Grenier, G. Richard (resp. of 1 UE)), *MVA-Paris Descartes/ENS Cachan* (Y. Grenier, G. Richard (resp. of 1 UE)), *ATIAM-UPMC* (R. Badeau, B. David (both resp. of 1 UE), G. Richard).
- Introduction of a new course of Signal processing based on active learning (e.g. problem and project based learning) for the 1st year of Telecom ParisTech engineering studies (B. David).
- Leading role in the reshape of the 1st year of study at Telecom ParisTech and in the proposal and then coordination of the newly introduced 6 months collaborative project (PACT, coord. B. David, [2470, 2474]).
- PhD students coordination: 17 PhDs awarded in the period. Amongst the 23 Phds students awarded in [2005 - 2011], 10 are now permanently employed in Academia, 2 at the European Patent office, 6 have permanent position in industry and 1 has started his company.
- Sessions for the benefit of "classes préparatoires" teachers, aka LIESSE: two sessions of a 2-day course on Python (A. Gramfort, S. Essid), 1 session on High Resolution Method (Y. Grenier, B. David, M. Maazaoui)

13.2 People

Team leader G. Richard (FP)

Faculty R. Badeau (AP), B. David (AP), Y. Grenier (FP), C. Févotte (–12/09), N. Moreau (FP, –03/2010), S. Essid (AP), J. Prado (AP,-02/2011); A. Gramfort (AP,10/2012-).

PhD students M. Betser (–06/08), N. Bertin (10/05-10/09), J-L. Durrieu (01/07-05/10), M. Ramona (10/06-06/10), C. Joder (11/07-09/11), L. Oudre (10/07-11/10), F. Vallet (11/07-09/11), S. Gulluni (02/08-12/11), R. Hennequin (10/08-11/11), M. Maazaoui (01/09-), S. Fenêt (01/10-); B. Fuentes (10/09-03/12); R. Foucard (10/09-); M. Moussalam (10/09-12/12); F. Rigaud (10/10-); A. Liutkus (01/10-11/12);N. Lopez (05/11-) A. Masurelle (10/11-); X. Jaureguiberry (10/11-); C. Fox (10/10-); A-C Conneau (01/12-); H. Bai (10/12-); N. Seichepine (10/12-).

PostDocs, engineers and sabbaticals M. Lagrange (Postdoc,10/08-09/09), A. Ozerov (02/08-07/09), T. Fillon (Postdoc,10/08-04/13), B. Mathieu (Engineer,10/08-12/10), H.Takeugming (12/11-11/12), A. Dielmann (PostDoc, 11/10-03/11), A. Drémeau (PostDoc, 09/11-08/13), C. Damon (PostDoc, 01/12-), D. Mauro (Post Doc, 01/13-)

External collaborators L. Daudet (Institut Langevin, Paris), O. Derrien (LMA-Marseille), E. Vincent (INRIA Nancy), L. Devillers (LIMSI-CNRS, Orsay), L. Girin (GIPSA-Lab, Grenoble), R. Boyer (LSS, Orsay), A. Ozerov (Technicolor), S. Marchand (Univ. de Bretagne occidentale), N. Bertin (CNRS-IRISA, Rennes), F. Gautier (LAUM, Le Mans), X. Boutillon (LMS, Polytechnique), N. Evans (Eurecom), T. Sikora (Technical Univ. of Berlin), N. O'Connor (Dublin City University), E. Izquierdo (Queen Mary Univ., London), P. Daras (CERTH, Thessaloniki), B. Thirion et G. Varoquaux (INRIA-Saclay), M. Hamalaïnen (Harvard), M. Descoteaux (Sherbrooke Univ.), Y. Hua (Univ. of California), D. Ellis (Columbia Univ., New York).

13.3 Overview

The overall objective of this research group is to develop digital signal processing methods with applications to audio, music, multimodal and biomedical signals. Its activities range from theoretical work on machine learning for signal processing, signal models and sparse representations to computational optimization of algorithms.

An increased effort was in particular dedicated to adaptive methods for high resolution sinusoidal components tracking [2387, 2388, 2386] and sparse signal representations with a specific interest on those based on Matching Pursuit (MP), Probabilistic Latent Component Analysis (PLCA) or Non-negative Matrix factorization (NMF), that allow to decompose a signal using a limited number of atoms or basis functions. Several very interesting results were for example obtained for NMF concerning the stability of multiplicative update algorithms [2389, 2462], or the description of beta-divergence as a subclass of Bregman divergence [2412]. Several extensions of the NMF were also explored including the introduction of a new generalized model for High-Resolution NMF [2455], the extension to multichannel [3936], the presentation of a novel geometric algorithm based on single-class Support Vector Machines [2487], and the proposal of a general formulation of underdetermined source separation of Gaussian Processes [2422]. The applicability of these methods to generic problems such as audio indexing in the (scalable) compressed domain [2434], audio source separation or music signal indexing was demonstrated by introducing specific constraints deduced from the audio signal properties (use of harmonicity or temporal constraints for music transcription [2390, 2465, 2439], use of source production or timbre models for source separation [2396, 2397], use of time-frequency activations to model non-stationary audio events [2411],...). This methodological effort explores both deterministic and statistical approaches.

Source separation also appears to be at the heart of this research group with applications in nearly all the individual research themes.

Besides this methodological axis, the research tackled by the group can be organized in three main themes (which will be further discussed in section 13.4):

1. *Machine listening and audio source separation:* The objective of this theme is to improve the capability of machines to analyse and interpret complex audio situations by developing specific digital signal processing methods. This is the main research theme of the group.

2. *Audio and multimodal signal processing:* The objective of this theme is first to develop novel generic models and approaches for audio signal representation and compression and second to automatically process multimodal data streams (segmentation, structuring,...).

3. *Biomedical signal analysis:* is dedicated to the analysis of biomedical signals, in particular electroencephalographic (EEG) and magnetoencephalographic (MEG).

In terms of bibliometry (source GoogleScholar), the group's faculty members have co-authored over 200 papers including 56 journal papers, 141 conference papers and 11 books or book chapters. Considering that each faculty is at most half-time on research, the group staff is 3.25 Equivalent Full Time (EFT) researchers and which leads an average number of 11,5 papers per year per EFT researcher. The H-number of the group for this period is 25 (e.g. 25 papers published in the period 2008-2013 are cited at least 25 times) and the ten most cited papers gather an average of 89 citations (ranging from 56 to 280).

Besides publications, the group promotes whenever possible research reproducibility by distributing open source software or by participating to open source software initiatives (for example, one of the members of the group is one of the lead developer of the scikit-learn which is a widely used machine learning toolbox and of the MNE-python toolbox for M/EEG data analysis). Recently, the group has been preparing jointly with with ENS-Cachan, with the support of the LMH (Hadamard) Labex, the launch of a new journal for reproducible research currently named *Audio and Signal Processing Algorithms Reviews*. This new journal will follow the spirit of an existing journal for image processing (IPOL).

In terms of attractivity and impact, the team is particularly visible at the international level with the participation in 5 European projects and the participation to international campaigns such as MIREX. Besides all members of the group are particularly active in Editing and Reviewing activities for major journals and conferences (editing activities in some of the most prestigious journals in this field including IEEE Transactions on Audio Speech and Language Processing, IEEE Journal on Selected Topics in Signal Processing, EURASIP journal on Advances in Signal Processing, Journal Frontiers in Brain Imaging Methods,...). Some members of the group are also particularly active in scientific bodies (SFA, IEEE Audio and Acoustic signal Processing TC) and are regularly invited to international PhD committees, area chair in major conferences such as ICASSP for example. The group is also regularly receiving visits from researchers from all around the world and candidacies for sabbatical. As an example, following a previous 2 months visit of Dr. Mads Christensen, Professor Juan Pablo Bello (New York University) will come to the AAO group for a one year sabbatical starting in January 2014 on a Fullbright grant.

The group has also strong interactions with the socio-economic world. First the group is involved in a variety of collaborative projects with industry. Then, the group is also developping bilateral collaborations with industry in particular through CIFRE PhD thesis (2 with INA, 1 with Orange, 1 with Arkamys, 1 with Audionamix, 1 with Parrot). In parallel of an active publication activity, the AAO group has also filed three new patents in the period. One of the patents previously filed was also transferred to the SME Invoxia in this period along with a scientific support for an efficient technology transfer.

13.4 Research Themes

13.4.1 Machine listening and audio source separation

Faculty B. David, Y. Grenier, S. Essid, R. Badeau, G. Richard, C. Févotte (–12/09);

Highlights: Scientific Production [2426] (collaboration with Fraunhofer, Columbia Univ. and Tampere University, cited 50 times), [2402] (cited 75 times), [2389] (collaboration with INRIA, theoretical results, cited 21 times), [3933] (collaboration with STA), [2414] (cited 23 times)

Highlights: Impact

- ANR projects: DReaM (*Active music listening*) and DESAM (*Audio object decomposition with application to music*).
- CapDigital-ROMEO (*a project within "pôle de compétitivité" CapDigital, led by Aldebaran Robotics and aiming at creating a humanoid robot*), ROMEO2 (*a PIA "Projet d'Investissement d'Avenir", a follow-up to ROMEO aimed at bringing learning skill to a humanoid robot*)
- PhD prize in 2010 (jointly awarded by EEA club, GRETSI and ISIS) (N. Bertin);
- Organisation of a special issue in Eurasip Journal on Advances in Signal Processing on Informed Acoustic source separation analysis (2013, collaboration with Tampere Univ. of Techn., Bogazici Univ., Dublin Institute of Technology and Technicolor).
- OSEO-QUAERO (*Towards multimedia and multilingual search engines for professional and general public applications*), a very large scale French/German project.

Highlights: Interactions with Society

- Technology transfer to SME Invoxia (Patent transfer and scientific support for the development of a hands-free IP telephone, including microphone array and loudspeaker array).
- 2 patents filed including 1 in 2013 on Audio Fingerprinting.
- The open-source software YAAFE (*Yet Another Audio Features Extractor*). Growing impact (with over 2300 Downloads since March 2010 and 463 downloads between 01/01/2013 and 01/04/2013 from 79 different countries (mainly France, United States, Germany and United Kingdom)).
- Public scientific conference at "Espace Pierres Gilles de Genes, ESPCI" ("Does the computer has the sense of rythmn ?").
- 3 CIFRE PhD theses (with INA on Electro-acoustic music segmentation and transcription, Arkamys on speech dereverberation and with Parrot on noise reduction).

The objective of this theme is to improve the capability of machines to analyse complex audio situations by developing specific digital signal processing methods. This research theme encompasses a variety of situations ranging from speech signal dereverberation using a single microphone to complex audio and music scene analysis using one or several sensors.

Music analysis and audio source separation

A topic of major interest to the group is *Music transcription and source separation*, which are two intricate problems. Indeed, efficient source separation facilitates the transcription of the resulting sources and vice-versa. In music signal transcription, the group is directly interested in the four main problems which are *multiple fundamental frequencies estimation* (e.g. detection of simultaneous notes in a polyphonic musical recording [2402, 2439, 2505]), *rhythmical information tracking* (tempo and beat estimation [2526], *harmonic information estimation* (recognition of the chords sequence [2591, 3933, 3934]) and *timbre recognition* (musical instrument recognition

[2413, 2532]). Whenever possible, the results obtained are submitted to national or international evaluation campaigns. In particular in 2011, our group has obtained the best results in several subtasks of the Quaero competitive internal evaluation campaigns. Further, source separation approaches were developed for specific music transcription tasks such as piano transcription [2402] and main melody estimation (by the use of a NMF-based source-filter model for separating the singing voice from the musical accompaniment [2397]) but also for specific audio rendering tasks such as stereo signal remastering [3936].

Another topic of interest in the group, related to the recognition of musical audio events discussed above, is the so-called audio fingerprinting problem. The objective of audio fingerprinting is to identify a given audio excerpt (e.g. obtaining metada such as title and artist identification in the case of a musical song) using the sole audio signal. Our work in this domain has concentrated on the introduction of simple *audio fingerprints* which are highly robust to the major signal degradations observed in broadcast streams [2494] and on its capacity to scale up to very large databases or dynamically growing databases [2495]. More recently, a major extension was introduced which led to a versatile system capable of identifying not only identical excerpts but also "semantically similar" excerpts with large acoustical variations (such as re-recording, live/studio versions and in some cases cover versions recorded with complete different musicians). A patent was recently filled on this topic.

Another topic of interest to the group is *multimodal music classification* where the focus is on the incorporation of prior knowledge on the nature and structure of music data into discriminative classifiers, both at the signal level and the semantic level, using all the available data, including ancillary information possibly attached to the content (available meta-data, tags...) and/or user interaction (*relevance feedback*). As such, efforts have been dedicated to the alternative route to music transcription that consists in achieving *music-to-score-alignment*, given that musical scores have become widely available over the Internet, which has made the approach of using such scores for music transcription highly appealing. Our contributions along this line are mainly the introduction of an effective and scalable statistical framework using *Conditional Random Fields* [2414, 2415]. Further, user-interactive systems have been devised that rely on *active learning* techniques for the analysis of the structure of particular forms of music, namely *electro-acoustic music*, which cannot be envisaged without taking into account the viewpoint of a human analyst [2510, 2511, 2512]. Finally, in view of music similarity analysis [2418, 2499], the task of music auto-tagging (that is predicting user-tags for musical pieces) has been addressed, where multi-level, especially multi-scale classification systems have been developed using boosting techniques [2500, 2501].

Robot audition and blind source separation

A strong focus in robot audition is on multiple microphone techniques: beamforming for microphone arrays and blind source separation, some of these techniques being also applied to single microphone source separation and dereverberation.

Current work addresses the difficult problem of humanoid robot audition which needs, using a limited number of sensors, to be robust to movements of the robot and to highly variable environments. This task is part of the Romeo project that aims at building an humanoid robot (Romeo) that can act as a comprehensive assistant for persons suffering from loss of autonomy. Our approach follows a two-stage blind source separation strategy. The first stage consists in a fixed beamforming preprocessing to reduce the reverberation and the environmental noise. Due to the highly constrained context of robot audition, pre-recorded Head Related Transfer Functions (HRTFs) are used to estimate the beamforming filters. The use of the HRTF to estimate the beamformers allows to capture the head and torso effect on the manifold of the microphone array. The second stage is a blind source separation algorithm based on a l_1 norm minimization sparsity criterion. The results obtained highlighted the merit of the fixed beamforming preprocessing for improving the separation performances [2544, 2424]. A recent extension was also proposed by using a modified l_p norm blind source separation criterion based on the source sparsity in the time-frequency domain. We followed a tempered approach where the sparsity constraint could

be reinforced by varying the parameter p of the l_p to dynamically change from l_1 to l_0 norm. This variation is driven by a sigmoid function which allows to obtain smooth transition and to avoid the divergence of this tempered approach. The merits of this method were demonstrated and compared to more classical schemes [2545].

Our cooperation with Invoxia has permitted to develop a combination of a microphone array and a loudspeaker array that allows hands-free communications with high quality of the captured speech, and a 3D restitution of various distant speakers in a local listening room. The transfer of a patent (Y. Grenier inventor) to Invoxia was the conclusion of this study. Invoxia has already designed two products using our technology (they call it In Vivo Acoustic: http://www.invoxia.com/fr/technologies/invivoacoustic), and the first of these products NVX 610 received a Best Innovation Award in CES 2012 (Las Vegas).

Another axis in this domain relates to signal capture in reverberant environment using a single sensor and a dedicated collaboration with the company Arkamys has permitted to develop novel dereverberation algorithms, based upon an estimation of the reverberation time [2542].

13.4.2 Audio and multimodal signal analysis

Faculty R. Badeau, S. Essid, G. Richard, N. Moreau (–03/2010);

Highlights: Scientific Production [2433] (2008, cited 37 times; collaboration with Institut Langevin); [2425] (collaboration with Institut Langevin); [2438] (collaboration with INA), [3888] (collaboration with 5 European partners); [2430] (collaboration with Technicolor,).

Highlights: Impact

- 2 European Networks of Excellence: FP6 Network of Excellence (NoE) IST Kspace (*Knowledge Space of Semantic Inference for Automatic Annotation and Retrieval of Multimedia Content*) and FP7-ICT NoE 3DLife (*Bringing the Media Internet to Life*)
- 1 European Integrated project FP7-ICT REVERIE (*REal and Virtual Engagement in Realistic Immersive Environments*)
- ANR DReaM (*Active music listening*) with collaboration with INPG Grenoble, Institut Langevin, University of Brest, Iklax.
- ACM MM' Grand Challenges: organization and data production for the 2011-2012 3DLife/Huawei challenges on *Realistic Interaction in Online Virtual Environments*;
- Organisation of the 14th edition of the International Workshop on Image and Audio Analysis for Multimedia Interactive Services (WIAMIS) 2013 - technically co-sponsored by IEEE SPS (http://wiamis2013.telecom-paristech.fr).

Highlights: Interactions with Society

- 1 Patent jointly filled with INPG Grenoble on Informed source Separation.
- Collaboration with Technicolor on Informed source Separation.
- 1 CIFRE Phd Thesis with INA on Audiovisual document structuring

Sound source compression, Acoustics and 3D Audio

In audio compression, the work was mostly dedicated to low to medium bit rate parametric audio coding. For low bit rate music coding applications, parametric coders are an efficient alternative to transform coders. In particular, sinusoidal modeling is widely used in response to the fact that most real-world audio signals are dominated by tonal components. Less used, the exponentially damped sinusoidal model (EDS) combined with a variable-length time segmentation is however considered as more powerful, but at the cost of an increased number of parameters. Our work has shown, however, that it is possible to design a joint scalar quantizer for amplitude, damping and phase parameters and obtain increased coding capabilities compared to the more traditional

sinusoidal model. Our model incorporates in particular a dynamic temporal segmentation and psychoacoustic modeling and an asymptotically optimal entropy-constrained quantization method for the four sinusoid parameters (e.g. including damping) [2475, 2395].

On the other hand, investigations were pursued to develop highly scalable transform coders which can seamlessly operate from very low bit rate up to transparency. To that aim, sparse over-complete representations are used to decompose the audio signals over a redundant union of bases (such as Modified Discrete Cosine Transform bases at different scales)[2433]. It was also shown that the high flexibility of the signal representations used in this coder allows to address various audio indexing tasks (such as beat tracking or musical genre recognition) directly in the transformed domain [2434] or to perform a large variety of music similarity tasks or structural-based audio coding [2557]. More recently, a novel Random Matching Pursuit algorithm was designed which allows to simulate a local search in a larger dictionary while operating at the cost of a search in a sub-sampled dictionary. The approach consists in using a non adaptive random sequence of subdictionaries in the decomposition process, thus parsing a large dictionary in a probabilistic fashion with no additional projection cost nor parameter estimation. Based upon a theoretical modeling exploiting order statistics and experimental evidences, it was shown that the novel algorithm can be efficiently used on sparse approximation problems and successfully applied to signal compression [2425]. On a more transversal axis, a comparative study of sparse greedy algorithms that had been independently introduced in speech and audio research communities was conducted. It was in particularly shown that the Matching Pursuit (MP) family of algorithms (MP, OMP, and OOMP) are equivalent to multi-stage gain-shape vector quantization algorithms previously designed for speech signals coding. Following this unified view, a new family of algorithms was introduced based on cyclic minimization principles and on the recent Cyclic Matching Pursuit [2398].

In parallel, our work on Informed source separation allowed us to propose a novel framework to close the gap between source separation and audio coding domains by exploiting source separation models and principles for multichannel audio coding [2423]. This novel approach, called Coding-based ISS (CISS) encodes the individual sources using not only a model as in source coding but also the observation of the mixture. This approach has several advantages including state of the art performance for multi-source audio coding in terms of rate-distorsion using Nonnegative Tensor Factorization as a source model [2567, 2430].

The group is also pursuing its activity in Acoustics and especially in audio rendering (or Audio3D) and musical acoustics. The audio rendering activity also benefits from the two European projects 3DLife and REVERIE. The group is in particular interested in developing novel hybrid approaches between pure physics-based approaches and perception-based approaches. One of the current lines of research consists in extending radiance-based transfer method to be effective for both the early part of the reverberation (early echoes) and late reverberation for which it was initially designed for. The musical acoustics activity is particularly focused to applying subspace methods and enumeration methods to the modal analysis of musical instruments, where it allows to investigate successfully the mid-frequency range [2401, 2400, 2399, 2575, 2485]. This activity benefited from the ANR PAFI project, a four years project in collaboration with French instrument makers.

Audio-visual content and human activity analysis

As far as multimedia content analysis is concerned, the group's efforts are mainly geared towards audio-visual document segmentation and structuring, where the focus has been mainly on radio and TV content analysis [2571, 2588, 2452].

On the methodological level, a special interest has been directed to kernel-based methods (Support Vector Machines, probabilistic distances, kernel change detection...) [2572, 2432, 2438] allowing us to develop original and effective architectures for tasks such as *audio diarization*, that is segmentation into broad classes of events (especially music/speech discrimination) and more specifically *speaker diarization* [2438].

Another line of work, conducted in collaboration with the STA group, is concerned with the development of new matrix factorisation techniques, which turn out to be particularly useful for document structuring [4082, 3889]. More recently, the focus has been on methods allowing a meaningful joint decomposition of "temporally related" parallel streams of data, especially the audio and visual streams of a video content [4152].

In parallel, the topic of *human activity analysis* has attracted a growing interest within the AAO group, especially as part of its involvement in the 3DLife, EMC^2 and REVERIE European projects. The work is centered at the development of machine learning and signal processing techniques[1] amenable to the analysis of data recorded through multiple capturing devices of different natures (microphone and video-camera arrays, inertial measurement units and motion capture devices, depth sensors, physiological sensors...). In general, the originality of our approach lies in the adoption of methodologies whereby the useful information is hunted for by spotting regularities emerging jointly across the concurrent streams of observed data. From the applicative viewpoint the group's work revolves around multimodal action/gesture classification, especially dance gesture analysis, motivated by a use-case that has been promoted by the 3DLife/Huwaei Grand Challenge within ACM multimedia 2011-2013, that is a virtual dance class scenario [3888, 3489, 2489]. Problems of interest include dance performance alignment [2491, 2476], representation [2536] and recognition.

13.4.3 Biomedical signal analysis

Researchers J. Prado (-02/2011), S. Essid (30%), A. Gramfort (100%);

Highlights: Scientific Production [2410] (collobaration with INRIA/Neurospin, Harvard medical school, Ilmenau university, Supelec); [2593] (conference acceptance rate $\leq$ 20%; collaboration with INRIA/Neurospin and Ecole Centrale); [2471] (collaboration with ESPCI).

Highlights: Impact
- DGA-DGCIS project MEEGAPERF (*Monitoring EEG pour l'Anticipation des PERFormances*);
- European project FP7-VERVE (*Vanquishing fear and apathy through E-inclusion: personalized and populated Realistic Virtual Environments for clinical, home and mobile platforms*)
- Development of the MNE-Python (http://martinos.org/mne/) package supported by 2 Google Summer of Code student in 2013

The third research direction of the group is dedicated to the analysis of biomedical signals, in particular electroencephalographic (EEG) and magnetoencephalographic (MEG) which are respectively electrical and magnetic signals induced by the electrical activity of active neurons. M/EEG offer a unique opportunity to non-invasively measure the brain activity at a millisecond time scale with clinical applications (epilepsy, sleep disorders) as well as for cognitive neurosciences and brain computer interfaces (BCI).

The team has pursued its long-standing work on asleep subjects recorded using a single pair of EEG electrodes. The developed approach has two technological breakthroughs: an automated analysis pipeline and the use of a single EEG channel. The efficiency and robustness of the developed method have been quantified and experimentally validated in collaboration with a French company called Physip founded by a former PhD student. Another application of interest was the analysis of biomedical data about colonic transit time (CTT). In particular, a dedicated approach was designed to robustly estimate this colonic transit time even in situations where the patient omits to ingest the radiopaque markers for one or two days [2392].

The effort of the group in the domain of biomedical signal processing (especially multichannel EEG analysis) has been strengthened with the acceptance of two research projects. The first project (MEEGAPERF), started in September 2009, is centered at EEG-analysis for the realtime detection of physical performance decrease, using portable and lightweight EEG devices.

[1] often related to the ones developed for multimedia content analysis

The most recent work has been on artifact rejection [2471] with specific constraints: noisy experimental setups and limited number of electrodes. The second project (FP7-VERVE) aims at developing dedicated tools to support the treatment of people who are at risk of social exclusion due to fear and/or apathy associated with a disability. The group's work is focused on the analysis of a patient's emotional state as he/she is submitted to a serious game treatment, based on EEG and ECG recordings used to monitor him/her.

The recent arrival of a new associate professor in biomedical signal processing, A. Gramfort, will allow this research topic to be further developed. Current directions are on the use of time-frequency representations for brain source localization [2410], as well as data-driven representation learning using sparse coding and dictionary learning techniques. In his research, A. Gramfort works on the development of statistical machine learning techniques for mining brain imaging data (MEG, EEG and functional MRI). A recent collaboration with Ecole Centrale Paris led to a paper at the IPMI conference [2593], known for being very selective.

13.5 Achievements

13.5.1 Scientific Productions

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Invited Talks and Tutorial

[2594] B. David and G. Richard. L'ordinateur a-t-il le sens du rythme ? In *Conférence Grand Public, Espace Pierre Gilles de Genes*, Paris, France, Dec. 2008.
[2595] G. Richard. Multimedia music signal processing. In *Tutorial at ACM Multimedia Conference*, Phoenix, USA, Nov. 2011.
[2596] G. Richard. Multimodal music processing. In *Dagstuhl Seminar on Multimodal music processing*, Dagstuhl, Germany, Jan. 2011.
[2597] G. Richard. Indexation des signaux musicaux polyphoniques. In *Keynote aux Journées d'Informatique Musicale*, Rennes, France, May 2011.
[2598] G. Richard. Audio processing research and technologies. In *International Korea university Workshop*, Seoul, Korea, Mar. 2012.
[2599] G. Richard. Audio and multimedia music signal processing. In *Keynote at 13th International Workshop on Image Analysis for Multimedia Interactive Services*, Dublin, Ireland, May 2012.

Talks and Seminars

[2600] R. Badeau. Analyse spectrale à haute résolution appliquée au traitement des signaux de musique. In *Seminar of SFA at TSI/AAO, Télécom ParisTech*, Paris, France, 2011.
[2601] R. Badeau. Modèles probabilistes de représentations temps-fréquences. application au traitement des signaux de musique. In *Seminar at LIF/LATP, Aix-Marseille Université*, Marseille, France, May 2012.
[2602] R. Badeau. High resolution spectral analysis and nonnegative decompositions applied to music signal processing. In *Seminar at C4DM, Queen Mary University of London*, London, UK, 2013.
[2603] R. Badeau. Probabilistic modelling of time-frequency representations with application to music signals. In *Seminar at C4DM, Queen Mary University of London*, London, UK, 2013.
[2604] R. Badeau. Probabilistic modelling of time-frequency representations with application to music signals. In *Seminar at MLG, City University London*, London, UK, 2013.

[2605] R. Badeau. Probabilistic modelling of time-frequency representations with application to music signals. In *Seminar at SigProC, University of Cambridge*, Cambridge, UK, 2013.
[2606] S. Essid. Classification automatique de signaux multimédia. In *Seminar at IRISA, INRIA*, Rennes, France, Nov. 2009.
[2607] S. Essid. Music-to-score temporal alignment with discriminative graphical models. In *Seminar at the Music and Audio Research Laboratory, New York University (NYU)*, New York, USA, Oct. 2011.
[2608] S. Essid. The 3dlife multimodal dance corpus and applications. In *Seminar at The University of Tokyo*, Tokyo, Japan, Mar. 2012.
[2609] S. Essid. Audio-driven multimedia content analysis. In *Tutorial at MediaSense 2012: Summer School on Multi-modal Data Analytics*, Dublin, Ireland, May 2012.
[2610] A. Gramfort. Supervised and unsupervised learning in brain imaging: from sparsity for the meg inverse problem to dictionary learning for fmri and dmri. In *Athena INRIA Team Group meeting*, Sophia-Antipolis, FR, 2012.
[2611] A. Gramfort. Functional brain imaging: how to use meg and fmri to know the "where" and "when". In *Probabilistic structures of the brain*, Cergy, FR, 2012.
[2612] A. Gramfort. Sparse methods for brain imaging. In *Workshop on Sparse Models and Machine Learning*, INRIA/IRISA, Rennes, FR, 2012.
[2613] A. Gramfort. Decoding in source vs sensor space. In *Neurospin Decoding Symposium*, Gif sur Yvette, FR, 2013.
[2614] A. Gramfort. An introduction to regularized risk minimization for predicting from neuroimaging data. In *Pattern Recognition in Neuroimaging (PRNI) conf.*, Philadelphia, USA, 2013.
[2615] A. Gramfort. Analyse temps-fréquence et parcimonie pour la localisation de sources par eeg et meg. In *Société de mathématiques appliquées et industrielles (SMAI)*, Seignosse, FR, 2013.
[2616] M. Moussallam. Greedy pursuits in random sequential sub-dictionaries. In *Seminar at Columbia University*, New York, USA, Oct. 2012.
[2617] G. Richard. Beyond the bag-of frames approach for musical instrument recognition. In *Seminar at Aalborg University*, Aalborg, Denmark, 2009.
[2618] G. Richard. Beyond the bag-of frames approach for musical instrument recognition. In *Seminar at Dublin Institute of Technology*, Dublin, Ireland, 2009.
[2619] G. Richard. Beyond the bag-of frames approach for musical instrument recognition. In *Seminar at INESC, Porto*, Porto, Portugal, 2009.
[2620] G. Richard. Automatic extraction of the main melody from polyphonic music signals: With application to transcription and separation. In *Seminar at Queen Mary University of London*, London, UK, 2010.
[2621] G. Richard. Greedy pursuits algorithms for representing audio signals: with applications to compression, source separation and audio fingerprint. In *Seminar at ICSI, Berkeley University*, Berkeley, USA, 2012.
[2622] G. Richard. Greedy pursuits algorithms for representing audio signals: with applications to compression, source separation and audio fingerprint. In *Seminar at Los Angeles University*, Los Angeles, USA, 2012.
[2623] G. Richard. An overview of audio research at telecom paristech. In *Seminar at Technical University of Berlin*, Berlin, Germany, 2012.
[2624] G. Richard. Some research in audio, music and multimodal signal processing. In *Seminar at Fraunhofer Institute*, Ilmenau, Germany, 2013.

13.5.2 Public Fundings

Period	Project details	Funding	Principal investigator
2011-2014	REVERIE - Realistic and immersive 3D Environnements	Europe (IP)	S. Essid
2011-2014	VERVE - Vanquishing fear and apathy through E-inclusion	Europe (STREP)	S. Essid
2010-2013	3Dlife - Analysis/synthesis of 3D audiovisual content for 3D models animation, virtual humans and virtual environments creation	Europe (NoE)	G. Richard
2008-2013	QUAERO - Automatic analysis, indexing of multimedia and multilingual documents	OSEO	G. Richard
2009-2013	DREAM - Sound Separation, transformation and watermarking for active listening	ANR	G. Richard
2008-2011	ROMEO - Sound capture by microphone arrays for Humanoid robots	Cap Digital	Y. Grenier
2012-2016	ROMEO 2 - Sound scene capture for Humanoid robots	OSEO	Y. Grenier
2008-2013	PAFI - Modular platform for music instruments	ANR	B. David
2009-2013	ARTIS - Articulatory inversion of audiovisual speech for augmented speech	Europe	S. Maeda
2012-2013	SPOL : Sound Processing On Line	Labex LMH 2012	G. Richard
2011-2014	EMC2- Support action towards excellence in media computing and communication	Europe	G. Richard
2013-2016	Marie Curie IOF Fellowship	Europe	G. Richard

Total funding 2 512 k€

13.5.3 Private Fundings

Period	Project details	Funding	Principal investigator
2008-2009	Sound source localisation	Grande Paroisse	Y. Grenier
2008-2011	CIFRE PhD (S. Gulluni) on Audio segmentation	INA	G. Richard
2009	Database collection	INA	S. Essid
2011	Algorithms	Egonocast	S. Essid
2011-2014	EEG Monitoring	MeegaPerf	S. Essid
2011-2014	CIFRE PhD on Speech dereverberation	Arkamys	G. Richard
2011-2012	CIFRE PhD on source separation	Audionamix	G. Richard

Total funding 254 k€

13.5.4 Patents and software

Patents

- Sébastien Fenet, Yves Grenier and Gaël Richard (TSI), *Audiofingerprinting "Generation d'une signature d'un signal audio musical"*, Patent filled under N° FR 13/51752
- Antoine Liutkus, Laurent Girin, Roland Badeau and Gaël Richard, *Procédé et dispositif de représentation et de séparation/filtrage des composantes d'un signal mixé*, Patent filled under N° FR 10/58348
- Nicolas Lopez, Gaël Richard and Yves Grenier, *Procédé de suppression de la réverbération tardive*, Patent filled under N° 26875 FR.

Softwares

- Benoit Mathieu, Jacques Prado, YAAFE, (open source) software referenced under N° IDDN.FR.001.100013.000.S.P.2010.000.20000
- Benoit Mathieu, Jacques Prado, YAAFE extension, software referenced under N° IDDN.FR.001.100014.000.S.P.2010.000.20000
- Jacques Prado, Benoit Mathieu, SMARC, sotfware referenced under N° IDDN.FR.001.080018.000.S.P.2010.000.20000
- Jacques Prado, Benoit Mathieu, SMARC (Language C), sotfware referenced under N° IDDN.FR.001.080017.000.S.P.2010.000.20000

13.6 PhDs

13.6.1 Defended PhDs

[2625] N. Bertin. *Les factorisations en matrices non-négatives. Approches contraintes et probabilistes, application à la transcription automatique de musique polyphonique.* PhD thesis, Télécom ParisTech, Oct. 2009.

[2626] M. Betser. *Modélisation sinusoïdale et applications à l'indexation sonore*. PhD thesis, Telecom ParisTech, June 2008.

[2627] J.-L. Durrieu. *Transcription et Séparation automatique de la mélodie principale dans les signaux de musique polyphoniques*. PhD thesis, Télécom ParisTech, May 2010.

[2628] B. Elie. *Caractérisation vibratoire et acoustique des instruments à cordes - Application à l'aide à la facture instrumentale*. PhD thesis, LAUM, Nov. 2012.

[2629] V. Emiya. *Transcription automatique de la musique de piano*. PhD thesis, TELECOM ParisTech, Oct. 2008.

[2630] S. Fontana. *Déconvolution et applications à la technologie binaurale*. PhD thesis, TELECOM ParisTech, July 2008.

[2631] B. Fuentes. *L'analyse probabiliste en composantes latentes et ses adaptations aux signaux musicaux. Application à la transcription automatique de musique et à la séparation de sources*. PhD thesis, Télécom ParisTech, Mar. 2013.

[2632] S. Gulluni. *Un système interactif pour l'analyse des musiques électroacoustiques*. PhD thesis, Télécom ParisTech, Dec. 2011.

[2633] R. Hennequin. *Décomposition de spectrogrammes musicaux informée par des modèles de synthèse spectrale : modélisation des variations temporelles dans les objets musicaux.* PhD thesis, Télécom ParisTech, Nov. 2011.

[2634] C. Joder. *Alignement temporel musique-sur-partition par modèles graphiques discriminatifs*. PhD thesis, Telecom ParisTech, Sept. 2011.

[2635] A. Liutkus. *Processus gaussiens pour la séparation de sources et le codage informé*. PhD thesis, Télécom ParisTech, Nov. 2012.

[2636] M. Maazaoui. *Séparation de sources pour l'audition des robots*. PhD thesis, Télécom ParisTech, May 2012.

[2637] M. Moussallam. *Représentations Redondantes et Hiérarchiques pour l'Archivage et la Compression de Scènes Sonores*. PhD thesis, Télécom ParisTech, Dec. 2012.

[2638] V. S. Nguyen. *Etude de caractéristiques de la langue vietnamienne en vue de sa synthèse et de sa connaissance automatique. Aspects statiques et dynamiques.* PhD thesis, Télécom ParisTech, Dec. 2009.

[2639] L. Oudre. *Reconnaissance d'accords à partir de signaux audio par l'utilisation de gabarits théoriques*. PhD thesis, TELECOM ParisTech, Nov. 2010.

[2640] M. Ramona. *classification automatique de flux radiophoniques par machines à vecteurs de support*. PhD thesis, Télécom ParisTech, June 2010.

[2641] F. Vallet. *Structuration automatique de talk shows télévisés*. PhD thesis, Télécom ParisTech, Sept. 2011.

13.6.2 Ongoing PhDs

[2642] H. Bai. *Analyse automatique et synthese dynamique de secenes 3D audio*. PhD thesis, Télécom ParisTech.

[2643] A.-C. Conneau. *Identification automatique et dynamique de l'état émotionnel par analyse de signaux biologiques hétérogènes*. PhD thesis, Télécom ParisTech.

[2644] S. Fenet. *Identification audio par le contenu*. PhD thesis, Télécom ParisTech.

[2645] R. Foucard. *Fusion multi-niveaux pour la recherche par similarité musicale*. PhD thesis, Télécom ParisTech.

[2646] C. Fox. *Reduction de bruit acoustique en environnement automobile*. PhD thesis, Télécom ParisTech.

[2647] X. Jaureguiberry. *Fusion et optimisation de modèles pour la séparation de sources audio*. PhD thesis, Télécom ParisTech.

[2648] N. Lopez. *Méthodes partimonieuses pour la déréverbération des signaux audio*. PhD thesis, Télécom ParisTech.

[2649] A. Masurelle. *Analyse automatique de scènes multimodales par approches discriminatives*. PhD thesis, Télécom ParisTech.

[2650] F. Rigaud. *Apprentissage de modèles génératifs pour un instrument de musique sur des données enregistrées*. PhD thesis, Télécom ParisTech.

[2651] N. Seichepine. *Factorisations multimodales pour la structuration non-supervisée des documents audiovisuels*. PhD thesis, Télécom ParisTech.

Chapter 14

Image Processing and Understanding (TII)

14.1 Executive Summary

Team Leader Isabelle Bloch (FP)

Initial Staff Permanent positions : 5 full professors, 5 associate professors, 4 Research scientists (CR1 CNRS).

Staff who left One full professor left in 2010, one associate professor left in 2012.

Staff who were hired One associate professor (formerly senior scientist at Saarland University) was hired in 2009, two research scientists (CR2 CNRS) (formerly post-docs at Caltech and University of Utah) were hired in 2010 and 2011.

Scientific Highlights The reputation of the team is based on its two main components:

1. Its contributions to modeling, based on formal methods of different natures, with pioneer work, such as (just to name a few):

• stochastic image modeling : non local methods for various noise distribution, texture modeling, a contrario methods for image matching (probabilistic and statistical models),

• optimal transport, with new results on the circle, both in the discrete and continuous cases (analytical models),

• mathematical morphology in various complete lattices, providing a core framework for imperfect knowledge representation and spatial reasoning (algebraic models),

• adaptive meshing and scalable mesh processing (geometrical models),

2. Its contributions to large application domains, with several original results, such as:

• structural anatomical knowledge modeling to drive medical image understanding,

• realistic modeling of the human body (from fetus to adult) from medical images, combining image understanding and computer graphics,

• analysis and indexing of natural textured images,

• analysis of multi-modal (optical, radar) and multi-temporal data in remote sensing,

• efficient visualization and visual search in images, videos and 3D object databases.

Scientific Production 191 Journals; 7 Books; 34 Book chapters; 315 Articles in Proceedings; 62 Phd theses.

Major Publications • L. Bibin, J. Anquez, J. de la Plata Alcalde, T. Boubekeur, E. D. Angelini, and I. Bloch. Whole body pregnant woman modeling by digital geometry processing with detailed utero-fetal unit based on medical images. IEEE Transactions on Biomedical Engineering, 57(10):2346-2358, Oct. 2010.

• I. Bloch. Mathematical morphology on bipolar fuzzy sets: general algebraic framework. International Journal of Approximate Reasoning, 53:1031-1061, July 2012.

• M. Delbracio, P. Musé, A. Almansa, and J.-M. Morel. The non-parametric sub-pixel local point spread function estimation is a well posed problem. International Journal of Computer Vision, Sept. 2011.

• C.-A. Deledalle, L. Denis, and F. Tupin. How to compare noisy patches? Patch similarity beyond Gaussian noise. International Journal of Computer Vision, Feb. 2012.

• J. Rabin, J. Delon and Y. Gousseau. Transportation distances on the circle. Journal of Mathematical Imaging and Vision, 41(1):147-167, Sep. 2011.

• G. Fouquier, J. Atif, and I. Bloch. Sequential model-based segmentation and recognition of image structures driven by visual features and spatial relations. Computer Vision and Image Understanding, 116(1):146-165, Jan. 2012.

• S. Ladjal, J.-F. Aujol, and S. Masnou. Exemplar-based inpainting from a variational point of view. SIAM Journal on Mathematical Analysis, 42(3):1246-1285, Jan. 2010.

• G.-S. Xia, J. Delon, Y. Gousseau. Accurate junction detection and characterization in natural images. International Journal of Computer Vision, to appear, 2013.

• H. Sahbi, J.-Y. Audibert, and R. Keriven. Context-dependent kernels for object classification. In Pattern Analysis and Machine Intelligence (PAMI), 4(33):699-708, Apr. 2011.

• J.-M. Thiery, J. Tierny, and T. Boubekeur. Cager: Cage-based reverse engineering of animated 3d shapes. Computer Graphics Forum, Dec. 2012.

Impact and Attractivity

- Distinctions: Eurographics Young Researcher Award (2012, E. Eisemann), Best student paper at ICIP 2010 (C.-A. Deledalle, F. Tupin), First Price for the Student Paper Award of EUSAR 2008 (A. Ghaleb, L. Vignaud and J. M. Nicolas), Best Paper Award at the Eurographics Symposium on Parallel Graphics and Visualization 2013 (J. Tierny), Honorable mention of the Dirk Bartz Prize for Visual Computing in Medicine (2011, J. Anquez, I. Bloch, T. Boubekeur, E. Angelini), Best PhD Award of Fondation Telecom (B. Buchholz), PhD Award in Signal, Image, Vision 2012 for C.-A. Deledalle.
- Organization: International conferences (MICCAI 2008, ISBI 2008, CIARP 2010, High Performance Graphics 2012, Eurographics, Visu 2012), international workshop Optimal transport, algorithms and applications (IHP 2011, J. Delon), symposium and special sessions (SIAM IS, EGSR 2012, SMAI, Gretsi).
- Editorial duties (associate editors): IEEE TGRS (F. Tupin), IPOL (A. Almansa, Y. Gousseau), CGF (Journal of the Eurographics Association, T. Boubekeur), IEEE SMC (until 2012), FSS and CVIU (I. Bloch), IEEE TBME (E. Angelini, 2008-2012).
- Invited conferences.
- Common Labs and Chairs (WHIST, Isa, Imaginaires), financed international and national collaborations.

Interaction with Economic and Social Spheres

- Collaborations with major industrial actors in our main application fields (biomedical imaging, remote sensing imaging, digital photography, computer graphics).
- Benchmark for evaluating photographic devices (texture quality) used worldwide (NASA, Nikon, Popular photography, FNAC, Chasseur d'images, etc.).
- Stereo algorithm used by CNES to process the most recent Pleiades images.
- The algorithm "Phong tessellation" is included in most 3D middleware of modern video games (Unreal engine, Cry engine).
- Several PhD thesis results included in software platforms used in companies and hospitals (segmentation for oncology applications, retina layers segmentation and quantification), large diffusion of anatomical models for research purposes.

Contributions to Higher Education

- Organization of the "Image" program at Telecom ParisTech, formation of high level engineers mostly dedicated to research and development.
- In charge of the IMA Master 2 program, UPMC (I. Bloch) and lectures (I. Bloch, T. Boubekeur, S. Ladjal, F. Tupin).
- MVA Master 2 program : lectures (A. Almansa, J. Delon, Y. Gousseau, J.-M. Nicolas, F. Tupin) and organization of the Telecom-MVA cursus.
- Launching the biomedical master program BME-Paris, chair of the M1 (E. Angelini).

14.2 People

Team leader Isabelle Bloch (FP).

Faculty A. Almansa (CR1 CNRS, HDR), E. Angelini (AP, HDR in 2011, on leave in Australia at CSIRO for six months in 2010, on leave at Columbia University since January 2012), I. Bloch (FP, on leave from February to July 2013), T. Boubekeur (AP, HDR in 2012), H. Brettel (CR1 CNRS, HDR), M. Campedel (AP), J. Delon (CR1 CNRS, HDR in 2011), E. Eisemann (AP, since 12/09 and until 9/12), Y. Gousseau (FP, HDR in 2009), S. Ladjal (AP), H. Maître (FP, Emeritus since March 2013), P. Memari (CR2 CNRS, since 10/11), J.-M. Nicolas (FP), S. Rital (Research Engineer, until 01/13) M. Roux (AP), H. Sahbi (CR1 CNRS, HDR in 2011), T. Tanzi (FP, until 2010), J. Tierny (CR2 CNRS, since 10/10), F. Tupin (FP).

PhD students *Defended (dates are for the defense):* A. Baillard (12/08), N. Bonnier (9/08), M. Costache (9/08), J. Dellière (6/08), T. Hurtut (3/08), A. Kermi (10/08), H. Khotanlou (2/08), I. Kyrgyzov (5/08), P. Lopez-Quiroz (11/08), C. Millet (1/08).
E. Aldea (12/09), J. Anquez (9/09), C. Le Men (9/09), D. Lesage (10/09), J. Rabin (12/09), N. Sabater (12/09, with ENS Cachan).
J. Baussé (10/10), M. Bredif (5/10), D. Cerra (5/10), N. Chenouard (1/10), D. Craciun (7/10), G. Fouquier (2/10), B. Galerne (12/10, with ENS Cachan), G. Lehureau (4/10), C. Mallet (11/10), F. Mosca (10/10), T. Napoléon (7/10), G. Palma (2/10), A. Shabou (11/10), H. Sportouche (12/10), N. Widynski (11/10, with UPMC), J. Wojak (12/10).
S. Audière (12/11), P. Birjandi (9/11), P. Blanchart (9/11), M. Bouali (6/11), E. Bughin (10/11, with ENS Cachan), C. Deledalle (11/11), V. Duval (6/11), G. Hochard (3/11), M. Marim (4/11), B. Petitpas (12/11, with Univ. Marne la Vallée), H. Soubaras (1/11), M. Tepper (3/11, with Univ. Buenos Aires), C. Vanegas (1/11), G.-S. Xia (3/11).
I. Ghorbel (4/12), J. Caron (5/12, with Univ. Amiens), A. Graciano (6/12, with Univ. Sao Paulo), G. Vialaneix (11/12), J.-M. Thiery (11/12), A. Roquel (12/12, with U. Paris Sud), B. Buchholz (12/12), G. Pizaine (12/12).
J. Huang (2/13), M. Höllander (3/13), M. Delbracio (3/13 with ENS Cachan), N. Faraj (6/13).
Current (dates are for the beginning of PhD): C. Aguerrebere (4/11, with UdelaR, Montevideo), E. Au (12/11, with LIP6), D. Aubry (9/12), L. Avanthey (10/12, with ESIA), T. Baar (10/12), E. Benhaim (10/11, with Parrot), N. Bourdis (1/10, with EADS), S. Calderon (11/11), I. Cléry (2/12, with IGN), A. Deblonde (4/12, with Morpho), F. Dellinger (10/10, with CNES), K. Falkenstern (2/12), M. Gargouri (11/11), R. Gauriau (6/12, with Philips), N. Geeraert (9/11, with GE), T. Guillemot (10/10), E. Guy (10/12), C. Herold (12/10, with Morpho), P. Irrera (7/12, with EOS Imaging), Q. A. Le (10/09), Y. Le Montagner (10/10, with Institut Pasteur), B. Mazin (9/10), J.-C. Michelin (12/11, with IGN), C. Miloudi (9/12, with ISEP and hôpital des XV-XX), B. Morel (12/12, with hôpital du Kremlin-Bicêtre), A. Newson (9/10, with Technicolor), J.-B. Poisson (10/10), J. Preciozzi (3/11, with UdelaR, Montevideo), G. Quin (9/10, with CEA), A. Roman Gonzalez (9/09), L. Schemali (1/11, with Useful Progress), X. Su (10/11), S. Tabti (10/12), G. Tartavel (10/11), Y. Traonmilin (7/11), U. Verma (10/10), P. Vo (10/10), B. Wang (10/12, with Shondong University), Y. Yang (10/10), F. Yuan (9/10-9/11).

Post-docs, engineers and sabbaticals R. de Aldama (3/13–12/13), J. Anquez (1/10–6/10), L. Babou (7/09–2/11), A. Bretto (1/10–8/10), F. Cao (9/10–4/11), S. Chevallier (3/11–8/11), S. Dahdouh (10/11–6/13), J.-P. De la Plata (8/09–7/11), A. El Ghoul (01/12–1/14), D. Günther (05/13–11/14), E. Erdem (7/09–3/10), F. Fayard (5/10–4/11), G. Fouquier (7/09–3/11), M. Horta (4/11–9/11), O. Kyrgyzov (7/12–6/13), S. Lee (7/09–2/11), X. Li (6/09–6/10), M. Lindenbaum (3/11–8/11), K. Loquin (3/10–10/11), A. Marquez (9/9–10/10), M. Moghrani (9/09–8/10), V. Pascucci (6/11–), Y. Pinto (3/11–10/11), E. Provenzi (04/13–03/14), T. Ritschel (5/10–9/11), X. Rondeau (10/09–3/11), Y. Rouchdy (10/09–12/10), A. Serrurier (2/12–12/12), H. Sportouche (4/11–03/12), O. Tankyevych (1/11–8/11), V. Tayanov (10/09-12/09), J.-M. Thiery (12/12–12/13), C. Vanegas (1/11–4/11), I. Yu (04/12–05/13), A. Zureiki (7/09–10/09).

Associate members Mihai Datcu (DLR, until June 2010), Hong Sun (Univ. Wuhan), Catherine

Adamsbaum (Univ. Paris Sud, CHU Bicêtre).

14.3 Overview

The objective of the group is to develop methodologies and theoretical tools for image, scene and 3D object processing and interpretation. This includes analyzing, transforming, representing, understanding and synthesizing images, digital volumes and objects. The main approach consists in solving globally complex problems, based on rigorous theoretical foundations, and integrating multiple and complementary techniques, in order to derive interpretations from data. Applications focus on medical imaging, aerial and satellite imaging, natural image analysis. Contributions of the group can therefore be found at theoretical level (knowledge and information representation and modeling, in 2D as well as 3D, processing, interpretation and reasoning on spatial data), at algorithmical level (in particular to implement the developed models for large and complex data sets), and at applicative level. With a strong theoretical and methodological anchoring, along with close links with applications, the contributions of the group are at the cross-road of applied mathematics, computer science and artificial intelligence. The group is well recognized, in academic, institutional and industrial domains, in particular for his noticeable contributions in mathematical modeling of images, digital geometry and rendering, image retrieval, mathematical morphology and spatial reasoning, radar imaging, medical imaging. It has numerous collaborations with other universities, and is supported by grants and contracts. The different research activities are closely linked together, which is one of the distinguishing features of the group.

The group is involved in several joint labs: CoC with DLR and CNES, which was finished during this period (see Section 14.4.5), WhistLab with Orange Labs and Telecom Bretagne, IDentity & Security Alliance (The Morpho and Telecom ParisTech Research Center), as well as in the "Chaire Modélisation des Imaginaires". It is also involved in the new French Initiatives, such as the Labex Smart and DigiCosme, and the Equipex Digiscope.

Over the period covered by this report, the group has benefited from the appointment of two CNRS researchers (P. Memari and J. Tierny) and one associate professor (E. Eiseman), strengthening research axes mainly in computer graphics, but also in medical imaging. E. Eiseman left in 2012 to be promoted as a professor at the University of Delft. Over the same period, one professor (T. Tanzi) left to join a research team in Sophia-Antipolis at Mines ParisTech. The good reputation of the group and its visibility, in France as well as at an international level, are confirmed by the number of publications, but also by the number of collaborations, mentioned below for each research axis, and by its attractiveness for CNRS candidates, post-docs and PhDs.

The scientific animation of the team includes a general seminar and several specific ones (medical imaging, compressed sensing, radar imaging, 3D and computer graphics...). PhD candidates are invited to publicly present their work at the end of the first year of their PhD, so as to gather comments from the whole team and initiate discussions among them, thus favoring cross-fertilization of ideas. A mid-term evaluation is also organized for all PhD candidates. We also pay attention to the accompanying process of the PhD theses, beside the direct scientific supervision, including a help to prepare their future.

14.4 Research Themes

14.4.1 Mathematical methods for images

Faculty A. Almansa, I. Bloch, J. Delon, Y. Gousseau, S. Ladjal, F. Tupin.

Highlights: Scientific Production [2792, 2740, 2762, 2820, 2698, 2837]

Highlights: Impact Research project funding : ANR projects (CALLISTO, FREEDOM, LOGIMA, MATAIM, OTARIE), FUI (9th call) CEDCA, ECOS Sud (U06E01), STIC AmSud (MMVP-

SCV), CNES PhD funding, ONERA PhD funding, Cifre PhD fundings, DGA/REI MRIS and Tracking.

Collaborations : MAP5, LIP6, LRI, CMLA, CEREMADE, Ponts ParisTech, ECP, GREYC, Institut Camille Jordan, Laboratoire Jean Kuntzmann, Université Bordeaux 1, Université Saint-Etienne, CESBIO, IGN, Institut Pasteur, U. Las Palmas et UPF Barcelone (Espagne), Univ. Dresden (Germany), Technion (Israël), Polytechnique Montréal (Canada), Caltech, UCLA et U. Minnesota (USA), Universidad de la Republica (Uruguay), UBA (Argentine), Univ. Merida (Venezuela), U. Wuhan (Chine), Poncelet Lab. Moscou (Russie).

Organisation : Colloque *Optimal Transport, algorithms and applications* (IHP 2011), symposium and special sessions SMAI, GRETSI, SIAM.

Highlights: Interactions with Society Industrial collaborations : CNES, DxO, Morpho, Shlumberger, Technicolor.

A stochastic image model developed in our team (Y. Gousseau) has been introduced in the latest version of DxO's *Analyzer* software. As such, it is used by economic actors such as La Fnac, foreign research agency such as the NASA, industrial actors such as Nikon or specialized press such as Chasseur d'images or Popular Photography.

One of our stereoscopy algorithm (A. Almansa) has been implemented by the CNES to process images from his most recent satellites, such as Pleiades and successors.

Texture and natural images modeling This research theme deals with the stochastic modeling of natural images. These models (dead leaves, shot-noise, transparent models) are grounded in the theory of marked point processes, whose marks are geometrical structures. The most notable works in this area are concerned with texture synthesis using spot-noise models, see [2740, 2739], sparse modeling [3154], as well as the stochastic modeling of transparency [2738]. Much effort has also been devoted to the study of the impact of various restoration image models on the textured aspects of natural images, as explained below, see [2703, 2719, 2720]. An important achievement is that a model previously developed in our team, the *scaling dead leaves model*, has been retained by the company DxO to evaluate the ability of imaging devices to preserve textures in natural images and is included in the latest version of their software *analyzer* as mentioned above.

Image analysis and computer vision These last years, we have developped a large body of work in the field of computer vision. Contributions include both methodological studies and competitive algorithms, in particular for image matching and comparison problems.

A first methodological aspect of our work is concerned with optimal transportation equations. These equations enable the definition of metrics between weighted features and yield elegant ways to compare images. We have proposed several complementary studies on the subject of optimal transportation on the circle, one in a continuous setting [2708] and the other one in a discrete setting [2792, 2794]. This last study compares for different retrieval tasks the transportation metrics with the classical distances used in computer vision. More recently, we have focused on transport problems with concave costs [2709], which are more realistic in many applications, especially in economic situations. In the same research field, a sliced approximation of the optimal transport is introduced in [3113] and used for texture mixing.

Another methodological aspect of our researches deals with *a contrario* methods, developed by Desolneux et al. to automatically fix detection thresholds for image analysis. An attempt to evaluate the collaboration of Gestalt grouping laws in vision using this *a contrario* framework is proposed in [2748]. Another attempt to extend this framework to the interactions between collaborations and conflicts of simple grouping laws was proposed in [2820] in the context of contrast and regularity for edge detection. To a great extent, we also applied these *a contrario* methods to the problem of image matching. We have developed a complete chain for the matching of images from local descriptors (such as SIFTs). This procedure encompasses the descriptors themselves,

a transportation metric adapted to circular histograms, an unsupervised matching criterion, and a validation, RANSAC-like step [2792, 3110]. This procedure is adapted to the case of color images in [3070]. A close research direction concerns the accurate detection of junctions in natural images [3188, 2837]. In the particular case of block-matching of epipolarly-rectified stereo pairs, the *a contrario* methodology has proven very efficient to build up semi-dense sets of reliable matches [2804]. This yields disparity maps computed up to an unprecedented accuracy level, closely matching our theoretical accuracy estimation [2803]. Check also the accompanying online demo[1]. The a contrario methodology also allows for parameterless and unsupervised graph-based clustering [2819] without any shape prior. Applications ranging from high-dimensional data analysis to restoration of images and 3D data are being explored. Another approach for point matching was developed for change detection problems based on a new interest point matching approach combined with the epipolar geometry [2810]. Eventually, we also have developed an extension of the *a contrario* approach, in which the hypothesis of independence classically made for the null hypothesis is alleviated. This is permitted by the use of graphical models and has been applied to alignment and object detection [2782].

Still in a probabilistic framework, new graph-cut based optimization approaches of Markovian models have been proposed. They allow an efficient compromise between memory size and quality of the obtained optimum [2812].

Among the other tools that we have investigated and applied, let us quote hiererarchical morphological image representations. These tools, and in particular the topographic map, turn out to be particularly efficient for perceptual edge detection [2820], for the indexing of satellite images [2769], the indexing of texture through extensions of the classical granulometry from mathematical morphology [2836] or the analysis of artistic line-drawings [2755]. A strong asset of all such approaches is a flexible control on a wide range of geometrical and radiometric changes.

Restoration of images and image sequences In the last few years, our group has become quite active in the field of image restoration.

In the case of single-frame restoration, many denoising problems have been tackled. We have proposed several extensions and studies of Non-Local Means methods. In [2720], we proposed an in-depth study of such denoising methods and give a solution for the automatic and local setting of parameters. In [2703], it is proposed to use adaptive and generic patches to improve denoising results. In [2701], the method is extended in a probabilistic approach, allowing to process images for which a distribution of the parameters of interest is available (Poisson, Gamma, Wishart distributions...). This framework also permits to process vectorial data [2702].

We have recently proposed an adaptation of non local approaches for the removal of impulse and mixed Gaussian-impulse noise [2968, 2706]. Still in the domain of impulsive degradations, we have conducted an extensive study of the popular TV-L1 model, showing that it is equivalent to some morphological filtering and acts as a granulometry [2719]. The TV regularization model under local L2 constraints showed effective in the context of irregularly sampled blurred and noisy data [2731, 2887]. It was also shown useful for destriping MODIS images [2774].

In order to restore larger and more extreme degradations of images, we also took interest in image inpainting. We developed an approach relying on the automatic combination of patch-based methods and geometrical interpolation [2683], permitting the restoration of both the texture and the geometry of images over large regions. This subject has also been addressed in a related work on the variational interpretation of copy-paste methods [2762]. Some of the previous works require an accurate knowledge of internal camera parameters like the intrinsic blur kernel (PSF). In [2698] and the corresponding online demo [2700] we showed how accurate estimation of the subpixel PSF from a single aliased photograph becomes a well posed problem: An appropriate white noise image has to be used as a callibration pattern. If a second rescaled snapshot is available, the pattern may be unknown, and some deviations from the optimal pattern are still admissible as shown in [2699] and the accompanying IPOL demo [2].

[1] http://dev.ipol.im/~monasse/ipol_demo/bms_binocular_stereo_pipeline/

[2] http://www.ipol.im/pub/algo/damm_blind_psf_estimation_from_scaled_image_pairs/

Recently, we have oriented an important part of our restoration activity toward multi-frame restoration. This research direction is intimately related to different research projects, in particular ANR FREEDOM JCJC (2007-2011) on movie restoration, the collaborative FUI project CEDCA with DxO Labs on protocols for quality enhancement in digital photography, and two PhD theses (one with Technicolor SA and the other in the context of the project CEDCA). As part of the research project FREEDOM, we have proposed two contributions related to contrast and color: the first one concerns the restoration of local radiometric problems in image sequences [2705], and the second one is an efficient method for the removal of artifacts [2793] introduced by contrast and color changes. Another contribution deals with the detection and restoration of occluding defects in movies [2930]. Our recent contributions on the subject of multiframe restoration mainly concern the outlier-resistant enhancement of dynamic and resolution in images. On the creation of *high dynamic range* (HDR) images, we have proposed an a statistical study of the efficiency of HDR algorithms for static scenes. We also adressed the case of dynamic scenes, with a patch-based method for the simultaneous denoising and HDR creation [2884]. Concerning multi-image *super-resolution* our study [3160], extends theoretical bounds on well-posedness of the problem to the case of affine motions, and takes advantage of these predictions to preserve more details by automatic fine-tuning of the required regularization. When the previous study is reformulated in the robust L^1 data-fitting framework, it turns out that simultaneous super-resolution and *outlier detection & restoration* is possible [3161] under sparsity constraints on the outlying artifacts, that are closely related to the null-space property commonly used in *compressed sensing*.

Tracking Another contribution based on probabilistic methods addresses tracking issues in image sequences, by incorporating different types of information in the probabilistic model [2728, 2727, 2834, 2835] (collaboration with LIP6). Our approach is based on particle filtering, and we have proposed original ways to introduce spatial relations, represented in a fuzzy set framework (see Section 14.4.2), either between different positions of one object during time, or between several objects for multiple object tracking problems (PhD of N. Widynski). In this case, we also proposed a ranked partitioned sampling method, so as to handle the most visible objects first. Multiple appearance models and adaptive fusion of multiple cues have also been proposed. These new models and the associated algorithms provide better results than state of the art methods, in terms of accuracy of tracking, object association, and handling partially occluded objects. Multiple object tracking has also been addressed using multiple hypotheses methods, for biological applications in cluttered environment [2950, 2951, 2952] (collaboration with Institut Pasteur).

Tracking has also been exploited in segmentation problems, in particular for elongated structures such as blood vessels, using particle filters and minimal paths according to adaptive metrics (see also Section 14.4.4). A new project on multi-view tracking has also been launched, based on particle filter, to estimate the shape parameters and the pose of a face for authentication based on face matching (collaboration with LIP6 and Morpho, PhD of C. Herold). The originality is to integrate static parameters in the particle filter [2872, 3022].

Mathematical morphology In parallel to the work mentioned above on granulometry and TV restoration, our contribution in mathematical morphology concerns the representation and handling of qualitative and imprecise information in different settings, such as formal logics [2653, 2896], including description logics for ontological reasoning, fuzzy sets [2672], and more recently hypergraphs [2918, 2676, 2919], concept lattices [2898], and bipolar information [2916, 2673, 2674, 3029] to model both positive information (observations, preferences) and negative information (constraints). In all these frameworks, we proposed appropriate complete lattices and connectives, leading to good properties of mathematical morphology operations. These operations can then be used for various tasks, such as preference modeling and spatial reasoning (see Section 14.4.2). This work was partly carried out in collaboration with LRI, ECP, GREYC, university Merida (Venezuela), university Dresden (Germany).

14.4.2 Image understanding, learning and spatial reasoning

Faculty I. Bloch, H. Brettel, M. Campedel, M. Datcu (until 2010), H. Sahbi.

Highlights: Scientific Production [2662, 2737, 2805, 2827, 2844]

Highlights: Impact CIARP 2010 conference.

ANR DAFOE, Infomagic, K-Space, ANR DESCRIBE, ANR LOGIMA, CNES PhD thesis and research projects funding, collaboration with J. Atif (LRI), C. Hudelot (ECP), J. Inglada (CESBIO), S. Le Hégarat-Mascle (IEF), R. Cesar (U. Sao Paulo, Brazil), F. Distel (Univ. Dresden).

Highlights: Interactions with Society Collaboration with Mondeca, IGN, CNES.

Spatial reasoning Our work on modeling spatial relations within the fuzzy set framework has evolved towards complex relations such as *along*, *surrounds*, *to go across*, *parallel to*, both for individual objects and for groups of objects [2817, 3262, 3167]. New fuzzy connections have also been proposed, and applied to filtering problems [2784, 2790]. A new direction of research concerns spatial relations in a bipolar setting. These relations are based on mathematical morphology operators, and their use for spatial reasoning was formalized in different settings (PhD of G. Fouquier, C. Vanegas, A. Graciano). One relies on graph-based reasoning, where a graph modeling the available knowledge about a scene (on objects and their spatial relations) guides a sequential segmentation and recognition process [2737]. The order in which structures are segmented is adapted to each image, by combining spatial relations and saliency information. Another approach relies on the search for a global solution by expressing the recognition as a constraint satisfaction problem [2785, 2786, 2827], or as an inexact graph matching problem [2788]. Finally ontological reasoning was proposed, by introducing mathematical morphology operators in description logics in order to define spatial relation concepts [3029]. In the same line, a method associating description logics, formal concept analysis and mathematical morphology was developed. The first reasoning service we proposed within this framework is abduction, in order to provide the best explanation of a scene according to the available knowledge [2896, 2662]. Extension to fuzzy abduction is currently addressed.

A renewed interpretation of conflict within the belief function framework was developed during the PhD thesis of A. Roquel (in collaboration with IEF), and an original decomposition of the conflict was proposed, to allow interpreting its causes and then adapting the fusion process [3118].

During the ANR project DAFOE4app (2007-2010), an engineering collaboration between Telecom ParisTech and Mondeca has been initiated which received the support of CNES. The goal was to create and develop interactive tools to assist satellite image interpreters through the creation of two OWL ontologies: one to describe the image content and the feature extraction process, the other to manage the land cover classes; these ontologies integrate spatial relationships between image objects as well as other semantic relationships. A prototype of the annotation tool, based on Mondeca technology has also been built. Although it needs further engineering development to make it fully operational, it is ideal to demonstrate the usefulness of both low-level image processing algorithms and semantic reasoning in the context of satellite image interpretation.

Two important projects were completed during this period, Infomagic and K-space, leading to the publications of one book and a significant contribution to a second one [2844, 2869].

This research theme was also developed specifically in the context of remote sensing imaging, as described in Section 14.4.5.

Machine learning • Besides recognition and spatial reasoning, spatial relations have also been used in structural learning for image classification, based on original graph kernels including spatial relations [2850] (PhD of E. Aldea).

• In our work on interconnected networks & activity recognition, we improved support vector machines (SVMs) scene annotation and retrieval by using a new class of kernels referred to as

context-dependent (CD). The main contributions of our method ly in the variational approach to design the CD kernel and in the proof of convergence of this kernel to positive definite fixed-point. When plugged in SVMs, our CD kernel consistently improves the performance of image annotation and retrieval, compared to context-free kernels, on hundreds of thousands of Flickr images [3125, 2805, 3126]. We also extended this CD kernel in order to handle logo detection and recognition [2806] as well as activity indexing and recognition in video sequences [3196, 2842].

• We proposed a novel approach for kernel map learning that goes beyond the naive use of existing kernels and their restricted combinations in order to design "model-free" transductive kernels. They are based on the minimization of an energy function mixing a reconstruction term (product of a learned dictionary and a learned kernel map), a fidelity term ensuring consistent label prediction, and a smoothness term. Experiments conducted on object class segmentation and image annotation, show that our kernel achieves at least comparable results with related state of the art methods on different standard databases [3173, 3172].

• Automatic speech analysis is currently evolving towards hybrid systems that combine both visual and acoustic information. We introduced in this work an original visual speech recognition approach including the design of a similarity function, based on string kernels, that models the dynamics as well as the appearance of visual features in talking faces, and a kernel combination procedure based on multiple kernel learning, that makes visual feature selection effective and also more tractable. Experiments conducted on a standard digit database show that the proposed algorithm outperforms current state-of-the-art methods [2902].

• We also proposed a novel superpixel-based framework for object class segmentation using conditional random fields (CRFs). The framework proceeds in two steps: (i) superpixel label estimate, and (ii) CRF label propagation. Step (i) is achieved using multi-scale boosted classifiers over superpixels and makes it possible to find coarse estimates of initial labels. Fine labeling is afterward achieved in Step (ii), using an anisotropic contrast sensitive pairwise function designed in order to characterize the intrinsic interaction potentials between objects according to 4-neighborhoods. Finally, a higher-order criterion is applied to enforce region label consistency of OCS. Experimental results demonstrate the effectiveness of the proposed framework [3053].

• In a process of learning semantic manifolds for mental image search we designed an algorithm based on a novel principle that unmixes semantics from images and maps them from an initial ambient space (related to low level visual features including texture, color and shape) to an output space spanned by a well defined semantic basis. We cast this problem as a convex quadratic programming (QP) optimization, constrained in a simplex spanned by few pure semantic basis vectors. The advantage of the proposed approach is a significant reduction in the input space dimensionality (which is difficult to explore/visualize), and an easier interpretation of retained features. Therefore, searching for a mental target is achieved by simply scanning and targeting image data according to their coordinates in the learned semantic subspace.

• We introduced a complete "2D to 3D object" retrieval framework. Given a (collection of) picture(s) or sketch(es) of the same scene or object, the method allows us to retrieve the underlying similar objects in a database of 3D models. The contribution of our method includes a generative approach for alignment and the application of an efficient and effective matching method used for ranking. The results are reported through the Princeton Shape Benchmark and the Shrec benchmarking consortium evaluated/compared by a third-party. In the two gallery sets, our approach achieves good performance and outperforms the other runs [2783].

Color perception Another aspect of the research deals with the human perception [2829, 2883]. In our work on color processing by the human visual system, we have studied the excitation of photoreceptors other than the three types of cone cells in the human eye. Besides being a visual stimulus, light entering the eye may be captured by melanopsin, a photosensitive pigment that has been recently discovered in some retinal ganglion cells. To examine the effects of light on melanopsin, we theoretically decomposed the light spectrum in two components: a fundamental color stimulus that controls the three cone responses and a metameric "black" that

has no effect on cones but can drive other receptor responses. Using seven color LEDs, we produced real metamer illuminations and could show that two lights of equal luminance may result in different pupil apertures and thus different retinal illuminance. The results have implications for understanding light effects which are not explained by trichromatic theory, and are practically relevant to the development of LED lighting and other energy-efficient lighting technologies.

14.4.3 Computer Graphics

Faculty T. Boubekeur, E. Eisemann (until 10/12), P. Memari (since 10/11), J. Tierny (since 10/10).

Highlights: Scientific Production [2724, 2815, 2780, 2715, 2822]

Highlights: Impact Eurographics Young Researcher Award (E. Eisemann), D. Bartz Prize for Visual Computing in Medicine, Honorable Mention (T. Boubekeur), Best PhD Award of Fondation Telecom (B. Buchholz), Best Paper Award at the Eurographics Symposium on Parallel Graphics and Visualization 2013 (J. Tierny), 4 (resp. 5) E.U. (resp. national) public grants.

Highlights: Interactions with Society Chaire Ubisoft/Dassault Systèmes/PSA/Orange “Modélisation des Imaginaires”, Organization of conferences (High Performance Graphics 2012, Eurographics, EGSR 2012, Visu 2012), CIFRE EDF, CIFRE Renault-PSA, EU project with Disney Research

The algorithm "Phong tessellation" is included in most 3D middleware of modern video games (Unreal engine, Cry engine), as well as in the reference GPU benchmark 3Dmark.

The research activities in computer graphics focus on geometric modeling, rendering and visualization, as well as on some graphics-related aspects of computer vision and imaging. Our expertise covers most of the computer graphics chain, from capture to synthesis of 3D shapes, appearance and motion.

Geometric Modeling In computational geometry, the group studied the large space of triangulations [3071] and their dual complexes in arbitrary dimension, showing that compatible dual complexes exist only for a particular type of triangulation which extends the well known (weighted) Delaunay/Voronoi duality. The provided geometric parameterization of this space is particularly valuable in discrete optimization problems such as optimal meshing [2780]. The group also investigated weighted triangulations as discrete, augmented approximations of surfaces [2696], and derived a discrete Laplace-Beltrami operator that preserves core properties of its continuous counterpart, with applications to circle and sphere packing problems.

In geometry processing, the group has developed several fast and scalable mesh processing operators, including a locally separable feature-preserving filtering operator [3169], a stochastic adaptive simplifier [2678] with linear time and memory complexity; a collection of real time mesh upsampling methods ranging from fast visually smooth polygon tessellation [2677, 2863] to high quality subdivision surface synthesis [2656, 3024], with view-dependent control [2924]. The group also introduced the first non-local meshless surface model [3015], which dominates local approaches in self-similar surface structure reconstruction.

In interactive geometric modeling, the group proposed several systems tackling open problems: GeoBrush [2816] for interactive 3D shape fusion; VoxMorph [2733] for interactive volume editing, with application to medical data modeling and physical simulation [2995]; an interactive quad remesher [2825] for polygonal surfaces integrating user constraints on-the-fly [2825] and an alternative approach reusing exemplar databases for generating new quadrangulations from predefined styles [2824].

In geometric analysis, the group has proposed several high level structure extraction mecanisms from raw data, including the CageR system for stable cage-based reverse engineering of animated shapes [2822] and a new parametric curve skeleton model [2821], with applications of

these structures to filtering, compression, transfer and modeling. Last, the group has developed a co-dimensional methodology exploiting 2D and 3D lines to analyze and transform 2D and 3D geometry, with application to 3D search [2724], shape learning [2758], 2D painting [2903] and freeform modeling [3134].

Rendering and Visualization In realistic rendering, the group has developed new algorithms for efficient global illumination, including ManyLoDs [2749], a fine-grained real time level-of-detail algorithm, as well as a factorized reflectance function learning method [2681]. Screen-space [3501, 2750], object-space [2801] and hybrid-space [3114] techniques have been proposed to quickly approximate complex effects such as ambient/directional occlusion, color blending, (indirect) soft shadows and deferred antialiasing

In expressive and perceptual rendering, the group has worked on the link between the geometry of the scene and its visual impact, focusing in particular on binary shading [2682], animated line drawing [2932], amortized rendering methods [3023] and stereo rendering [2975].

Optical phenomena stemming from virtual cameras model, such as depth-of-field, lens-flare and motion blur, have been studied in detail to improve realism but also to offer artistic control [2764, 2753] in a real time environment. Finally, a remote rendering system has been developed [2789].

Several projects have been conducted on the perceptual component of rendering techniques and have led to new methods offering a higher (perceived) screen resolution than the physical one [2713], and a better detail preservation [2714], as well as higher quality stereo rendering [2715].

In visualization, a new approach was proposed to explore interactively large-scale simulations based on a topology pre-analysis [2679]. Additionally, a new method for topological verification was able to illustrate the shortcomings of various realizations of isosurface-extraction methods that are publicly available [2730]. Finally, a new combinatorial approach for the general simplification of scalar fields on surfaces has been proposed [2823]. This approach improves on previous work by its simplicity, efficiency and generality.

Vision and Imaging Beyond modeling and rendering, the group also works intensively at the frontier between computer graphics and other visual computing research fields.

In computer vision, 2D [2722] and 3D [2724] visual search engines were developed, together with dedicated descriptors, benchmarks and user studies, allowing to query interactively images, videos and 3D shapes using rough line drawings. These engines are the state of the art in sketch-based search at the current time and were instrumental in developing a new visual content creation paradigm [2723, 2816] combining large data collections and interactive compositing. At the junction between 2D and 3D vision, another method has been proposed to register photos and 3D terrain models [2901], with applications to automatic geo-localisation, object recognition and to add annotations.

In imaging, a new approach for the stitching of pre-registered images for panorama creation [2815] has been proposed. This approach provides an automatic stitching algorithm that is orders of magnitude faster than previous approaches, while achieving equal, if not better, quality. Being extremely fast, this approach enables new interaction mecanisms, yielding for the first time real-time user interactions on the image seams.

14.4.4 Medical and biological imaging

Faculty E. Angelini, I. Bloch, T. Boubekeur, J. Delon, P. Memari, J. Tierny.

Highlights: Scientific Production [2659, 2660, 2744, 2773, 2790]

Highlights: Impact Honorable mention of the Dirk Bartz Prize for Visual Computing in Medicine [2697]. Launch of new International Master of Biomedical Engineering BME-Paris. Participation in Labex SMART on human body modeling. ANR (FETUS, Kidpocket, IPHOT, ReVeal),

ANSES ACTE, MINIARA. Visiting Scientist fellowship at CSIRO (Australia) and at University Columbia (USA). Collaborations with Institut Pasteur (J.C. Olivo-Marin), ISEP (F. Rossant), Columbia University (A. Laine), hospitals (Cochin - Saint Vincent de Paul, Bicêtre, Robert Debré, XV-XX, Lariboisière...).

Highlights: Interactions with Society Joint Lab with Orange Labs (WHIST). Collaborations with Siemens, Philips, General Electric, Dosisoft, Echosens, Fovea, EOS Imaging, Orange Labs (J. Wiart), CIFRE PhD theses funding.

Several softwares developed by our team are used within hospitals for clinical research (characterization of cerebral tumor evolution in IRM imaging, segmentation for oncology, quantitative analysis of retina layers in optical coherence tomography, etc.)

Our work on segmentation of normal and pathological brain structures is strongly related to our research in spatial reasoning (see Section 14.4.2), where anatomical knowledge is represented using structural formalisms, and used to guide the segmentation and recognition [2737, 2785] (PhD of G. Fouquier). These ideas have also been exploited in other medical applications. A new direction on pathologies focuses on neonatal images (PhD of B. Morel) [3078].

Analysis of longitudinal changes of brain pathologies has been an important focus of research, supported by very active collaborations with several academic and clinical sites. The project on low-grade brain tumor growth has matured [2659, 2889, 2808] and is being pursued. A new collaboration with CSIRO was launched, on the topic of longitudinal analysis of brain white matter lesions on Alzheimer patients.

Quantitative longitudinal image analysis is likely to become a major field of investigation for our group. As an example, a new collaboration with Columbia University and University of Iowa has been initiated, to work on emphysema segmentation and texture analysis, from very large longitudinal US databases of full-lung CT scans acquired on patients suffering from COPD (chronic obstructive pulmonary disease). As a first step, Markov-field segmentation has been demonstrated to be robust to very high noise level involved with varying scanning conditions and tomographic reconstruction algorithms [3019]. Such an automated segmentation solves the current issue of the current clinical paradigm based on simple thresholding of pixel intensities, to quantify emphysema evolution on heterogeneous databases of longitudinal scans. Close links are currently being built with several groups from the University Paris Descartes, specialized in human and small animal vascular and tumoral imaging for longitudinal evaluation and identification of biomarkers.

Anatomical modeling has also benefited from great activities and strong links between the medical imaging and the computer graphics teams (see Section 14.4.3). Several joint supervisions of PhD students, post-doctoral fellows and research engineers have led to the strengthening of this activity, focusing on the segmentation of obstetrical images in US and MRI [2892, 2894, 2893, 2660, 2958] (PhD of J. Anquez), and the design of dedicated modeling tools for the construction of pregnant women bodies from segmented medical images [2665, 2666, 2697], deformed in various positions for dosimetry simulations. Models of the fetus growth were also proposed, as well as an interpolation and deformation method enabling to generate fetus models at any age and in any position [3140]. In the same line, segmentation of whole body MRI children images for anatomical modeling at different ages was addressed [3002]. These works were carried out in close collaboration with Orange Labs, within the joint laboratory WHIST, for numerical dosimetry studies [3176, 3175, 3039]. A recent collaboration was initiated with the car manufacturer Renault and its research laboratory (LAB) for the co-supervision of the PhD thesis of M. Gargouri, focusing on the enrichment of numerical models of the human skeleton based on the segmentation of a large database of whole-body CT scans. An approach exploiting the random forests classifier is pursued, proposing shape-specific descriptors robust to high variability in image quality and patient positioning [3004].

Vascular imaging was also an important focus of research, with a collaboration with Siemens Corporate Research (PhD of D. Lesage) and then Philips Healthcare (PhD of G. Pizaine). Stochastic, discrete and continuous methods were investigated for the segmentation of small and large

vessels [3052, 3102, 3104], with various types of geometric constraints and various levels of supervision and training. A new direction of investigation focuses on the combination of geometric constraints and vessel tree labeling constraints. We developed a "topologically correct" segmentation method for two dimensional images of vascular network, starting with a simple geometric model which has the right topology [2658], which is then refined using a "phase field" segmentation procedure.

The long-term collaboration with Columbia University has led to the graduation of a jointly supervised PhD student working on IVUS images (PhD of A. Katouzian), for the segmentation of coronary vessels [3034, 3035, 3036, 2759, 3037] and the joint supervision of a PhD candidate (PhD of A. Lorsakul) on the quantification of myocardial strain from 3DUS images [3060]. We have also continued the work on the reformulation of deformable models with Active Surface Function [2717, 2718] for real-time segmentation performance.

A new collaboration was initiated with Echosens for the co-supervision of the PhD of S. Audière on impulsional elastography for the assessment of liver fibrosis. Novel algorithms and numerical models were developed for the FEM-based simulation of elastography experiments and the extraction of discriminant spectral parameters toward more robust estimations of liver elasticity from the RF data [4042, 3994]. A new maximum likelihood formalism was also designed to jointly estimate liver elasticity and the angle of the line of sight [3996], paving the way to new impulsional elastography acquisition setups.

A new project on liver segmentation based on models was initiated in collaboration with Philips (PhD of R. Gauriau). Extensions to multi-organ segmentation will then be addressed.

During this period, the MINIARA project on oncological applications was completed, with contributions on the segmentation of tumors and organs at risk, exploiting complementary information from PET and CT data (PhD of J. Wojak), and on the follow-up of patients, using constrained level sets approaches [3182, 3184]. Dedicated registration tools for protontherapy were also developed (PhD of J. Baussé).

In mammography, in collaboration with General Electric, we focused on the analysis of tomosynthesis images and developed original filters [2790] (see Section 14.4.1), and segmentation methods, dedicated to masses, using fuzzy approaches, and spiculated lesions, using *a contrario* approaches [2895, 3095, 3093] (PhD of G. Palma). Recently, questions related to dose assessment and risk were also addressed, based on a physical model and an estimation of the breast density [3006, 3007].

Still in X-ray imaging, a new collaboration with EOS Imaging (PhD of P. Irrera) led to new results on image denoising and enhancement on very low dose acquisitions [3031]. The developed approach relies on adaptive non-local methods, according to the different parts of the body.

Activities on nuclear imaging have been initiated with Columbia University, working on ringing artefact suppression in PET reconstruction using PSF modeling [3072].

A few years ago, a new research track was investigated in biological imaging, in collaboration with Institut Pasteur (PhD of N. Chenouard), with new results on multiple objects tracking in cluttered environment, both in 2D and in 3D [2692, 2950, 2951] (see Section 14.4.1). Regarding the activity in optical imaging, the group has launched a fruitful collaboration with Institut Pasteur and the ESPCI/Institut Langevin for the exploitation of Compressed Sensing in microscopy imaging. The Phd of M. De Moraes Marim has led to breakthrough publications introducing CS-based denoising [3063], temporal acquisition schemes and digital holography imaging [3066, 2772, 2773] for fast image sampling and efficient image reconstruction in realistic microscopy imaging setups[3]. A PhD student (Y. Le Montagner) is working on the optimization of the image reconstruction process dedicated to temporal CS microscopy imaging [3044, 3046, 3047, 3048]. A collaboration with Ecole Polytechnique, UPMC and Mines ParisTech was initiated on the 3D segmentation and analysis of collagen fibrils on multiphoton images [2657].

A close collaboration with ISEP and XV-XX hospital was launched on eye imaging, using multiple modalities. In optical coherence tomography (OCT) we proposed an original method to detect all retinal layers, using parallel deformable models, which applies in normal and patholog-

[3]This work has received a best student paper award at the conference ISBI 2010 [3066].

ical cases, and from which quantitative measures are derived, supporting the analysis of retinal structure variability and the early detection of alterations [2744] (PhD of I. Ghorbel). A recent technique based on adaptive optics was then exploited to detect photoreceptors and estimate their density [3058, 3059]. This technique is currently further explored to have a more precise estimation of the photoreceptors using multiple incidence images (PhD of C. Miloudi). Finally, eye fundus images were used for the segmentation of blood vessels and their classification into arteries and veins [2802].

A new topic was recently launched within the WHIST lab, on brain-computer interfaces (BCI), for large public applications. The first contribution concerns the detection of eye movements and blinking in EEG signals [3193], and their use as control signals for BCI tasks (PhD of Y. Yang). Optimal selection of spatial filters and of the number of electrodes has also been addressed [3192, 3191, 3194]. This activity is now moving to AAO team.

14.4.5 Remote Sensing

Faculty A. Almansa, M. Campedel, M. Datcu (until 2010), J. Delon, Y. Gousseau, H. Maître, J.-M. Nicolas, S. Rital (until 1/13), M. Roux, F. Tupin, H. Sahbi.

Highlights: Scientific Production [2804, 2731, 2812, 2704, 2770]

Highlights: Impact CNES PhD theses and research projects funding, ANR EFIDIR, REI-DGA, SWOT CNES project, Terra Numerica.
Collaborations with DLR (A. Reigber), U. Parthenope II Italy (G. Ferraioli), U. Sao Paulo Brazil (T. Perciano, M. Horta), Univ. Wuhan (H. Sun), Shanghai Jiao Tong University, CEA (R. Binet, B. Puysségur), U. UPEMLV, IGN, Télécom Saint-Etienne (L. Denis), ONERA (H. Oriot).
Awards: PhD Award in Signal, Image, Vision 2012 for C.-A. Deledalle. Best student paper at ICIP 2010 (C.-A. Deledalle, F. Tupin and L. Denis, [2965]). Antoine Ghaleb, First Price for the Student Paper Award of EUSAR 2008 (A. Ghaleb, L. Vignaud and J. M. Nicolas, [3008]).

Highlights: Interactions with Society CEA-Recalage, Magellium, CIFRE Thales, CIFRE EADS.

Remote Sensing stays an important application field of the group with different sensors (optical images, SAR, SMOS, lidar data, ...) and different applications (denoising and artefacts removal, 3D reconstruction, segmentation and classification, change detection, image visualization and navigation, ...).

3D point clouds and lidar data As long as 3D model generation from multiple images is concerned, our focus is in the construction of a low cost system allowing non-specialists to make 3D measurements with a minimal set of constraints on the image acquisition [3252]. The concerned applications are related to surface roughness and dendrometric parameter measurements (PhD of B. Petitpas with UPMLV).

In a study devoted to the analysis of full-waveform lidar data for automatic classification either for urban areas or for littoral scenes, the contribution of radiometric calibration features to obtain a high accuracy was demonstrated [2771, 2770] (PhD with MATIS, IGN).

For automatic plane detection from point clouds, a-contrario based techniques showed a great efficiency [3218, 2933], while in cases where 3D point-clouds are noisy or at low-resolution, non-local methods proved more effective [3015].

New investigations are presently undertaken towards the generation of underwater 3D models with Unmanned Underwater Vehicle (UUV) (PhD of L. Avanthey with ESIEA, DGA funding).

Stereovision In stereovision, our research within the MISS project focused on the feasibility of the $\frac{1}{10^{th}}$ to $\frac{1}{100^{th}}$-pixel accurate disparity maps, required for sub-meter-accurate digital elevation models in urban areas from high-resolution low-baseline stereoscopy as provided by Pleiades,

and future CNES missions. We showed that such accuracy requirements are close to information-theoretic bounds [2803], and that they can be met at about 50% of the pixels, once unreliable areas have been automatically rejected by a statistical criterion [2804]. The software that implements this technique was found to greatly improve the accuracy of state-of-the-art software used at CNES and IGN [3122]. It also was a key element that allowed our colleagues at IMAGINE (ENPC) to win the PRoVisG Mars 3D Challenge. Such accuracy levels are only possible if satellite microvibrations are first estimated (PhD of J. Caron) and the resulting irregular samples restored to produce an image on a regular grid. This is an ill-posed inverse problem requiring advanced variational techniques [2731]. In the process, a precise knowledge of the sub-pixel blur kernel is required. A new calibration pattern makes this estimation problem possible from a single image [2698, 2699, 2700].

SMOS data (Soil Moisture and Ocean Samlinity) RFI (Radio Frequencies Interferences) outlying artifacts in **SMOS** images made numerous single snapshots from this earth observation mission completely useless. Our study [3107] shows that automatic detection and removal of such artifacts is possible with high accuracy. The technique combines an accurate image formation model, with TV-L^0-L^2 minimization (similar to the celebrated geometry-texture decomposition) in order to separate actual image information from outlier artifacts and sensor noise.

SAR imagery • At the signal level, works on the statistical modeling of SAR images based on Mellin transform have been completed with the introduction of Meijer distributions which allow the definition of a unifying framework. All usual SAR distributions can be seen as Meijer distributions, and this new formalism is a powerful tool to model geometric, harmonic or arithmetic means.

• We demonstrated the efficiency of non-local means (NLM) for denoising, when properly extended to a probabilistic framework both for amplitude images [2701], or interferometric / polarimetric data [2702] [2704] (PhD of C. Deledalle, see also Section 14.4.1). We extended NLM to multi-temporal series denoising (PhD of X. Su). To solve the “rare patch effect” and for classification purpose, approches based on invariant dictionaries are now being investigated (PhD of S. Tabti). A Markovian formalism and different estimators with adapted optimization approaches define an elegant context for the fusion of multi-channel interferometric data [2736, 2811, 2810, 2812] (PhD of A. Shabou, REI project).

• For pattern recognition and image interpretation, many efforts have been dedicated to the fusion of SAR and optical images (PhD of G. Lehureau, and H. Sportouche) with SVM methods or with explicit object detection and likelihood optimization [2814]. SAR descriptors, adapted to SAR data statistics, have also been defined to propose efficient registration schemes (PhD of F. Dellinger). Network extraction is still an important problem. We adopt Markovian approaches to detect rivers with SWOT images in a CNES project and for road detection in a multi-temporal and multi-sensor framework (PhD of T. Perciano).

• Important efforts have been devoted to multi-temporal series analysis since a new generation of SAR sensors (2 Terrasar-X, 4 CosmoSkymed), with metric resolution images and a short repeat time, has raised new issues. Thanks to different projects (ANR Efidir, DLR or ASI projects), many multi-temporal datasets have been acquired. Novel registration approaches with sub-pixel accuracy have been developed and novel change detection methods, based on statistics, have been proposed. (PhD of G. Quin in collaboration with CEA). They have been used for glacier monitoring (ANR EFIDIR) with adapted similarity criteria [2732] (PhD of R. Fallourd). Man-made corner reflectors have also been positioned on Argentiere glacier to serve as ground truth and help understanding the backscattering mechanisms of metric resolution images. In the PhD of G. Hochard, the analysis of long temporal series on the Serre-Ponçon dam has led to a selection method for interferograms which could also be applied for change detection.

In collaboration with ONERA, the detection of moving target in circular imagery has been investigated (PhD of J.-B. Poisson).

Aerial video change detection The detection of significant changes in aerial videos is an interesting problem for various applications. This task is also challenging in many aspects; on the one hand, it is tedious when performed by human operators and on the other hand, most of the existing automatic solutions suffer from the variability related to irrelevant changes (parallax effects due to camera motion, changes in illumination, etc.). In this work, we address these issues and we introduce novel solutions that make change detection resilient to irrelevant changes while being effective for relevant ones. More precisely, our change detection approach processes videos to recover camera parameters and to build robust appearance models, and it also exploits the redundancy in videos in order to further enhance the performances (PhD of N. Bourdis with EADS).

Satellite image visualization and navigation Most of satellite image search engines are based on existing meta-data or precomputed visual indices, and rely on ad-hoc functionalities such as zooming and panoramic navigation. When using large and complex images, provided by high resolution satellite sensors, these basic functionalities become helpless in order to efficiently explore these images. In Vo Dinh Phong' PhD, we address this issue and introduce a new image database visualization and navigation method that relies on learning a mapping from an initial ambient space (related to low level visual features) to an output space spanned by a well defined semantic basis (where data can be easily explored by the user). With this method, searching for a visual target reduces to scanning data according to their coordinates in the learned semantic space.

Joint CNES-DLR-Télécom ParisTech Competence Center (CoC) CoC was created in June 2005, and ended in June 2010. Its activities were focused on information extraction and satellite image understanding for optical images. Numerous PhD theses have been defended since 2009 on a high variety of subjects going from low level image description [2667], classification [2766] to (semi-) supervised active learning tools [2668] and knowledge representation [3262].

Even if this project is now finished, strong collaborations with CNES[4] were maintained on specific applicative projects, from 2008 to 2011, in the context of rapid mapping (EXITER project, SAFER European project and KAL-Haïti ANR). Close relationships with expert interpreters from SERTIT[5] were also developed to better promote the competence center results related to the quick production of relevant land cover maps. SERTIT and CNES provided us with rich datasets to precisely evaluate information extraction and classification tools and also to derive new products (as processing softwares) to be used by interpreters, in the context of different disasters (earthquake, flooding and forest fire). As a consequence scientific and applicative evaluations were performed exploiting platforms like KEO (ESA platform) as well as public tools like OTB (Orfeo Toolbox[6]) and GIS (Geographical Information System). Simultaneously to such engineering works, methodological ones were conducted based on consensual clustering [2934] and hypergraph representation [2929, 2680].

[4] http://www.cnes.fr
[5] http://sertit.u-strasbg.fr/
[6] http://orfeo-toolbox.org/otb/

14.5 Achievements

14.5.1 Scientific Productions

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Invited Talks

[3199] E. Angelini. 10 open challenges for medical image processors. In *2nd Workshop US-Turkey advanced meeting on Global Healthcare Challenges and Opportunities*, Antalya, Turkey, 2011.
[3200] E. Angelini. Designing fast and robust algorithms for medical image processing. In *Annual Workshop "Large Data Sets in Medical Informatics"*, Institute for Mathematics and Its Applications (IMA), University of Minnesota, USA, 2011.
[3201] I. Bloch. Morphologie mathématique floue, applications en raisonnement spatial et en logique. In *LFA 2008*, pages 2–9, Lens, France, 2008.
[3202] I. Bloch. Fuzzy and Bipolar Mathematical Morphology, Applications in Spatial Reasoning. In *Symbolic and Quantitative Approaches to Reasoning with Uncertainty ECSQARU*, volume LNAI 5590, pages 1–13, Verona, Italy, 2009.
[3203] I. Bloch. Mathematical morphology, lattices, and formal concept analysis. In *8th International Conference on Concept Lattices and Their Applications (CLA 2011) - Invited conference*, page 1, Nancy, France, Oct. 2011.
[3204] I. Bloch. Structural models and spatial reasoning - Application to segmentation and recognition of anatomical structures in medical images. In *International Conference on MEDICAL IMAGING using BIO-INSPIRED and SOFT COMPUTING (MIBISOC) (Invited Conference)*, page 1, Brussels, Belgium, May 2013.

14.5.2 Public Fundings

Period	Project details	Funding	Principal investigator
2008-2012	EFIDIR - Displacement measurement through radar imaging	ANR	J.-M. Nicolas
2008-2012	CMCU - Radar differential interferometry using minimal cutson image series	UTIQUE	F. Tupin
2008-2009	SOFIA	CNES	M. Datcu
2008-2008	TEMPO SAR	OSEO	F. Tupin
2008-2009	Knowledge representation and platform development	CNES	M. Campedel
2008-2008	Segmentation	CNES	H. Maître
2008-2011	REI - Multi-objects tracking	DGA	I. Bloch
2009-2013	MATAIM - Anisotropic texture modeling	ANR	Y. Gousseau
2009-2013	CALLISTO - Calibration procedures for multi-image stereo	ANR	Y. Gousseau
2009-2010	REI - Radar image regularization using minimal cuts	DGA	F. Tupin
2009-2010	CELUM - Turbulence analysis in under-water acoustics	DGA	J.-M. Nicolas
2009-2009	ICS - Satellite image classification	CNES	M. Campedel
2009-2009	SAFER - Fast cartography for natural disaster monitoring	CNES	M. Campedel
2009-2009	Compressed images	CNES	M. Datcu
2009-2013	MEDIAGPU - Parallel algorithms for real-time rendering on GPU	ANR	T. Boubekeur
2009-2011	IPHOT - Clinical imaging of photoreceptors	ANR	I. Bloch
2009-2011	KIDPOCKET - 3D modeling and deformations for analyzing the exposure of children to magnetic vawes	ANR	I. Bloch
2010-2010	SIFTI	CNES	A. Almansa
2010-2011	SWOT - River extraction for the future SWOT sensor	CNES	F. Tupin
2010-2011	TICA	CNES	M. Datcu
2010-2012	Venise - Satellite image visualization and exploration	CNES	H. Sahbi
2010-2012	SAFER - Fast cartography for natural disaster monitoring	CNES	M. Campedel
2010-2012	Hyper-graphs	CNES	S. Rital
2010-2013	VISUNET - Object tracking in multimedia sensor networks	Digiteo	H. Sahbi
2010-2013	FETUS - Modeling and deformation for fetus and pregnant woman exposure evaluation to telecom new wireless usages and systems	ANR	I. Bloch
2010-2013	MLVIS - Machine learning for visual annotation in social media	ANR	H. Sahbi
2010-2013	RELIR - Multi-relational machine learning for image retrieval and annotation in large social sharing media	Digiteo	H. Sahbi
2010-2013	CEDCA - Embedded correction systems for camera defaults	FUI 9	Y. Gousseau
2010-	3DLife - Real-time modeling and rendering	Europe	T. Boubekeur for TII

2011-2013	Registration of Terrasar X images	CEA	J.-M. Nicolas
2011-2014	SPACE&TIME - Rendering of urban data	ANR	T. Boubekeur
2011-2014	REVERIE - Capture, transmission and interactive rendering	Europe	T. Boubekeur for TII
2011-2011	Image information	DLR	M. Datcu
2012-2016	LOGIMA - Logic, structural representation, mathematical morphology and uncertainty for semantic interpretation of images and videos	ANR	I. Bloch
2012-2013	Benchmark for artifact detection	CNES	M. Campedel
2012-2013	ACTE - Analysis and characterization of very young children exposure to telecommunication systems	ANSES - FT	I. Bloch
2013-2013	Num2Phy - Pedagogical innovation	IMT	M. Campedel, J.M. Nicolas
2013-2015	REVEAL - High resolution imaging of retinian vessels	ANR	I. Bloch
2013-2015	DESCRIBE - Online detection of visual events in videos	ANR	I. Bloch
2013-2015	UnTopoVis - Visualization of uncertain scalar data	FCS Campus Paris Saclay	J. Tierny

Total funding 3 567 k€

14.5.3 Private Fundings

Period	Project details	Funding	Principal investigator
2009-2012	OCT retina imaging	FOVEA CIFRE	I. Bloch
2009-2010	Risk measures for decision under uncertainty	Thales	I. Bloch
2009-2012	Vascular imaging	Philips CIFRE	I. Bloch
2009-2012	Parallel geometric processing	EDF CIFRE	T. Boubekeur
2009-2010	Segmentation and modeling of children body	Orange	I. Bloch
2010-2011	Parametrization of animated lines	Adobe	T. Boubekeur
2010-	Imaginaires Chair - 3D shape and universe modeling	Ubisoft, DS, Orange, PSA, Alcatel Lucent	T. Boubekeur for TII
2010-2011	Ingrid - Transfer of image processing tools in the DGA platform	Magellium	F. Tupin
2010-2011	Brain-Computer Interfaces	Orange	I. Bloch
2010-2014	Segmentation and modeling of soft tissues and bones	Orange	I. Bloch
2010-2013	Content-based colour management for print	Oce CIFRE	H. Brettel
2010-2013	Pose and shape estimation in face videos	Morpho CIFRE	I. Bloch
2010-2013	Aerial image change detection	EADS CIFRE	H. Sahbi
2011-2013	Degraded films restoration and video inpainting	Technicolor - CIFRE	Y. Gousseau
2011-2013		Usefull Progress CIFRE	E. Eisemann
2011-2014	Mammography and dose estimation	GE CIFRE	I. Bloch
2011-2014	Lip-reading and visual speech recognition	Parrot CIFRE	H. Sahbi
2011-2015	Modeling of skeleton from medical images	Renault CIFRE	E. Angelini
2012-2013	BCI	Orange	I. Bloch
2012-2015		Morpho CIFRE	A. Almansa
2012-2015	Multi-organ segmentation	Philips CIFRE	I. Bloch
2012-2015	Low-dose X-ray imaging	EOS Imaging CIFRE	I. Bloch
2012-2013	Information fusion for surfaces extraction	CSSI	F. Tupin
2012-2015	Optimization of print quality with multi-channel printing	Oce CIFRE	H. Brettel
2013-2013	Acquisition of ORV for geological survey of India - Expertise for testing sonar IXBLUE	Wartsila	J.-M. Nicolas

Total funding 995 k€

14.6 PhDs

14.6.1 Defended PhDs

[3205] E. Aldea. *Apprentissage de données structuées pour l'interprétation d'images*. PhD thesis, Télécom ParisTech, Jan. 2009.

[3206] J. Anquez. *Modélisation de la femme enceinte à partir d'images 3D ultrasonores et IRM anténatales, pour l'étude de la dosimétrie*. PhD thesis, Télécom ParisTech, 2009.

[3207] S. Audiere. *Traitement du Signal et Simulations pour l'Elastographie Impulsionnelle*. PhD thesis, Télécom ParisTech, Dec. 2011.

[3208] A. Baillard. *Détermination automatique des paramètres morphologiques des galaxies*. PhD thesis, Ecole Nationale Supérieure des Télécommunications, Dec. 2008.

[3209] J. Baussé. *Recalage et planification du traitement en radiothérapie et protonthérapie*. PhD thesis, Télécom ParisTech, Oct. 2010.
[3210] P. Birjandi. *Modelling, Extraction and Description of Intrinsic Cues of High Resolution Satellite Images: Independent Component Analysis based approaches*. PhD thesis, Télécom ParisTech, Sept. 2011.
[3211] P. Blanchart. *Fast learning methods adapted to the user specificities: application to earth observation image information mining*. PhD thesis, Télécom ParisTech, Sept. 2011.
[3212] N. Bonnier. *Contribution aux algorithmes de mise en correspondance de gammes de couleurs spatialement adaptatifs*. PhD thesis, Eco, Sept. 2008.
[3213] J. B. Bordes. *Inférence de connaissances sémantiques : application aux images satellitaires*. PhD thesis, Ecole Nationale Supérieure des Télécommunications, Apr. 2009.
[3214] M. Bouali. *Destriping data from multidetector imaging spectrometers: a study on the MODIS instrument*. PhD thesis, Télécom ParisTech, June 2011.
[3215] N. Bourdis. *Détection de changements entre vidéos aériennes avec trajectoires arbitraires*. PhD thesis, Telecom ParisTech, May 2013.
[3216] M. Brédif. *Modélisation 3D de bâtiments : reconstruction automatique de superstructures de toits et recalage cinétique de toits polyédriques prenant en compte la topologie*. PhD thesis, Télécom ParisTech, May 2010.
[3217] B. Buchholz. *Abstraction and processing of animated 3D data*. PhD thesis, Télécom ParisTech, Dec. 2012.
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[3263] G. Vialaneix. *Algorithmes parallèles de manipulation de maillages*. PhD thesis, Télécom ParisTech, Nov. 2012.
[3264] N. Widynski. *Intégration d'informations spatiales floues dans un filtre particulaire pour le suivi mono- et multi-objets dans des séquences d'images 2D*. PhD thesis, UPMC, Nov. 2010.
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14.6.2 Ongoing PhDs

- Cecilia Aguerrebere (04/11–), *Restauration multi-images. Création d'images à grande plage dynamique*.
- Emilie Au (depuis décembre 2011, avec le LIP6) Machines d'annotation dans les bases d'images relationnelles.
- Loica Avanthey (depuis octobre 2012, avec l'ESIA) Mosaiquage de données 3D obtenues par des drones hétérogènes à l'interface air/eau.
- Teun Baar (depuis octobre 2012) Optimisation de la qualité d'impression multi-canaux.
- Eric Benhaim (depuis octobre 2011, CIFRE avec Parrot) Analyse visuelle et fusion pour la reconnaissance de la parole.
- Stéphane Calderon (depuis novembre 2011) Capture et modélisation 3D dynamique.
- Isabelle Cléry (depuis février 2012, avec l'IGN) Valorisation géométrique et radiométrique d'un patrimoine de photographies anciennes scannées.
- Antoine Deblonde (depuis avril 2012, avec Morpho) Mise en correspondance et recherche d'empreintes digitales.
- Flora Dellinger (depuis octobre 2010, avec le CNES) Représentation des informations et détection de changements sur des images de télédétection de haute résolution hétérogènes.
- Kristyn Falkenstern (depuis février 2010) Rendu des images imprimées.
- Mariem Gargouri (depuis octobre 2011, avec Renault) Caractérisation des usagers de la route par imagerie.
- Romane Gauriau (depuis juin 2012, CIFRE avec Philips) Segmentation et mise en correspondance de structures anatomiques en imagerie médicale 3D, application aux problématiques inter- et intra-patient, multi-modalité et multi-structures.
- Nausikaa Geeraert (depuis septembre 2011, avec KUL, CIFRE avec GE) Evaluation quantitative de la densité et de la structure fibroglandulaire en mammographie numérique et application à la stratification du risque et à la dosimétrie.
- Thierry Guillemot (depuis octobre 2010) Nuage de courbes : géométrie numérique par la vision.
- Emilie Guy (depuis octobre 2012) Structure de Contrôle de Formes Automatique.
- Catherine Herold (depuis décembre 2010, avec Morpho) Estimation et filtrage temporel de la forme 3D des visages.
- Paolo Irrera (depuis juillet 2012, CIFRE avec EOS Imaging) Traitement d'images de radiographie à faible dose.
- Quoc Ang Le (depuis octobre 2009, ANR GV-Lex) 3D Expressive Gesture Models.

- Yoann Le Montagner (depuis octobre 2010, avec l'Institut Pasteur) Prototypage d'un système d'acquisition de microscopie avec schémas d'acquisition parcimonieuse dans le domaine de Fourier pour l'imagerie optique biologique à très haut débit d'information.
- Baptiste Mazin (depuis septembre 2010) Invariances colorimétriques et radiométriques pour la comparaison d'images.
- Jean-Christophe Michelin (depuis décembre 2011, avec l'IGN-MATIS) Qualification automatique de bases de données 3D de bâtiments.
- Chahira Miloudi (depuis septembre 2012, avec l'ISEP et l'hôpital des XV-XX) Analyse d'images de la rétine en optique adaptative et tomographie de cohérence optique.
- Baptiste Morel (depuis décembre 2012, avec l'hôpital du Kremlin-Bicêtre) Analyse quantitative de pathologies cérébrales en IRM.
- Alasdair Newson (depuis septembre 2010, avec Technicolor) Restauration de défauts persistants dans les films et inpainting spatio-temporel.
- Guillaume Pizaine (depuis juin 2009, avec Philips) Segmentation de vaisseaux sanguins et détection de pathologies.
- Jean-Baptiste Poisson (depuis octobre 2010, avec l'ONERA) Imagerie SAR circulaire.
- Javier Preciozzi (doctorant à l'etranger UdelaR) Restauration d'images satellitaires.
- Guillaume Quin (depuis septembre 2010, avec le CEA).
- Avid Roman Gonzalez (depuis septembre 2009) Détection d'éléments structurés en imagerie satellitaire.
- Leila Schemali (depuis janvier 2011, avec Useful Progress) Visualisation de gros volumes de données et rendu.
- Xin Su (depuis novembre 2011) Exploitation de séries satellitaires multi-temporelles.
- Sonia Tabti (depuis octobre 2012) Nouveaux modèles d'images pour la restauration, la compréhension et la détection de changements en imagerie radar.
- Guillaume Tartavel (depuis octobre 2011) Modélisation parcimonieuse des textures.
- Jean-Marc Thiery (depuis octobre 2009) Géométrie Numérique et Géométrie Algorithmique pour le Design 3D Interactif.
- Yann Traonmilin (depuis juillet 2011) Comparaison entre modèle d'image et supplément d'information pour la super-résolution.
- Guillaume Vialaneix (depuis décembre 2009, avec EDF) Algorithmes parallèles de manipulation de maillages.
- Ujjwal Verma (depuis octobre 2010, avec l'ISEP) Traitement et classification de signaux multimedia et d'images multi-temporelles.
- Phong Vo (depuis octobre 2010) Visualisation et navigation dans les bases d'images par apprentissage des variétés.
- Bebei Wang (depuis octobre 2012, avec l'université de Shondong, Chine) Illumination globale sur des ressources hybrides.
- Ling Wang (depuis janvier 2012) Graphes appliqués aux réseaux sociaux et à la vidéo.
- Yuan Yang (depuis octobre 2010, avec Orange Labs) Interfaces homme-cerveau pour des applications grand public.
- Fei Yuan (depuis septembre 2010, avec l'Académie des Sciences de Chine) Méthodes à base de graphes pour la recherche dans les bases d'images et les séquences vidéo.

Chapter 15

Multimedia (MM)

15.1 Executive Summary

Team Leader Béatrice Pesquet-Popescu

Initial Staff 5 Professors; 2 Research Scientists; 8 Engineers; 10 Postdocs; 25 PhD Students.

Staff who Left 2 Permanent Staff (103 months); 13 PhD Students (403 months) ; 17 Postdocs (213 months).

Staff who Were Hired

- Marco Cagnazzo – Télécom ParisTech – previously post-doc at l'Univ. Nice Sophia-Antipolis
- Catherine Pelachaud – CNRS – previously professor at l'Univ. Paris 8
- Frédéric Dufaux – CNRS – previously research scientist at l'EPFL
- Giuseppe Valenzise – CNRS – previously post-doc at Télécom ParisTech
- Chloé Clavel – Télécom ParisTech – previously research ingineer at l'EDF

Scientific Highlights

- F. Dufaux, B. Pesquet, M. Cagnazzo Editors, Emerging technologies for 3D video: content creation, coding, transmission and rendering, Wiley Eds., May 2013
- D. Petrovska, G. Chollet et B. Dorizzi, Guide to Biometric Reference Systems and Performance Evaluation, Springer, 2009, series on Computer Imaging, Vision, PR and Graphics
- GRETA is a real-time platform of an embodied conversational agent,endowed with socio-emotional capabilities, able to communicate verbally and nonverbally with users.
- GPAC is the leading open source software in the academic world for the encoding, the delivery and the playback of multimedia content, ranging from simple audio/video presentations to complex interactive multimedia services.
- F. Temmermans, F. Dufaux and P. Schelkens, JPSearch: Metadata Interoperability During Image Exchange, IEEE Signal Processing Magazine, vol. 29, no. 5, pp. 134-139, Sept. 2012

Scientific Production 80 Journals; 9 Books; 28 Book chapters; 270 Articles in Proceedings; 10 Invited talks; 146 standardization contributions

Major Publications

- A-L Bianne, F. Menasri, C. Mokbel, R. Al-Hajj, C. Kermorvant, L. Likforman-Sulem, Dynamic and Contextual Information in HMM Modeling for Handwritten Word Recognition, IEEE PAMI, 2011, Vol. 33, no 10
- A. Fraysse, B. Pesquet, J.-C. Pesquet, On the Uniform Quantization of a Class of Sparse Sources, IEEE Trans. on Information Theory, vol.55, issue 7, July 2009, pp. 3243-3263
- C. Pelachaud, Modelling Multimodal Expression of Emotion in a Virtual Agent, Philosophical Transactions of Royal Society B Biological Science, B 2009, vol. 364, 3539-3548
- L. Zouari et G. Chollet, Efficient codebook for fast and accurate low resource ASR systems, Speech Communication, Mar. 2009
- A. Abou-Elailah, F. Dufaux, J. Farah, M. Cagnazzo, and B. Pesquet-Popescu, Fusion of Global and Local Motion Estimation for Distributed Video Coding, IEEE Trans. on Circ. Syst. for Video Tech., vol. 23, no. 1, pp. 158-172, Jan. 2013

Major Documents

- C. Pelachaud, T. Boubekeur, Guest Editors, special issue, Digital Human Faces: From Creation to Emotion, IEEE Computer Graphics and Applications, 2010
- Corpus of ancient printed characters: L. Likforman and M. Sigelle, Recognition of degraded characters using dynamic Bayesian networks, Pattern Recognition, Vol. 41, 3092-3103, 2008 (http://perso.telecom-paristech.fr/lauli/ENST_ANCIENT_CHAR/).
- Co-Chairs and Co-Editors of the following standards: ISO/IEC MPEG-U, W3C EmotionML, ISO/IEC JPSearch, ISO/IEC JPEG2000 Wireless
- F. Dufaux, Guest Co-Editor of the Special Issue: "Intelligent Video Surveillance for Public Security and Personal Privacy", IEEE Trans. on Inf. Forensics and Security, 2013
- B. Pesquet, Guest Co-Editor of the IEEE Transactions on Circuits and Systems for Video Technology, special issue on " Emerging Research and Standards in Next Generation Video Coding (HEVC)", Dec. 2012

Impact and Attractivity

- C. Pelachaud - invited presentation at Royal Academy, Computation of Emotions in Man and Machines, London, April 2009
  (http://royalsociety.org/events/2009/computation-emotions/)
- F. Dufaux is Editor in Chief of Elsevier Image Communication since 2010, B. Pesquet is member of the Signal Processing Magazine editorial team since 2012
- B. Pesquet elected 2013 Fellow IEEE (youngest woman IEEE Fellow in France)
- B. Pesquet was General Co-Chairs of EUSIPCO2012 (750 participants)
- B. Pesquet was secretary of the Executive Subcommittee of the IEEE Signal Processing Society Conference Board and is member of the IEEE SPS Awards Board

Interaction with Economic and Social Spheres

- J. Lefeuvre and C. Concolato pioneered a Digital and Visual Radio receiver (Diabolo, in parternship with a French SME): appearing on the front cover of a national general public science magazine; and demonstrated during the 2010 International Paris Motor Show
- L. Likforman in collaboration with A2iA won the first place among corporations in Arabic and French handwriting recognition competition
- J. LeFeuvre and C. Concolato have a collaboration with Samsung since 2008
- B. Pesquet is Scientific Director of the UBIMEDIA common laboratory with Alcatel-Bell Labs
- B. Pesquet was cited in Apr. 2012 by Usine Nouvelle among the "100 who matter in the digital world" in France

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Contributions to Higher Education

- J.-C. Moissinac is responsible for the Master CPM, in collaboration with INA
- L. Likforman and B. Pesquet are responsible resp. for the "parcours" AFA and SAMVA; coordination of the teaching modules SI221, SI222, MDI343, SI350, SI380
- More than 20 modules of continuous education in the field of multimedia
- Responsible for the training module dedicated to "classes prépas" professors, LIESSE 2013, on new challenges in video

- 2 chapters in the E-Reference book on Signal Processing, Elsevier, 2013
- 9 ISO Certificates of Appreciation for standards editing
- 146 documents of contribution to standardization
- 3 presentations in GDR workshops

15.2 People

Team leader Béatrice Pesquet-Popescu (FP).

Faculty M. Cagnazzo (AP, 02/08 –), C. Clavel (AP, 02/13 –), C. Concolato (AP), J. Lefeuvre (AP), L. Likforman (AP), J.-C. Moissinac (AP), M. Sigelle (AP), G. Chollet (SRS, – 07/12, then Emeritous SRS); F. Dufaux (SRS, 10/10 –), C. Faure (JRS, –02/12), C. Pelachaud (SRS, 10/08 –), G. Valenzise (JRS, 10/12 –).

PhD students M. Abid (05/09 – 10/12), A.B. Abou El Ailah (12/09 – 12/12), A-L Bianne (09/08 – 11/11), M. Bendris (10/08–07/11), R. Bouazizi (11/12 –), N. Bouzakaria (12/12 –), M. Calemne (11/13 –), G. Chierchia (10/11 –), M. Chollet (11/11 –), M. Decombas (10/10 –), Y. DING (01/11 –), A. Fiengo (11/13 –), N. Fourati (11/11 –), R. Galvao de Oliveira (01/09–09/12), N. Glas (01/13 –), C. Greco (10/08–06/12), V. Gros (03/12 –), M. Kaaniche (10/08–12/10), Huang (10/09 – 02/13), S.J. Hyniewska (01/09 – 03/13), H. Khemiri (09/10 –), P. Lauga (11/11 –), Q.A. Le (10/08 – 06/13), M. Meddeb (11/13 –), H. Medina (11/10 –), P. Milhorat (04/12 –), E. G. Mora (11/10 –), O. Morillot (10/11–), I. Nemoianu (11/09 – 06/13), C. Oprean (10/11 –), F. Pecune (12/12 –), G. Petrazzuoli (11/09 – 01/13), P. Perrot (–12/10), B. Ravenet (03/12 –), B. Rodriguez (02/09–02/13), M. Sarkis (04/13 –), Y. Xing (01/12 –).

Post-docs, engineers and sabbaticals V. Atanasiu (08/10–04/11), R. Chiang (08/12–01/13), M. Kieffer (09/09–), M. Trocan (10/11 –), R. Bouqueau (06/09–05/12), L. Daud (01/10 – 12/11), F. de Simone (11/12 –), J. Deslis (09/12 –), J.C. Dufourd (10/11 –), J. Feldmar (12/11 – 12/12), R. Gaetano (09/10 – 05/13), J. Gorin (01/13 –), C. Greco (07/12 –), M. Kaaniche (12/10 – 10/11), A. KOZ (10/11 –), C.K. Nguyen (01/11–12/11), V. Nguyen (05/12 – 04/13), X.H. Nguyen (05/12-03/13), R. Niewiadomski (10/08 – 04/13), M. Ochs (09/09 –), S. Pammi (01/12–02/13), A.M. Pez (11/08–), P. Philippe (01/11–12/11), K. Prepin (11/08–), B. Rodriguez (03/12 – 03/13), S. Schlögl (12/12 –), S. Selle (01/10 – 11/11), A. Shafiei (10/12 –), A. Sharma (04/12 – 03/13), J. Sillan (01/09 –12/10), S. Thomas (01/10 – 12/11).

15.3 Overview

The Multimedia team research activity concerns all the life cycle of multimedia documents and signals: acquisition, coding, transmission, transport, interactivity.

In particular, the team has an intense activity in image and video compression, producing a very consistent track of publications in the major international journal and conferences. In the 2008-2013 period, the team has continued its work on “classical” video coding, a field that has witnessed an uninterrupted activity by the research community, as testified by the deployment of a new video compression standard in January 2013. At the same time, we have been working on compression for emerging formats, frameworks and applications. In particular, we considered the compression of multi-view video and multi-view plus depth video (a format that is particularly suitable for new services as free-viewpoint television), and the processing and compression of high dynamic range video and images. We have had a very intense activity on the emerging framework of distributed video coding, which is particularly attractive for low-complexity applications, sensor networks, robust transmission. Alternative approaches for robust video streaming have been considered, such as multiple description coding, network coding, and their combinations. We have also been active in content-aware video streaming over wired and wireless network, developing robust transmission protocols that take into account the characteristics of compressed video. Within the Multimedia team, research focuses also on various multimodal contents. In particular, the team has developed several HMM-based (Hidden Markov Models) approaches for handwriting recognition looking at word and text-line recognition. Particular attention was given to the restoration of ancient documents. A new approach resulting from the combination of Total Variation and Non Local Means has been proposed. Lately, not only written document but also web pages became a subject of study. Models to decompose web pages

into functional blocks were proposed in view of adapting web pages to small screens and mobile phones. Another important research line of the team regards speech where we studied speech recognition and synthesis, but also silent speech, audio-visual speech analysis, and lately face tracking and spoken dialog system. The latest topic was also approached from the perspective of the development of socio-emotional embodied conversational agents. The platform of the virtual agent Greta was integrated within an interactive system allowing users to dialog with the agents. The behaviors of the agent were further developed to encompass a large set of emotional and social signals such as blend of emotions, different smiles, or even laughter. These researches gave rise to various working systems that are continuously extended as new research questions are tackled. These studies are conducted collaboratively, within several European and National projects. The Multimedia team has been involved in many research projects, both national and international. The excellence of the team scientific production is testified by the several awards received, both for single papers (MMSP Top 10% award, “High quality paper” reocgnition by the review IEEE MMTC-R Letter for one of our articles [3293]) and for personal achievements (B. Pesquet-Popescu has received the IEEE fellowship elevation, F. Dufaux is editor in chief for the Elsevier *Signal Processing: Image communication* journal, other teams members are associate editors for several reknown journals). This has allowed us to keep a high level of attractivity for the team, as witnessed by the recruitement of internationally recognized researchers (F. Dufaux, C. Pelachaud).

The team has also an intense activity in scientific conference organization. In particular, the team members have been involved in the organizations of the following conferences. IEEE MMSP 2010 (150 participants): general co-chair, electronic media chair; EUSIPCO 2012 (750 participants): general co-chair, publicity chair;; IEEE ICIP 2014: general chair and vice-chair, several other key positions (around 1300 participants expected); IEEE ICM22012: panel co-chair (2400 participants); EUSIPCO2011 : tutorial co-chair (650 participants); IEEE ICIP2011: awards co-chair (1100 participants); IEEE VCIP2010 : tutorial and panel co-chair (450 participants); EUVIP2013 : technical chair (200 participants); AAMAS 2013 (Virtual agents track chair; around 700 participants); IVA 2013 (general co-chair; around 120 participants); ACII 2013 (general co-chair; around 150 participants); AAMAS 2012 (Tutorial co-chair; 700 participants); AAMAS 2010 (Demo co-chair; 700 participants); ACII 2009 (Doctorial consortium co-chair; around 150 participants).

15.3.1 Robust Compression and Transmission of Visual Data

Faculty B. Pesquet-Popescu, F. Dufaux, M. Cagnazzo, G. Valenzise

Highlights: Scientific Production 1) J. Garbas, B. Pesquet-Popescu, and A. Kaup. Methods and tools for wavelet-based scalable multiview video coding. IEEE Trans.on Circ. and Syst. for Video Tech., Feb. 2011.

2) M. Kaaniche, A. Benazza-Benyahia, B. Pesquet-Popescu, and J.-C. Pesquet. Vector lifting schemes for stereo image coding. IEEE Trans. on Image Proc., Nov. 2009.

3) C. Greco, M. Cagnazzo, and B. Pesquet-Popescu. Low-latency video streaming with congestion control in mobile ad-hoc networks. IEEE Trans. Multimedia, Aug. 2012. Selected as “High quality paper” by the review IEEE MMTC-R Letter, Jan. 2013.

4) G. Valenzise, M. Tagliasacchi, and S. Tubaro. Revealing the traces of JPEG compression anti-forensics. IEEE Trans. on Inform. Forensics and Sec., Feb. 2013.

5) M. Agostini, M. Cagnazzo, *et al*. A new coding mode for hybrid video coders based on quantized motion vectors. IEEE Trans. Circ. Systems Video Tech., July 2011.

Highlights: Impact 1) Organization of conferences such as IEEE MMSP 2010 (General Co-Chair), IEEE ICIP2014 (General Chair, Vice General Chair), Euvip2013 (Technical Chair), 3DRPC IG within ICME2012 (General Co-Chair).

2) B. Pesquet-Popescu is a member of the several IEEE Technical committees : SPS Image, Video and Multidimensional Signal Processing (IVMSP), SPS Multimedia Signal Processing (MMSP), IEEE Comsoc Multimedia Communications, Member of IEEE SPS Awards Board, and of IEEE SPS Seasonal Schools Subcommittee.

3) 2 papers selected in the Top10% at the conference IEEE MMSP2009, Second Best Student Paper Award at IEEE ICIP2011 for G. Valenzise.
4) 5 Projects funded by ANR, 1 by DIGITEO, 4 FUI, 1 ITEA2.
5) 6 special issues organized: IEEE TCSVT, IEEE TIFS, Annals of Telecoms, JASP (2), IEEE JSTSP.

Highlights: Interactions with Society 1) CIFRE PhD Theses (SFR, Orange, Amiriel, Thalès)
2) Industrial contracts with AMIRIEL (2013–), SFR (2005-2008)
3) M. Cagnazzo is Area Editor for 2 *Elsevier* journals (SPIC and Sig. Proc.)
4) B. Pesquet-Popescu is member of the Editorial Board for IEEE Signal Processing Magazine, Associate Editor for 3 *IEEE Transactions* (Circ. Systems Video Tech., Image Proc., Multimedia), and Area Editor for one *Elsevier* journal (SPIC).
5) B. Pesquet is Chair of the IEEE Industrial DSP standing committee since Jan. 2013

As far as **video coding** is concerned, our group worked on to 2D and 3D video compression. In the first field, we proposed new and efficient methods based on motion vector quantization [3267, 3424] and competition [3302, 3304], mode information inference [3303], efficient lossless coding [3274], adaptive wavelet coding [3596, 3597], and more theoretical contributions concerning rate-distortion theory [3330] and convex optimization for sparse criteria [3297, 3295]. For 3D and multiview compression and processing, our contributions include stereo compression; novel techniques for disparity estimation and coding [3313, 3281, 3331, 3291, 3275]; multi-view video coding [3448, 3331]; and depth image coding [3331, 3448, 3653, 3567, 3316, 3315]. Finally, we have been the editors of a book on emerging technologies for 3D video [3351]. Regarding the content **trasmission**, we proposed a protocol for real-time video streaming over mobile ad-hoc networks [3292] with rate/congestion optimization [3293] and we developed novel robust transmission techniques based on multiple description coding (MDC) [3492], network coding (NC) [3571, 3572] and the combination of both [3570, 3493]. We have had an intense activity in the emerging framework of **distributed video coding** [3627, 3626] and we have proposed methods to improve the compression performance using high-order motion interpolation [3625, 3623, 3624], fusion techniques for multiview video [3544, 3463, 3332], iterative decoding and combination of global and local motion estimation [3465, 3396, 3399, 3401, 3269].

Other research activities in this theme include: **semantic-oriented** and content-aware compression using seam carving [3453, 3454, 3456] (a patent has been filed); **High Dynamics Range** representation, for which we developped new algorithms for inverse tone-mapping [3523, 3524]. and a specific video coding scheme taking into account the constraints of backward compatibility [3525]; **video quality assessment** [3455, 3285] and interoperability for **image search and sharing** [3337, 3347], contributing to a new international standard.

15.3.2 Multimedia Services Adaptation, Transport and Presentation

Faculty C. Concolato, J.-C. Dufourd, J. Le Feuvre, J.-C. Moissinac

Highlights: Scientific Production Communicating and migratable interactive multimedia documents [3278], Authoring of Scalable Multimedia Documents [3325], Design of an Efficient Scalable Vector Graphics Player for Constrained Devices [3277], Graphics Composition for Multiview Displays [3370], MPEG Multimedia Scene Representation [3372].

Highlights: Impact Participation to the EU Network of Excellence (INTERMEDIA), and to more than 15 other funded projects (France and EU), Organization of several international conferences, workshops and events such as DocEng 2012, SVG Open 2010, or Test The Web Forward 2012, Edition of several ISO/IEC and W3C standards [3754] [3712] [3769].

Highlights: Interactions with Society First worldwide Open-Source MPEG-DASH framework for content creation and playback (GPAC), Front cover with a Digital Radio Receiver of a general public scientific magazine, First worldwide Open-Source 3D renderer for autostereoscopic displays, 4-year collaboration with Samsung R&D Headquarter.

Multimedia Adaptation and Multimodal Interaction The adaptation of multimedia content to its context of use (terminal capabilities, network characteristics, user preference) to facilitate such media consumption is still a challenge. We address the problems related to multimedia adaptations by defining methods and languages facilitating the adaptation of multimedia documents[3325] [3282], as well as by using formal semantics for multimedia and interaction, as achieved in the implementation and extension of the Multimodal Interaction framework proposed by the W3C [3721].

Interactive Services and Transmedia The team has studied new ways to structure, package and transport interactive content, such as "widgets" or portable web applications, in particular in the home [3278], and has spearheaded the development of the MPEG-U standard [3712]. The team is now improving the developed concepts, as part of the work in the W3C Web and TV Interest Group and Device API Working Group. The second field investigated is interactive TV: the team is active in the development and promotion of the Hybrib Broadband Broadcast TV standard[3467].

Multimedia Transport The team has a strong activity on heterogeneous networking for multimedia, combined usage of broadcast (satellite, terrestrial) and broadband IP networks, Digital TV and Digital Radio [3755], [3445], [3444]. In this area, the team has contributed (more than 80 contributions) and participated to the editing of the following international standards: MPEG-2 Systems and MPEG-4 Systems, MPEG-DASH. The team has also published scientific papers on the topic [3444],[3445], hosted one of the DASH standardization meeting in Paris and created a large set of conformance files, available in the standard [3758] and a dataset for the research community.

Open Source Software The team maintains an Open Source platform called GPAC [3536]. This platform offers various tools for the encoding, the delivery and the playback of multimedia content, ranging from simple audio/video to complex interactive multimedia services. The platform is distributed under an LGPL license to the Open Source community or under specific licenses for industrial partners. In 2012, the software was licensed to two companies, including a major US-based company. GPAC is also used by the academic world (more than 50 citations in journals or international conferences) and has been advertised in the ACM SIG MM Newsletter. GPAC is the back-bone of the implementation of the team's work and is often demonstrated in conferences or standardization meetings [3763], [3686].

15.3.3 Multimodal Content and Interaction

Faculty L. Likforman-Sulem, M. Sigelle, G. Chollet, C. Faure, C. Pelachaud, C. Clavel

Highlights: Scientific Production 1) L. Likforman-Sulem, M. Sigelle (2008), Recognition of degraded characters using Dynamic Bayesian Networks, Pattern Recognition, Vol. 41, no 10, Oct. 2008, pp 3092-3103

2) A-L Bianne, F. Menasri, C. Mokbel, R. Al-Hajj, , C. Kermorvant, L. Likforman- Sulem (2011), Dynamic and Contextual Information in HMM Modeling for Handwritten Word Recognition, IEEE PAMI, Vol. 33, Nr 10

3) T. Hueber, EL. Benaroya, G. Chollet, B. Denby, G. Dreyfus, M. Stone, Development of a silent speech interface driven by ultrasound and optical images of the tongue and lips, Speech Communication 52 (4), 288-300, 2010.

4) K. Khurshid, C. Faure, N. Vincent: Word spotting in historical printed documents using shape and sequence comparisons. Pattern Recognition 45(7): 2598-2609 (2012)

5) R. Niewiadomski, S. Hyniewska, C. Pelachaud, Constraint-Based Model for Synthesis of Multimodal Sequential Expressions of Emotions, IEEE Transactions of Affective Computing, vol. 2, no. 3, 134-146, July 2011.

Highlights: Impact 1) Contracts: 10 European projects and 15 National projects (DGA (2); ANR (7); PEPS (2); FUI (3); FEDER (1))

2) Invited talks in international conferences: 8 (Royal Academy'09, MIG'09, HCSNet'09, FAA'10, JSMA'11, LREC'12, Tiger'13, Petra'13)

3) Best paper awards in international conferences: 3 (IVA'10)
4) Conference chair of international conferences: 6 (minisymposium in SIAM Conf. on Imaging Science 2010, W3C Workshop on Emotion Markup Language, IVA'10, IVA'13, ACII'13, AAMAS 2013 Virtual agent track chair)
5) International Journal guest editors: 4 special issues (IEEE Computer Graphics and Applications 2010, Journal on Multimodal User Interfaces 2012).

Highlights: Interactions with Society 1) 3 Industrial contracts
2) Presentation for large audience: Universcience TV 2011
3)Interventions in public events: 2 (Musée des arts et métiers, Paris, 2010 and 2013)
4) NATO: invited talk for Machine Translation for Coalition Operations working group
5) C. Pelachaud is Associate Editor for ACM Transactions on Interactive Intelligent Systems,IEEE Transactions on Affective Computing, Journal on Multimodal User Interfaces

Written Communication: We have developed efficient segmentation-free approaches for handwritten recognition [3290, 3273] and word spotting [3300]. These approaches include context-dependent Hidden Markov Models [3273], Dynamic Bayesian networks [3305] and Recurrent Neural Networks [3568]. Our developed systems have participated to ICDAR 2009 and 2011 word and text-line recognition challenges. At the document level, our objectives are to restore ancient document images by a combination of powerful filters [3306] or to provide style characteristics of handwritten documents [3395]. Web documents have also been converted to images in order to extract a combination of image and textual-based features, and to decompose them into meaningful blocks [3573].

Multimodal signal analysis and synthesis: We have developed several open-source software for the analysis of major biometric modalities (face, voice, audio-visual speaker, signature, iris, hand shape...). This work led to the publication of a reference book ([3356]) and to the development of databases, reference systems and benchmarking protocols ([3477]). Multilingual speech recognition is still a major topic for our team. Languages of interest include french, english, dutch, spanish, german and italian. Speech recognition and synthesis are being experimented in the context of Spoken Dialogue Systems. We are also extending an opensource Dialog system, called DISCO.

Multimodal modality and socio-emotional interaction: We have been working on developing a human-agent interaction system able to drive virtual and robotic agents [3582, 3533]. We have defined several computational models to enlarge the virtual agent repertoire [3319, 3589]. A new animation model allows rendering more natural facial and body motion [3462, 3500]. The agents are endowed with socio-emotional capacities [3320, 3318]; they can show their engagement through the emergence of behavior synchronization [3632]. Now we are focusing on enhancing the expressive animation model, on developing a cognitive model for the agent and model of social attitude.

15.4 Achievements

15.4.1 Scientific productions

Articles in Journals

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15.4.2 Public Fundings

Period	Project details	Funding	Principal investigator
2008-10	KIVAOU	ANR	CHOLLET G
2008-11	PINGO	DGE	CONCOLATO C
2008-10	SEBASTIAN2	DGE	PESQUET B
2008-10	RADIO+	ANR	CONCOLATO C
2008-12	CECIL	ANR	PELACHAUD C
2008-12	GV-LEX	ANR	PELACHAUD C
2009-10	CALLAS	EU	PELACHAUD C
2009-12	COMPANIONABLE	EU	CHOLLET G
2009-12	CALDER	ANR	LE FEUVRE J
2009-11	SEMAINE (Sustained Emotionally coloured Machine-human Interaction using Nonverbal Expression)	CEE	PELACHAUD C
2009-14	SSPNET (Social Signal Processing Network of Excellence)	NoE-CEE	PELACHAUD C
2009-13	PERSEE (Perceptual scheme for 2D and 3D video coding)	ANR Blanc	CAGNAZZO M
2009-12	IMMEMO	ANR	PELACHAUD C
2009-13	SURFONHERTZ	ANR	CHOLLET G
2010-12	ACDC (Adaptive Content Delivery Cluster)	DGE	PESQUET B
2010-13	SWAN (Source aWAre Network coding-Codage réseaux pour le multimédia)	DIGITEO	CAGNAZZO M
2010-11	EndT2End	DGE	LE FEUVRE J
2010-13	ANIPEV	DGE	PELACHAUD C
2010-11	VUE	DGE	MOISSINAC JC
2010-12	OPENWIDGET	DGE	DUFOURD JC
2010-12	ROME MOBILE	DGE	LIKFORMAN L
2010-13	HYB RADIO	ANR	CONCOLATO C
2011-13	ARHOME (Majordome électronique pour un bouquet d'échanges et de services à destination des acteurs des services et de l'hospitalisation à domicile, de l'action sociale et de leurs clients)	DGE	CHOLLET G
2011-13	IMEI - STIC ASIE (Investigating Multi-cultural, Empathic Interactions between a Human and an Embodied Conversational Agent in a Living Space)	AUTRE	PELACHAUD C
2011-14	HILAIRE (Incorporating Laughter into Human-Avatar Interactions: Research and Evaluation)	CEE	PELACHAUD C
2011-14	VERVE (Vanquishing fear and apathy through E-inclusion: Personalised and populated Realistic Virtual Environments for clinical, home and mobile platforms)	CEE	PELACHAUD C
2011-14	NEVEX (The next video experience)	DGE	DUFAUX F
2011-14	TARDIS (Training young adult's regulation of emotions and development of social interaction skills)	EU	PELACHAUD C
2011-14	VASSIST (Voice controlled assistive care and communication services for the home)	DGE	CHOLLET G

2012-16	MOCA (Mon petit monde de compagnons artificiels)	ANR	PELACHAUD C
2012-13	IDF EMOTIONS	AUTRE SEMI PUBLIQUE	PELACHAUD C
2012-14	PLAYSERIOUS	DGE	PELACHAUD C
2012-14	ILOT (Innovative Learning Objects for Teaching)	AUTRE	MOISSINAC JC
2012-15	COLTRAM	AUTRE	DUFOURD JC
2012-15	HACHETTE / CIFRE GROS	CIFRE	MOISSINAC JC
2012-15	4EVER (Développement de l'économie numérique)	FUI (13)	LEFEUVRE J
2012-15	AUSTRAL (Architecture universelle over the top sécurisée de télévision de rattrapage, à la demande et live)	FUI (13)	B PESQUET
2012-13	M44G (Multimedia for 4G)	PIA	LE FEUVRE J
2012-14	OPTISAT	FUI (14)	LEFEUVRE J
2012-14	MEDIA FACTORY	PIA	DUFOURD JC
2012-15	AVATAR A1&1 (Interactions avatars taille humaine)	PIA	PELACHAUD C

Total funding 8 948 k€

15.4.3 Private Fundings

Period	Project details	Funding	Principal investigator
2008-08	GEODIO	BILATERAL	MOISSINAC JC
2008-12	ALCATEL SOA2M	BILATERAL	MOISSINAC JC
2008-11	A2ia / BIANNE	CIFRE	LIKFORMAN L
2008-09	SAMSUMG	BILATERAL	CONCOLATO C
2008-10	SAMSUMG RICH MEDIA WIDGETS	BILATERAL	CONCOLATO C
2009-10	NVELLES APPROCHES	AUTRE	PESQUET B
2009-09	OSEO EMPREINTES MULTIMEDIA	BILATERAL	CONCOLATO C
2009-11	MY PRESENTING AVATAR	AUTRE	PELACHAUD C
2010-11	SAMSUMG ADVANCED INTERACTION SYTEMS	BILATERAL	CONCOLATO C
2010-10	OSEO-DOC ON DEMAND	BILATERAL	LIKFORMAN L
2010-15	CHAIRE IMAGINAIREA	AUTRE	PELACHAUD C
2010-13	DGA-MORILLOT	AUTRE	LIKFORMAN L
2010-13	FT CIFRE MORA	CIFRE	PESQUET B
2011-13	THALES / DECOMBAS	CIFRE	PESQUET B
2011-13	DIALONICS - INTELLIGENCE EMOTIONNELLE	BILATERAL	PELACHAUD C
2011-14	ITESOFT - RECONNAISSANCE DE MOTS CURSIFS	BILATERAL	LIKFORMAN L
2011-12	SAMSUMG HIGH EFFICIENCY VIDEO	BILATERAL	LE FEUVRE J
2011-13	B2M (Broadcast mobile multimedia)	AUTRE	DUFAUX F
2012-15	EMMA (Embedded software for mass market connected applications)	AUTRE	PELACHAUD C
2013-13	CANON DASH (Advanced streaming over HTTP)	BILATERAL	CONCOLATO C

Total funding 1 622 k€

15.4.4 Patents and Software

Period	Title	Funding	Authors	Status
2009	Schéma d'adaptation sur critère de minimisation d'erreur quadratique pour l'optimisation d'un codage H.264	CIFRE SFR	N. Tizon and B. Pesquet-Popescu	Accept.
2010	Scheduling Method For Data Streaming in a Telecommunication Network Infrastructure	Alcatel-Lucent	N. Changuel, B.Sayadi and M. Kieffer	Accept.
2013	Codage et décodage par héritage progressif	CIFRE Orange Labs.	E. Mora, J. Jung	Accept.
2013	Prédiction d'un bloc par héritage d'un champ de mouvement dense estimé par la technique du flux optique	CIFRE Orange Labs.	E. Mora, J. Jung, M. Cagnazzo, B. Pesquet	Submit.

15.5 PhDs

15.5.1 Defended PhDs

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[3809] M. Bendris. *Indexation audio-visuelle des personnes dans un contexte de télévision*. PhD thesis, Télécom-ParisTech, July 2011.

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[3811] C. Greco. *Diffusion robuste de la vidéo en temps réel sur réseau sans fil*. PhD thesis, TELECOM-ParisTech, July 2012.

[3812] T. Hueber. *Reconstitution de la parole par imagerie ultrasonore et vidéo de l'appareil vocal : vers une communication parlée silencieuse*. PhD thesis, UPMC, Dec. 2009.

[3813] W. Karam. *Imposture audio-visuelle et robustesse de la vérification de l'identité*. PhD thesis, Télécom-ParisTech, Feb. 2010.

[3814] G. Laroche. *Modules de codage par compétition et suppression de l'information de compétition pour le codage de séquences vidéo.* PhD thesis, Télécom ParisTech – Site Barrault – Amphi B312, May 2009.

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[3819] T. Petrisor. *Décomposition en ondelettes redondantes pour le codage par descriptions multiples des images fixes et des séquences vidéo*. PhD thesis, Télécom ParisTech – Site Barrault – Amphi Grenat, Sept. 2009.

[3820] B. H. Rodriguez. *Un modele SOA, multimodal et sémantique et son support pour la découverte et l'enregistrement de services d'assistance*. PhD thesis, Télécom ParisTech, Feb. 2013.

[3821] N. Tizon. *Codage vidéo scalable pour le transport dans un réseau sans fil Scalable video coding for wireless transmission*. PhD thesis, Télécom ParisTech – Site Barrault – Amphi B312, Dec. 2009.

15.5.2 Ongoing PhDs

- R. Bouazizi (11/12 –). *Création de services Transmédia pour la maison*.
- N. Bouzakaria (12/12 –). *Contributions au streaming adpatatif avancé*.

- M. Calemme (12/12 –). *Codage de cartes de profondeur par representation des contours comme courbes élastiques*.
- G. Chierchia (10/11 –). *Solutions de codage et transmission de la vidéo multi-vue pur des applications d'interactivité*.
- M. Chollet (11/11 –). *Modèles de comportements non-verbaux dans un contexte socio-émotionnel*.
- M. Decombas (10/10 –). *Codage vidéo bas débit pour des applications de reconnaissance*.
- Y. Ding (01/11 –). *Modèle d'apprentissage appliqué à l'animation d'agent virtuel*.
- A. Fiengo (12/12 –). *Optimisation debit-distorsion par allocation des ressources de codage dans le cadre d'un codeur video de nouvelle generation (HEVC)*.
- N. Fourati (11/11 –). *Modèles des mouvements émotionnels*.
- N. Glas (01/13 –). *Modèle d'engagement dans une interaction avec des avatars à taille humaine*.
- V. Gros (03/12 –). *de l'enrichissement sémantique des contenus pour fabriquer les e-Book de demain*.
- H. Khemiri (09/10 –). *Unified Data-Driven Approach for Audio Indexing, Retrieval and Recognition*.
- P. Lauga (11/11 –). *Etude des représentations HDR pour la vidéo numérique et mettre en œuvre de nouveaux algorithmes de conversion vidéo de LDR vers HDR*.
- M. Meddeb (02/13 –). *Compression et transmission vidéo pour un système de visioconférence innovant*.
- H. Medina (11/10 –). *Codage réseau de la théorie à la pratique*.
- P. Milhorat (04/12 –). *Conception d'un assistant personnel a interface vocale en langage naturel*.
- E. G. Mora (11/10 –). *Codage vidéo multi-view pour des nouveaux services multimédias*.
- O. Morillot (10/11–). *Reconnaissance de documents multilingues par réseaux Bayesiens dynamiques et Réseaux de neurones récurents*.
- I. Nemoianu. (10/09 – 06/13) *Codage réseau pour la diffusion de contenus vidéo de haute qualité*.
- C. Oprean (10/11 –). *Reconnaissance de textes manuscrits grand vocabulaire par adaptation de modèles de langage*.
- F. Pecune (12/12 –). *Modèle computationnel de l'influence de la personnalité d'un agent virtuel sur son comportement*.
- G. Petrazzuoli (11/09 – 01/13). *Signaux à taux d'innovation fini et applications à la vidéo distribué et multivue*.
- B. Ravenet (03/12 –). *Modélisation des relations sociales entre agents dans un environnement virtuel*.
- B. H. Rodriguez. *Définition de capacités multimédia abstraites de haut niveau et des moyens de leur composition automatique en réseau*.
- M. Sarkis (04/13 –). *Plateforme de services transmédia pour la maison*.
- Y. Tabet. *Représentation paramétrique du signal de la parole*.
- Y. Xing (01/12 –). *Codage vidéo pourl'holographie numérique 3D*.

Chapter 16

Statistics and Applications (STA)

16.1 Executive Summary

Team Leader S. Clémençon (FP) (F. Roueff (FP), –02/13)

Initial Staff 6 Professors; 6 Research Scientists; 0 Postdocs; 12 PhD Students.

Staff who Left 8 Permanent Staff (430 months) ; 23 PhD Students (550 months) ; 9 Postdocs (140 months).

Staff who Were Hired 1 Associate Professor (Post-doc at CNES), recruited on Nov. 2008; 1 Associate Professor (AP at Supélec), recruited on Dec. 2008; 1 Associate Professor (Post-doc at Duke University), recruited on Dec. 2012; 1 Research Scientist (Research Scientist in the AAO team of LTCI), recruited on Jan. 2010.

Scientific Highlights

- Developpement of the component separation algorithm [3854] used to process the data collected by the Planck satellite (officialy released in March 2013).
- Design of an on-line version of the celebrated Expectation-Maximization algorithm [3850].
- Organization at IHP of a reference seminar in the Paris area on Monte-Carlo methods (following the AdapMC and BigMC ANR projects).
- Design of TreeRank, a benchmark ranking algorithm [3860].
- Response to the Big Data trend through the industrial chair project "Machine-Learning", the scientific responsibility of the 7-th "Entretiens Telecom ParisTech" dedicated to Big Data and the lauch of the "Big Data: management and analysis (master spécialisé)" program.

Scientific Production 161 in Journals; 5 Book chapters; 181 in Proceedings; 47 Invited talks.

Major Publications

- Kullback-Leibler upper confidence bounds for optimal sequential allocation. Annals of Statistics, 2013 (to appear). O. Cappé, A. Garivier, O.-A. Maillard, R. Munos and G. Stoltz. [3853]
- Convergence of adaptive and interacting Markov chain Monte Carlo algorithms. Annals of Statistics, 39(6):3262–3289, 2012. G. Fort, E. Moulines and P. Priouret. [3897]
- Performance of statistical tests for single-source detection using random matrix theory. IEEE Transactions on Information Theory, 57(4):2400–2419, 2011. P. Bianchi, M. Debbah, M. Maïda, Mylène and J. Najim. [3845]
- Locally stationary long memory estimation. Stochastic processes and their applications, 121(4):813–844, 2011. F. Roueff and R. von Sachs. [3944]
- Adaptive partitioning schemes for bipartite ranking. Machine Learning, 83(11):31–69, 2010. S. Clémençon, M. Depecker and N. Vayatis. Machine Learning. [3864]

Major Documents

- TopRank software, registered at the APA (2008, F. Roueff and C. Lévy-Leduc).
- TreeRank software, registered at the APA, and patent (2012, S. Clémençon).
- Patent for an estimation method applied to fluorescence measurements (2010, F. Roueff).
- Patent for automatic source separation via joint use of segmental information and spatial diversity (2011, C. Févotte).
- CosmoPMC code to implement Monte-Carlo sampling method to explore the likelihood of various cosmological probes. (with contributions from O. Cappé, J-F. Cardoso and G. Fort).

Impact and Attractivity

- CNRS Silver medal (2010) and France Telecom Grand Prix of the French Academy of Sciences (2011) awarded to E. Moulines.
- Paul Doistau–Émile Blutet prize awarded to Jean-François Cardoso by the French Academy of Sciences (2013) for his contribution to the Planck mission.
- Participation to the steering committees of the GdR Isis (O. cappé, C. Févotte), the Gretsi society (O. Cappé) and the Institut Mines-Télécom's scientific network "Mathématiques Appliquées et Informatique Fondamentale" (G. Fort).
- Organization of two international workshops on large random matrices (J. Najim) and an international workshop on Performance Analysis of Monte Carlo methods (G. Fort); co-organization of reference seminars in the Paris area on statistics, machine-learning and Monte-Carlo methods (SemStat, Smile, BigMC).
- Editorial responsabilities: P. Bianchi (Signal Processing), O. Cappé (IEEE SPTM commitee, JRSSB), C. Févotte (IEEE MLSP commitee), G. Fort (Bernoulli), E. Moulines (SPA, JSPI, ESAIM P&S, Ed. in Chief of Bernoulli since 2012).

Interaction with Economic and Social Spheres

- Orange has been the team's main industrial partner (4 funded PhD theses).
- Other partners include CEA, DGA, Thales, Renault, Natixis and Exane.
- Support to the spin-off Score4Biz (S. Clémençon).

Contributions to Higher Education

- Co-responsability of the master programs "Applied mathematics and finance" and "Statistical learning and data mining" at Telecom ParisTech.
- Co-responsability of the domain "mathematics for engineers" at Telecom ParisTech.
- Master courses: O. Cappé (Dauphine), G. Fort (ENS Cachan), C. Levy-Leduc (Dauphine), E. Moulines (Paris 6, Paris 7, Dauphine, ENS Cachan), F. Roueff (Paris 6).
- Courses within ParisTech engineering schools: O. Cappé (Polytechnique), S. Clémençon (ENSAE, ENPC), F. Roueff (Polytechnique).
- Launch (in 2013) of a new specialized master program, dedicated to Big Data.

16.2 People

Team leader S. Clémençon (FP) (F. Roueff (FP), –02/13).

Faculty K. Abed Meraïm (AP, –08/12), G. Blanchet (FP, 06/13, Emeritus 07/13–), P. Bianchi (AP, 09/08–), O. Cappé (SRS), J-F. Cardoso (SRS), M. Charbit (FP, –06/13; Emeritus 07/13–), S. Clémençon (AP, –12/10; FP, 01/11–), C. Févotte (JRS, 01/10–12/12), G. Fort (JRS, –09/12; SRS, 10/12–), A. Garivier (JRS, –08/12), J. Jakubowicz (AP, 11/08–10/11), C. Lévy-Leduc (JRS, –08/12), E. Moulines (FP), J. Najim (JRS, –09/12), F. Roueff (FP), J. Salmon (AP, 12/12–).

PhD students A. Attaya (11/10–), S. Audière (10/08–12/11), S. Barembruch (–09/10), A. Bader (12/10–), A. Bellacheab (also with Telecom Sud Paris,10/12–) A. Ben Hadj Alaya (–10/08), H. Braham (12/12–), B. Jabbeur (–09/09), H. Benoudnine (–07/08, phd started at USTO, Algeria), N. Castaneda, (–07/08), E. Chautru (10/09–), J. Cornebise (–06/09, also at Univ. Paris 6), A. Dematteo (10/11–), M. Depecker (10/07–12/10), J.F. Germain (–10/08), F. Guilloux (–12/08, also at Univ. Paris 7), Z. Harchaoui (–11/08), O. Iacoboaiea (10/12–), M. Jala (11/10–, also with Orange Labs Issy-Les-Moulineaux), Y. Khan (04/11–), E. Kaufmann (09/11–), M. Kharouf (–06/10), O. Kouamo (–01/11, also at Univ. Yaoundé 1, Cameroon), N. Ksairi (10/08–03/10, also with Supélec), S. Le Corff (10/09–10/12), A. Lefèvre (10/10–10/12, also with INRIA/Sierra) A. Lung-Yut-Fong (10/08-12/11), N. Mahler (02/08-12/11, also at ENS Cachan), G. Morral Adell (10/11–), A. Nouvellet (03/13–, also with CEA List), S. Filipi (10/07–11/10), S. Robbiano (10/09–), A. Sanchez-Perez (09/12–), N. Seichepine (09/12–) P. Sendorek (04/11–), A. Schreck (09/11–), T. Rebafka (–11/09), E. Siboni (09/12–), T. Sim (03/13–, also with Telecom Sud Paris), N. Sokolovska (–02/10), M. Thameri (10/10–), J. Villard (11/08–12/11, also with Supélec), T. Wohlfarth (02/10–), J. Yao (09/10–), R. Zhang (10/10–), B. Zheng (02/10–).

Post-docs, engineers and sabbaticals T. Rebafka (12/09–09/10), T. Courtat (04/13–), O. Dikmen (02/10–01/12), C. Dhanjal (11/09–10/11, 12/12-), B. Miasojedow (10/11–08/12), R. Gaudel (09/10–08/11), L.-V. Lozada (02/10–08/10, 02/11–08/11, N. Mahler (08/11–04/12), D. Rohde (07/10–06/11), A. Roodaki (03/11–02/12), A. Saumard (11/10–11/11); M.S. Taqqu (Prof. at Boston Univ., 5 months), V. Reisen (MC, Vitória Univ., Brazil, 4 months).

16.3 Overview

During the last twenty years, scientific discovery has become increasingly dependent on the collection and interpretation of data and, more generally, quantitative information. There's a general consensus that the core academic disciplines that are most relevant to the information society encompass computer science, mathematics and statistics. The Statistics and Applications (STA) group at LTCI plays an important role in this context by focussing on statistical methods and their application in domains relevant to the information society at large.

The members of the STA group are actively participating to teaching, typically at the master level and in the fields of probability, statistics, signal processing, machine learning and applied mathematics, at Télécom ParisTech but also in several other Grandes Ecoles affiliated to ParisTech (Ecole Polytechnique, ENSAE, ENPC) and universities (M2 *Modélisation aléatoire* at Paris 7 Denis Diderot, M2 *Modélisation Vision Apprentissage* at ENS Cachan, M2 *Probabilités et Modèles Aléatoires* at Paris 6 Pierre et Marie Curie, M1 *Mathématiques de la Modélisation et de la Décision* at University Paris-Dauphine).

The STA group has developed long term research collaborations with several academic Parisian partners such as Univ. Paris 7 Denis Diderot (LPMA and ADAMIS), Univ. Paris 10 Nanterre (MODAL'X), Univ. Paris-Est (IGM), Institut d'Astrophysique de Paris, Univ. Paris-Dauphine (Cérémade), research groups in other ParisTech schools (CMBIO, Mines and CERMICS, Ponts) and with the Ecoles Normales Supérieures Ulm (INRIA projects TREC, WILLOW and SIERRA) and Cachan (CMLA). Such collaborations are essential to the group for achieving long term research

programs, and, more generally, for exchanging ideas and views within a stimulating academic environment.

These academic relationships parallel industrial partnerships. The latter have been developed in the framework of national research projects (ANR), bilateral contracts, or the funding of PhD theses (mainly through CIFRE conventions, but also with bilateral contracts). Beside favoring our financial autonomy, such partnerships bring practical applications which are helpful for our opening and to remaining active on new research prospects. In the last years, regular industrial partners include the Commissariat à l'Energie Atomique (CEA), Thales Avionics, Orange, Direction Générale de l'Armement (DGA), Natixis, Liligo.com.

The group enjoys a high national and international recognition with editorial board members in top ranked international journals such as Bernoulli (E. Moulines, Editor in Chief, G. Fort, associate Editor), ESAIM P&S, Stoch. Proc. and their Appl. Journal of Statistical Planning and Inference (E. Moulines, Associate Editor), the Journal of the Royal Statistical Society, Series B (O. Cappé), Signal processing (P. Bianchi) as well as regular participation as program committee members in the major international conferences (IEEE ICASSP, IEEE statistical Signal Processing workshop, International Conference on Machine Learning, Neural Information Processing Systems, Artificial Intelligence and Statistics). The group regularly organizes or co-organizes scientific events such as summer schools (E. Moulines, 13th Brazilian school of probability, 2009, 22nd Jyvaskyla Summer School, C. Févotte, *Ecole d'Eté en traitement du signal et des images* in Peyresq (2010)), special sessions in international conferences (G. Fort, AMSDA 06/11); national workshops (G. Fort, GDR ISIS 11/11, P. Bianchi, GDR ISIS 02/12), as well as recurrent scientific seminars in Paris (*séminaire parisien de statistiques*, ParisTech Machine Learning reading group *Smile*, BigMC seminar on Monte Carlo methods at IHP).

Members of the group are regularly invited to give talks or lectures. E. Moulines was a keynote speaker at the Journées MAS 2010, GRETSI 2011 and EUSIPCO 2012 and was invited speaker in numerous workshops and conferences including Stochastic approximation: methodology, theory and applications in statistics (Bristol, 2012), Structure and uncertainty: modelling, inference and computation in complex stochastic systems (Bristol, 2012). C. Lévy-Leduc and F. Roueff were invited to give talks at the 58th World Statistics Congress of the International Statistical Institute (2011). O. Cappé was a keynote speaker at the StatLearn'13 workshop in Bordeaux, invited speaker at the Allerton Conference on Communication, Control, and Computing in 2013 and gave a tutorial at the 2009 IEEE Workshop on Statistical Signal Processing.

Two members of the group have been distinguished by prestigious scientific prizes during the period. E. Moulines received the Silver Medal of CNRS in October 2010, for his work on Probabilities applied to Signal Processing and Machine Learning. He also received the 2011 France Telecom Grand Prix of the French Academy of Siences. Jean-François Cardoso received the Paul Doistau–Émile Blutet prize of the French Academy of Sciences in 2013 for his contributions in the field of astronomy.

In recent years, the group has seen a significant turnover with the departures of J. Jakubowicz (now associate professor in Télécom Sud Paris) in 2011, and of A. Garivier (now full professor at Univ. Toulouse), C. Lévy-Leduc (full professor at Agro Paristech), J. Najim (senior research scientist at LIGM - Univ. Paris Est) and C. Févotte (junior research scientist at Laboratoire Lagrange, Nice) in 2012 and the recruitment of J. Salmon in 2012. In 2013, two other members of the group (G. Blanchet and M. Charbit) will retire and a recruitment from Télécom parisTech (at the associate professor level) is scheduled for the second semester of 2013.

16.4 Research Themes

16.4.1 Statistical Learning

Faculty O. Cappé, A. Garivier, S. Clémençon, E. Moulines, F. Roueff, J. Salmon.

Highlights: Scientific Production [3853, 3850, 3953, 3869, 3908, 3869]

Highlights: Impact projects MGA (Graphical Models and Applications, ANR, 2008–2011), BEMOL (Prediction of internet users' behavior, simulation and collaborative filtering, 2008–2011), ERASM (recommending systems, Eurostars project, 2012–)

Highlights: Interactions with Society Contracts with Orange (two PhD theses), Renault (one PhD thesis), Liligo.com (one phd thesis) and with BNP Exane (one PhD thesis). Patent for the TreeRank algorithms.

The group has a long standing interest in **(dynamic) graphical models** and, more generally **Bayesian methods**. In the context of the MGA project, we contributed both to general methodological questions (in particular concerning the online learning of parameters [3983, 4149]) and to the advance of methods for statistical natural language processing. On the latter topic, as a follow up to our work on the use of Lasso (or L1) type regularization for training of large scale conditional random field (CRF) models [3950], we developed an highly efficient software called `Wapiti` [4122]. `Wapiti` is faster than existing alternatives and is highly competitive for sequence tagging tasks as demonstrated, in particular, by the independent evaluations posted on MLcomp `http://mlcomp.org/`, a community website for objective comparison of machine learning programs. Another important contribution of the period has been the development of an **online** version of the EM algorithm [3850], together with several extensions [3849]. More generally, the ubiquity of very large data sets has generated in recent years a renewed interest in online learning algorithms, for instance based on the stochastic approximation principle, that are both fast and scalable [3997].

Since 2007, the group has a raising interest in **reinforcement learning** and its applications to telecommunications. The PhD of Sarah Filippi (2007-2010), funded by Orange, was motivated by cognitive radio problems [3852] and targeted internet advertisement [4090]. In these applications, the environment is typically non-stationary; these applications brought us into investigating adapted bandit algorithms [4094]. We also promote the use of Kullback-Leibler divergence in optimistic algorithms: we proved in [4093, 3853] the optimality of a resulting upper-confidence bound algorithm for bandit problems, and we proposed in [4035] an improved algorithm for reinforcement learning in discrete Markov Decision Processes. The PhD of E. Kaufmann on the same topic has already produced an important result on the optimality of methods inspired by the Bayesian paradigm [4114, 4113] that are used, for instance, in the Google Analytics engine. The PhD thesis of Marjorie Jala, funded by Orange in the context of the Whist joint lab, is devoted to active learning methods for the estimation of upper quantiles of the exposition to electromagnetic fields which are also strongly inspired by bandits algorithms.

In the context of supervised learning, significant advances in the **ranking** problem have been made in [3860], [3861], [3864] and [3866] both from practical and theoretical perspectives. Strong empirical evidence supporting the efficiency of the Treerank technique thus are presented in the PhD thesis defended by Marine Depecker (2007/10, in collaboration with Renault Technocentre). This work has been extended in the PhD thesis of S. Robbiano by considering "multi-class" extensions and plug-in approaches, see [4049].

Unsupervised ranking, sometimes also described as *rank aggregation*, is also a crucial issue in e-commerce, in database middleware or in information retrieval. In the context of the Digiteo project Bemol (in collaboration with ENS Cachan and the company "Mille-Mercis"), novel techniques for rank aggregation have been developed in [4047], [4065] and [4095], offering promising alternatives to the classical "median approach". The pairwise clustering approach has also been studied from a theoretical perspective in [4044].

Non-parametric estimation and model selection is another important research theme in the group. Non-parametric prediction of time-series has been studied in the PhD theses of N. Mahler (2008/10, in collaboration with ENS Cachan and Strategic Risk Management) and R. Zhang (2010/13, in collaboration with ENS Cachan and BNP Exane) considering multivariate financial time-series, while the PhD thesis of Till Wohlfarth focused on travel price forecasting [4166, 4165]. Other related works focused on structured data such as functional curves in [4045] and graphs in [4046, 4061, 4062, 3986] or [4064] (projects ANR Viroscopy, Digiteo Bemol). Finally, the design of model selection techniques based on data-dependent complexity penalization has been

considered in the projects "Meta-Rank" (Institut Mines-Télécom Futur & Ruptures program) and "Crank-Up" (Digiteo funding, in collaboration with Lip6) [4060].

16.4.2 Blind Source Separation

Faculty J-F. Cardoso, C. Févotte.

Highlights: Scientific Production [3854, 3936]

Highlights: Impact Adoption of the SMICA algorithm [3854] in the Planck CMB processing pipeline (distinguished by the Paul Doistau–Émile Blutet prize awarded to Jean-François Cardoso), ANR project TANGERINE (Theory and applications of nonnegative matrix factorization, 2009–).

Highlights: Interactions with Society Patent in automatic source separation (2011, C. Févotte).

Data is often nonnegative by nature, consider for example pixel intensities, amplitude spectra, occurrence counts, food consumption, user scores or stock market values. **Nonnegative matrix factorization** (NMF) is a linear regression technique with growing popularity in the fields of machine learning and signal/image processing. NMF, and its extension to nonnegative tensor factorization (NTF), are young research topics that call for answers to many open problems. The background for most of the research on NMF in the Stats group is the ANR project TANGERINE. The following topics have been addressed: model selection and learning algorithms [3893],factorization with structural constraints [4127, 4085], online and stochastic algorithms [4128, 4088]. Several applications have been considered such as music transcription [3933, 3934], audio source separation [3936, 3985] and identification of dietary behaviors [3867].

The **Planck space mission** of the European Space Agency has delivered on March 2013 a large set of papers and scientfic products after a 20-year preparation since the intial design (see [3978] and the following references). The highlight of the mission is the production of a full-sky, high-resolution, high SNR map of the Cosmic Microwave Background, litterally a snapshot of our Universe in its infancy, the oldest image in the Universe. J.-F. Cardoso has been working within the Planck collaboration with increasing commitment for more than 10 years, bringing in his theoretical expertise in the field of Independent Component Analysis and Blind Source separation. Planck produces nine maps of the full sky seen in nine frequency channels (from 30 GHz to 857 GHz), containing all sorts of Galactic and extragalactic emissions. As it turned out, the blind statistical approach to component separation –as developped specifically for Planck data [3854]– provided the Planck mission with the best way to combine its nine channels into a single clean map of the Cosmic Background of unprecented quality.

16.4.3 Sensor Networks

Faculty K. Abed-Meraim, P. Bianchi, M. Charbit, G. Fort, J. Jakubowicz, E. Moulines, J. Najim, F. Roueff.

Highlights: Scientific Production [3843, 3845, 3916]

Highlights: Impact ANR project SESAME (consistent estimation and large random matrices). Two international workshops (subject: "Random Matrices and Their Applications") were organized at Télécom Paristech in 2010 and 2012, and partially funded by the ANR project SESAME.

ANR project SVELTE (Système d'évaluation de la dépense énergétique et de la condition physique pour la prévention et le traitement de l'obésité)

Highlights: Interactions with Society Research contracts with Thales and with CEA DAM.

Since 2008 (with the recruitement of P. Bianchi and J. Jakubowicz), the group has been gradually more involved in the development of mathematical and statistical tools for performance

evaluation and optimization of sensing and communication networks. The term *sensor* should be understood in a wide sense, including physical sensors (accelerometers, microphones, etc.), distributed processors, smart phones or mobile robots. We distinguish between centralized and distributed network architectures.

In the framework of **centralized systems**, a special attention has been devoted to applications to **source detection and localization**. In the context of a joint work with the CEA and CNRH-hospitals (ANR project SVELTE), signal processing and classification methods have been applied to accelerometric data collected by body sensors [3935, 4144]. Two industrial contracts with CEA leaded to original algorithms for the detection of infrasound sources and the estimation of their angles of arrival [4043, 4041]. A Phd thesis started in 2013 to investigate some theoretical aspects of this problem, in particular, how to build meaningful data sets to evaluate various detection algorithms in realist situations.

Motivated by application to *cognitive radio* (ANR project SESAME), we analyzed the performance of different hypothesis tests in terms of error exponents [3845, 3846]. The design of quantization methods maximizing the error exponents is addressed in [3980]. We used **random matrix theory** as a central tool for the analysis of detection problems in large sensor networks. For instance, the study of the fluctuations and the large deviations of the extreme eigenvalues of sampled covariance matrices are crucial to characterize error exponents [3845]. In parallel, random matrix theory has also been extensively used for solving wireless communication problems. We analyzed *Ricean* Multiple Input Multiple Output (MIMO) channels in [884, 3906]. The analysis is made difficult because of the presence of a line-of-sight component. The last part of ANR project SESAME has been devoted to two related issues. First, the detection and estimation issues in Large Antenna Networks [893, 894], in a context where the number of antennas scales with the dimension of the received signal. Second, the estimation of large covariance matrices and/or functionals of large covariance matrices.

In the framework of **distributed systems**, we investigated the issue of distributed optimization in a network of autonomous agents seeking to reach an agreement on some global parameter. In a first part of our work, we analyzed the asymptotic behavior of gossip-based distributed stochastic approximation methods [3843, 4142]. An extension of our method to distributed online expectation-maximization is proposed in [4028]. Applications to distributed power control, resource allocation, sensor localization, motion coordination and smart grids have are addressed respectively in [3843, 3916, 4027, 4039, 4069]. A theoretical analysis of the effect of misbehaving agents on the convergence is provided in [4013] where a robust distributed optimization method is also proposed. More recently, we proposed an asynchronous version of a proximal-point algorithm for finding the zeros of a sum of two monotone operators, and derived an asynchronous distributed optimization algorithm based on the alternating direction method of multipliers.

16.4.4 Monte Carlo Methods

Faculty O. Cappé, S. Clémençon, G. Fort, E. Moulines.

Highlights: Scientific Production [3897, 3899, 3919, 3885, 3981]

Highlights: Impact ANR Projects BigMC (Issues in large scale Monte Carlo, 2009–2012). C-FLAM (Coordination Flotilla Localization and Mapping, 2008–2011). Siminole (Large-scale simulation-based probabilistic inference, optimization, and discriminative learning with applications in experimental physics, 2011–2014). Viroscopy (Stochastic modeling and statistical inference for propagating infectious diseases: from micro to macroscopic behavior, 2008–2011). Digiteo project Bemol (2009–2011). G. Fort was a member of the organization committee of the international workshop on *Performance Analysis of Monte Carlo methods* held in November 2012, in Brown University. G. Fort also organized a monthly seminar on Monte Carlo methods (held at the Institut Henri Poincare) where many searchers from Paris and its region working or using Monte Carlo methods meet.

The group is internationally recognized for its contributions on Markov chain Monte Carlo

(MCMC), Sequential Monte Carlo (also called Particle Filtering), and novel Monte Carlo approaches at large. The group contributes actively to the theory and the methods of Monte Carlo simulation; it also considers applications to the so-called *Bayesian inverse problems*, most often in the context of collaborative projects.

New challenges in MCMC methods deal with **adaptive methods** (in which the simulation parameters are adapted to improve the mixing efficiency) and interacting Monte Carlo techniques (in which several Monte Carlo are run in parallel and interacts). The group has a strong expertise in convergence analysis of classical MCMC algorithms; in the past years, the group has responded to some of these new challenges by developing new tools for the theoretical study of these new MCMC samplers [3982, 3897, 3898, 3899]. We have developed and analyzed novel interacting algorithms, extending the so-called *equi-energy sampler*; see [3948]. These works have been developed in collaboration with researchers from Univ. Pierre et Marie Curie, Univ. Paris Est (in the context of the BigMC project), the Univ. of Michigan [3824, 3825] (USA), the Univ. of Jyvaskyla (Finland) [3929].

We have also contributed to the theory and methods of **sequential Monte Carlo**. In [3885], an efficient particle smoothing algorithm (called the Forward Filtering Backward Simulation, or FFBSi algorithm), with a complexity growing linearly with the number of particles, has been described. The consistency, asymptotic normality, and stability of the forward filtering backward smoothing algorithm has also been discussed in this work, which has later been extended to the approximation of smoothing functionals in [4081, 3887]. The long-term stability of sequential Monte Carlo techniques has only been established under rather stringent ergodicity conditions (uniform mixing for the Markov kernel). We have started to study the stability under much weaker conditions. A first step in this direction has been done in [3883] and [3884].

In the ANR project C-FLAM, lead by the LIRMM in Montpellier, the group has developed novel landmark-based Simultaneous Localization and Mapping algorithms. Our approach consists in solving the *marginal SLAM* problem by using Sequential Monte Carlo methods, and the Mapping problem by adapting online Expectation-Maximization algorithms (previously proposed by our group in [3849, 3983]) [4123, 4125, 3919, 3920].

Interacting and branching particle system techniques and sequential Monte-Carlo methods have been developed and used for *rare event simulation/probability estimation* in the contexts of food risk analysis and of mathematical epidemiology (ANR project `Viroscopy` - 2008/11), see [3859] and [3839]. In [4095] (Digiteo project `Bemol` - 2009/11), dedicated MCMC techniques have been developed for rank aggregation.

Following our past experience in the context of the ANR project `ECOSSTAT`, where the group contributed to the development of an original **adaptive importance sampling** scheme [3981, 3913, 4188] (with associated distributed software implementation [3913]) for Bayesian analysis of multi survey cosmological data, we launched a new project in this field in 2011. This project called Siminole and also funded by the ANR is lead by the LAL in Orsay and our contribution is focused on the exploitation of cosmic ray data gathered in the context of the Auger experiment. A first algorithm for solving switching label problems has been proposed in [3999]

16.4.5 Time Series

Contributors K. Abed-Meraïm, O. Cappé, M. Charbit, S. Clémençon, C. Lévy-Leduc, E. Moulines, F. Roueff.

Highlights: Scientific Production [3858, 3886, 3907, 3856, 3945]

Highlights: Impact CNRS-FRS-WBI mobility program, Project DGA REI (Recherche Exploratoire et Innovation) ISREPTMu (Interception de signaux radar en présence de trajets multiples), ANR project Mataim (Anisotropic models for textures with applications to medical imaging),

Highlights: Interactions with Society Research contract with Natixis (1 PhD thesis), Research contract with Echosens (1 PhD thesis)

Following the thorough analysis of semi-parametric Wavelet methods for estimating the **long memory parameter** that we conducted in the past years, we have explored new directions in this topic: robust estimation of the memory parameter ([3914]), non stationary (change-point and locally stationary) long memory modelling ([4116, 3915, 3944]), non-Gaussian and non-linear long memory processes ([3856, 3945]). We have studied the asymptotic properties of a new robust estimator of the autocovariance of Gaussian processes having either short or long-range dependence in [3926]. These results have been established thanks to the asymptotic properties of general U-processes in the long-range dependence context of [3924, 3925]. A large part of these works were conducted in a long standing collaboration with M.S. Taqqu (Boston Univ.).

We also pursued our work on the topic of **change point** detection. The method proposed in a previous research project for centralized anomaly detection in the Internet traffic has been extended to deal with a decentralized anomaly detection approach in [3928] and [4133] in which a robust change-point detection method based on multivariate rank statistics is proposed. Finally, we proposed a multiple change-point estimation with LASSO in [3907].

The Markov assumption being among the weakest assumptions involved in time series modelling, renewal theory for **Markov processes** has been used for analyzing the (asymptotic and non asymptotic) behavior of sample mean, U-statistics and extreme-value statistics based on general Markovian data, in [3837, 3858, 3898] and [3840]. We have also pursued our long-lasting work on the theory of Hidden Markov Model; in [3886] and [3881] we have obtained the convergence of the relative entropy in the HMM for both well- and mis-specified models, under the weakest known conditions. A preliminary discussion of a regenerative bootstrap approach for HMM has been considered in [4058].

Ongoing applications in statistical signal processing based on time series or random fields modelling include radar processing and medical diagnosis [4148, 3996]. A related field of interest for non-cooperative communications is **blind identification**: In the context of AINTERCOM project, we developed blind demodulation approaches using approximate Maximum Likelihood methods [3830], [3829].

16.5 Achievements

16.5.1 Scientific Productions

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[4163] J. Villard and P. Bianchi. Quantification vectorielle haute résolution pour la détection de processus stationnaires. In *GRETSI*, Bordeaux, Sept. 2011.
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detection of hidden Markov processes. In *ITW*, Oct. 2010.

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[4166] T. Wohlfarth, S. Clémençon, F. Roueff, and X. Casellato. A data-mining approach to travel price forecasting. In *ICMLA*, Honolulu (Hawaï), USA, Dec. 2011.

Invited Talks

[4167] P. Bianchi. Analyse en grandes dimensions de tests d'hypothèses pour la détection d'émetteur. In *Jounées MAAS 2009*, Bordeaux, Nov. 2009.

[4168] O. Cappé. An introduction to sequential Monte Carlo for filtering and smoothing. In *Workshop on statistical modeling of extremes in data assimilation and filtering approaches*, Strasbourg, France, June 2008.

[4169] O. Cappé. Inside sequential Monte Carlo methods (tutorial). In *2009 IEEE Workshop on Statistical Signal Processing*, Cardiff Wales, UK, Aug. 2009.

[4170] O. Cappé. Online EM algorithms for mixtures, HMMs and beyond. In *Mixture estimation and applications Workshop, International Centre for Mathematical Sciences*, Edinburgh, UK, Mar. 2010.

[4171] O. Cappé. Méthodes bayésiennes pour les modèles à variables latentes. In *5ème école d'été de Peyresq en traitement du signal et des images*, Peyresq, France, June 2010.

[4172] O. Cappé. From importance sampling to sequential Monte Carlo methods (tutorial). In *Second Training School of the EU MC Impulse Network*, Windermere, Cumbria, UK, Sept. 2011.

[4173] O. Cappé. Learning with the online EM algorithm. In *StatLearn'13 workshop*, Bordeaux, France, Apr. 2013.

[4174] S. Clémençon. Large population limits and inference for a stochastic sir model with contact-tracing. In *R0 and Related Concepts*, Paris, France, Oct. 2008.

[4175] S. Clémençon. Regeneration-based statistics for Markov chains. In *Journées MAS*, Rennes, Aug. 2008.

[4176] S. Clémençon. Ranking the best instances. In *Journées d'Apprentissage Statistique*, Orléans, France, Mar. 2008.

[4177] S. Clémençon. A stochastic epidemic model with contact-tracing. In *XII-th Congress in Operations Research*, La Havane, Cuba, Feb. 2008.

[4178] S. Clémençon. Extreme value statistics for Markov chains. In *Statistics for Dependent Data*, Malakoff, France, May 2008.

[4179] S. Clémençon. Exposition aux risques alimentaires et processus stochastiques. In *Congrès de la SMAI*, La Colle sur Loup, France, May 2009.

[4180] S. Clémençon. Recent advances in ranking. In *Learning Theory - State of the Art (SMF)*, Paris, France, May 2011.

[4181] J. Cornebise, E. Moulines, and J. Olsson. Adaptive methods for sequential importance sampling. In *Opening workshop of SAMSI 2008-09 Program on Sequential Monte Carlo methods*, Durham, Etats-Unis, Sept. 2008.

[4182] J. Cornebise, E. Moulines, and J. Olsson. Adaptive methods for sequential importance sampling. In *Journées MAS de la SMAI*, Rennes, France, Aug. 2008.

[4183] G. Fort. Fluid limit-based tuning of some hybrid MCMC samplers. In *Adap'SKI*, Bormio, Italie, July 2008.

[4184] G. Fort. Stability of Markov chains based on fluid limit techniques. applications to MCMC. In *Congrès SSC-SFDS*, Ottawa, Canada, July 2008.

[4185] G. Fort. On adaptive stratification. In *2009 INFORMS Applied Probability Society*, July 2009.

[4186] G. Fort. Limit theorems for adaptive MCMC algorithms. In *41eme journées de Statistiques de la SFDS*, Bordeaux, France, July 2009.

[4187] G. Fort. Adaptive MCMC : theory and methods. In *Optimization in MCMC*, Warwick, GB, July 2009.

[4188] G. Fort. Estimation of cosmological parameters using adaptive importance sampling. In *Workshop "Astro-Statistique"*, Grenoble, France, Dec. 2011.

[4189] G. Fort. New online-EM algorithms for general hidden Markov models. application to the slam problem. In *International Conference "Latent Variable Analysis - Independent Component Analysis"*, Tel-Aviv, Israël, Feb. 2012.

[4190] G. Fort. Adaptive equi-energy samplers. In *ISBA*, Kyoto, Japon, June 2012.

[4191] G. Fort. Stochastic approximation-based adaptation for interacting MCMC. In *Workshop "Advances in Markov chain Monte Carlo"*, Edimburgh, Royaume-Uni, Apr. 2012.

[4192] G. Fort. Adaptive and interacting Monte Carlo methods for Bayesian analysis. In *Workshop "Big Bang, Big Data, Big Computers"*, Paris, France, Sept. 2012.
[4193] G. Fort. Convergence and efficiency of the wang-landau algorithm. In *Winter School "New directions in Monte Carlo methods"*, Gainesville, USA, Jan. 2013.
[4194] G. Fort and E. Moulines. Parallel tempering and interacting algorithms. In *Workshop "Challenges and Advances in High Dimensional and High Complexity Monte Carlo Computation and Theory"*, Calgary, Canada, Mar. 2012.
[4195] S. Le Corff. The block online expectation maximization algorithm. In *14th Conference of the ASMDA International Society*, Rome, Italie, June 2011.
[4196] S. Le Corff. Nonparametric estimation in hidden Markov models. In *8th world congress in Probability and Statistics*, Istanbul, Turquie, July 2012.
[4197] S. Le Corff. Convergence of a particle based online estimation procedure in hidden Markov models. In *SMC 2012*, Warwick, UK, Sept. 2012.
[4198] T. Rebafka and F. Roueff. Minimax estimation of the mixing density of a mixture of exponential distributions. In *European Meeting of Statisticians*, Toulouse, France, Aug. 2009.
[4199] T. Rebafka, F. Roueff, and A. Souloumiac. Information bounds and MCMC parameter estimation for the pile-up model with application to fluorescence measurements. In *7th World Congress in Probability and Statistics*, Singapore, July 2008.
[4200] F. Roueff. Asymptotic statistics for the scalogram of time series. In *Fourier meets wavelets - in statistics*, Karlsruhe, Allemagne, Sept. 2010.
[4201] F. Roueff. Time-varying long memory estimation. In *Self-similarity and related fields*, Le Touquet, France, Sept. 2011.
[4202] F. Roueff. Wavelet analysis of long range dependent processes. In *Long-Range Dependence, Self-Similarity and Heavy Tails*, Research Triangle Park, North Carolina, USA., Apr. 2012.
[4203] F. Roueff. Nonstationary models with long memory. In *Multifractal, Non Stationarity, Risks*, Paris, France, July 2012.
[4204] F. Roueff. Some recent results fornon-linear processes with long range dependence. In *IWAP 2012 (workshop)*, Jerusalem (Israel), Aug. 2012.
[4205] A. Schreck. Adaptive equi-energy sampler: convergence and illustration. In *8th World Congress in Probability and Statistics*, istanbul, turquie, July 2012.
[4206] A. Schreck. An adaptive version of the equi-energy sampler. In *15th Annual Winter Workshop: New Directions in Monte Carlo Methods*, Gainesville, Etats-Unis, Jan. 2013.
[4207] B. Zheng. Price jump prediction in limit order book. In *Quantitative Methods in Finance*, Sydney, Australia, Dec. 2011.
[4208] B. Zheng. Price jump detection in limit order book. In *Interdisciplinary workshop on "Econometric and statistical modelling of multivariate time series"*, Louvain-La-Neuve, Belgique, May 2011.
[4209] B. Zheng, E. Moulines, and F. Abergel. Price jump prediction in limit order book. In *Market Microstructure Conference Confronting Many Viewpoints*, Paris, France, Dec. 2010.
[4210] B. Zheng, F. Roueff, and F. Abergel. Application of spread constrained limit order book hawkes process to financial high frequency data modelling. In *Market Microstructure: confronting many viewpoints*, Paris, France, Dec. 2012.

16.5.2 Public Fundings

Period	Project details	Funding	Principal investigator
2008-2012	SESAME - Consistent estimation and large random matrices	ANR MDCO	J. Najim
2008-2012	CFLAM	ANR PSIRob	E. Moulines
2008-2011	MGA - Modèles graphiques et apprentissage	ANR Blanc	O. Cappé
2008-2010	ULISS/AGEXPO	DGE poles	M. Charbit
2009-2011	VIROSCOPY	ANR	S. Clémençon
2009-2013	TANGERINE - Theory and application of non-negative matrix factorization	ANR JC	C. Févotte
2009-2012	BIG MC - Méthodes de Monte Carlo en grande dimension	ANR Blanc	G. Fort
2009-2011	BEMOL	Digiteo	S. Clémençon
2009-2013	SVELTE	ANR	P. Bianchi
2010	Modèles à mémoire longue variant dans le temps	CNRS-FRS-WBI	F. Roueff
2010-2014	ORIGAMI 2	ANR	M. Charbit
2010-2014	SIMINOLE - Méthodes de simulations pour la physique expérimentale	ANR Cosinus	O. Cappé
2012-2015	Allocation doctorale Sanchez Perez	Région IdF	F. Roueff
2012-2013	Projet Maths-Ingénierie	Labex LMH	F. Roueff
2012-2013	Projet Maths-Ingénierie	Labex LMH	S. Clémençon
2012-2014	ERASM	Eurostars	S. Clémençon

Total funding 1 400 k€

16.5.3 Private Fundings

Period	Project details	Funding	Principal investigator
2008-2011	CIFRE PhD S. Audière	Echosens	M. Charbit
2009-2010	Spécifications de capteurs	ONERA	E. Moulines
2009	Etude évaluation colmatage	EDF	E. Moulines
2009-2011	CIFRE PhD S. Grimoud	Orange	E. Moulines
2009-2011	Projet REI Irespt Mu	DGA	M. Charbit
2009-2010	Hybridation multiple IMU/GNSS	Thales	M. Charbit
2010-2013	CIFRE PhD T. Wohlfarth	Findworks	S Clémençon
2010-2013	CIFRE PhD B. Zheng	Natixis	E. Moulines
2010	Etude	Withings	K. Abed-Meraim
2010-2011	Infrasonore	CEA	M. Charbit
2010-2013	CIFRE Fox	Parrot	M. Charbit
2010-2013	CIFRE PhD M. Jala	Orange	C. Lévy Leduc
2010-2013	CIFRE PhD R. Zhang	Exane	S. Clémençon
2011-2014	CIFRE PhD P. Sendorek	Thales	K. Abed-Meraim
2011-2014	Allocation doctorale G. Morral Adell	DGA	P. Bianchi
2011-2014	CIFRE PhD A. Dematteo	GTT	S. Clémençon
2012-2015	CIFRE PhD Y. Khan	Orange	E. Moulines
2012-2015	CIFRE PhD H. Braham	Orange	E. Moulines
2012-2013	Infrasonore2	CEA	M. Charbit
2012-2015	CIFRE PhD O. Iacoboaiea	Orange	P. Bianchi
2012-2015	Approches Séquentielles pour l'estimation des quantiles	Orange	E. Moulines

Total funding 757 k€

16.6 PhDs

16.6.1 Defended PhDs

[4211] A. B. H. Alaya. *Métrologie dans les réseaux d'accès radio pour la gestion de ressources pour le développement du concept "Always Best Connected"*. PhD thesis, Télécom ParisTech, Dec. 2008.

[4212] S. Barembruch. *Méthodes de filtrage particulaire par la détection et l'estimation autodidacte*. PhD thesis, Télécom ParisTech, Sept. 2010.

[4213] N. Castaneda. *Géo-localisation adaptative par modèles bayésiens hiérarchiques*. PhD thesis, Télécom ParisTech, July 2008.

[4214] J. Cornebise. *Processus Empirique et approximation particulaire*. PhD thesis, Télécom ParisTech, June 2009.

[4215] M. Depecker. *Modélisation de la performance perçue à partir de données explicatives fonctionnelles issues de mesures physiques*. PhD thesis, Télécom ParisTech, Dec. 2010.

[4216] S. Filippi. *Apprentissage des processus de décision markoviens partiellement observés*. PhD thesis, Télécom ParisTech, Nov. 2010.

[4217] J.-F. Germain. *Contributions des méthodes statistiques et des techniques d'optimisation à la quantification de données multi-dimensionnelles d'agrément de conduite.* PhD thesis, Télécom ParisTech, Oct. 2008.

[4218] Z. Harchaoui. *Apport de l'analyse COR pour le classement semi-supervisé*. PhD thesis, Télécom ParisTech, Nov. 2008.

[4219] T. B. Jabeur. *Technique d'égalisation partielle du canal dans un système de transmissions numériques pultiparteuses OFDM*. PhD thesis, Télécom ParisTech, Sept. 2009.

[4220] A. Kammoun. *Contributions à l'égalisation et l'identification semi-aveugle et analyse de performances*. PhD thesis, Télécom ParisTech, Apr. 2010.

[4221] M. Kharouf. *Application de la théorie des matrices aléatoires à l'évaluation de performances en communications numériques*. PhD thesis, Télécom ParisTech, June 2010.

[4222] O. Kouamo. *Estimation du coefficient de memoire par analyse du scalogramme*. PhD thesis, Télécom ParisTech, Jan. 2011.

[4223] N. Ksairi. *Stratégie de coopération dans les réseaux mobiles de type DFDMA*. PhD thesis, Télécom ParisTech, Mar. 2010.

[4224] S. Le Corff. *Estimations pour les modèles de Markov cachés et approximations particulaires. Applications à la localisation et cartographie simultanées*. PhD thesis, Télécom ParisTech, Sept. 2012.

[4225] A. Lefevre. *Méthodes d'apprentissage de dictionnaire appliquées à la séparation des sources*. PhD thesis, Télécom ParisTech, Oct. 2012.

[4226] A. Lung-Yut-Fong. *Détection robuste de ruptures pour les signaux multidimensionnels. Application à la détection d'anomalies dans les réseaux*. PhD thesis, Télécom ParisTech, Dec. 2011.

[4227] N. Mahler. *Méthodes d'apprentissage pour des flok discrets multi-échelles et applications à la finance*. PhD thesis, Télécom ParisTech, Jan. 2012.

[4228] T. Rebafka. *Estimation d'une distribution de temps de réponse très rapide en fluorescence moléculaire*. PhD thesis, Télécom ParisTech, Oct. 2009.

[4229] N. Sokolovska. *Contributions to the estimation of probabilistic discriminative models: semi-supervised learning and feature selection*. PhD thesis, Télécom ParisTech, Feb. 2010.

[4230] J. Villard. *Stratégies de coopération ciblées pour réseaux de capteurs sans fil*. PhD thesis, Télécom ParisTech, Dec. 2011.

[4231] J. A. Ybanez. *Poursuite multimodales de personnes*. PhD thesis, Télécom ParisTech, June 2008.

16.6.2 Ongoing PhDs

- G. M. Adell *Optimisation stochastique distribuée dans les réseaux de capteurs*.
- A. Ataya *Algorithmes d'apprentissage pour les modèles de Markov cachés via une approche bayésienne*.
- A. Bader *Etude et optimisation de la partie couche physique des réseaux de relais multi-sauts évolutifs*.
- A. Bellachehab *Optimisation distribuée dans les variétés. Application aux réseaux de capteurs.*

- H. Braham (12/12–) *Environment aware radio resource optimization in next generation radio access networks*
- E. Chautru *Apprentissage statistique des ensembles de niveau et application à l'analyse risque-bénéfice en nutrition*.
- A. Dematteo *Etude statistique de la spatialisation du phénomène de sloshing et mesures du risque*.
- C. Fox *Réduction de bruit dans la prise de son, mono/multi microphones*.
- B. Guedj *Agrégation d'estimations et de classifications : théorie et méthodes*.
- M. Jala *Analyse statistique de l'exposition du fœtus aux emissions des equipements de communication sans fils*.
- E. Kaufmann (09/11–) *Approche bayésienne et sélection de modèle pour l'apprentissage par renforcement*.
- Y. Khan *L'optimisation automatique de la gestion des ressources radio dans les réseaux cellulaire de la 4ème génération*.
- N. Ksairi *Stratégie de coopération dans les réseaux mobiles de type DFDMA*.
- A. Nouvellet (03/13–) *Traitement statistique du signal pour les sources infrasonores*.
- S. Robbiano *Méthodes d'apprentissage pour le Ranking Multi-classe*.
- A. Sanchez-Perez (09/12–) *Estimation adaptative pour des séries temporelles localement stationnaires*.
- A. Schreck (09/11–) *Méthodes de Monté Carlo robustes pour la simulation dans des espaces de grandes dimensions*.
- N. Seichepine (09/12–) *Factorisations Multimodales pour la structuration non supervisée des documents audiovisuels*.
- P. Sendorek *Etude d'un système d'autolocalisation comportant plusieurs récepteurs GNSS-RVs utilisant un système de géolocalisation tel que le GPS et plusieurs centrales inertielles K-IMU*.
- E. Sibony *Approches nouvelles pour l'agrégation d'ordonnancements : Transport Optimal et analyse harmanique*.
- M. Thameri *Techniques de poursuite et d'estimation robuste avec analyse de performance*.
- T. Wohlfarth *Méthodes d'apprentissage statistique pour la prédiction de séries temporelles et application à la prévision du prix des voyages*.
- J. Yao *Estimation en grande dimension*.
- R. Zhang *Méthodes d'apprentissage statistique en gestion de portefeuille pour la sélection de titres, la gestion du risque et l'optimisation de portefeuille*.
- B. Zheng *Détection d'évènements rares dans les données hautes fréquences et applications au trading algorithmique*.