

Laboratoire d'excellence  
dans le cadre de l'Emprunt National

Projet Bézout :  
Grandes Dimensions, Ergodicité, Combinatoire, Algorithmique et  
Probabilités

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## Résumé en français du projet

Dans les dernières années, des avancées considérables ont été faites à la frontière entre mathématiques et informatique, permettant de concevoir de nouveaux algorithmes et de nouvelles méthodes pour les analyser. Le projet de laboratoire d'excellence Bézout<sup>1</sup> se situe sur cet interface particulièrement dynamique. Il réunit plus de 200 chercheurs et doctorants, issus du Laboratoire d'Informatique Gaspard-Monge (unité mixte CNRS, ENPC, ESIEE, UPEMLV<sup>2</sup>, du Laboratoire d'Analyse et de Mathématiques Appliquées (unité mixte CNRS, UPEC, UPEMLV) et du Centre d'Enseignement et de Recherche en Mathématiques et Calcul Scientifique (ENPC). Ces trois laboratoires, tous évalués A+ par l'AERES lors de la dernière campagne, constituent déjà un axe majeur du PRES Université Paris-Est (UPE, réunissant ENPC, ESIEE, LCPC, UPEMLV et UPEC), possédant des équipes qui sont leaders en France sur certaines

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1. Étienne Bézout : mathématicien du 18<sup>e</sup> siècle ayant vécu en Seine-et-Marne, fondateur de l'algorithmique et grand pédagogue.

2. CNRS : Centre Nationale de la Recherche Scientifique

ENPC : Ecole des Ponts ParisTech

ESIEE : École Supérieure d'Ingénieurs en Électronique et Électrotechnique

LCPC : Laboratoire Central des Ponts et Chaussées

UPE : pôle de recherche et d'enseignement supérieur Université Paris-Est

UPEMLV : Université Paris-Est Marne-la-Vallée

UPEC : Université Paris-Est Créteil

thématiques (algorithmique et combinatoire, analyse en grande dimension, modélisation probabiliste ; analyse multifractale,...) ; l'un des objectifs de ce projet est de conforter ces thématiques et de créer de nouvelles synergies entre elles.

Le projet fédère une offre de formation de très haut niveau : les masters recherche en informatique et en mathématiques (là également, ce dernier est commun à l'UPEMLV et à l'UPEC) sont directement reliés à la qualité de la recherche des équipes ; les masters professionnels en informatique et en mathématiques valorisent un savoir faire par une formation répondant à des besoins professionnels forts. Ainsi 50 étudiants par an sont formés par le master d'informatique, 50 sont formés par le master de mathématiques. Le taux d'embauche des diplômés de master est très élevé (supérieur à 90% et le taux de chômage au bout de cinq mois est négligeable).

La formation doctorale, de l'ordre de 50 doctorants par an issus de ces équipes, aboutit à une formation de très haut niveau irriguant l'enseignement supérieur et la recherche d'une part, la recherche industrielle d'autre part. Cette formation doctorale s'inscrit au sein de l'Ecole Doctorale MSTIC (Mathématiques, Sciences et Techniques de l'Information et de la Communication) de l'UPE.

L'animation scientifique du projet sera assurée par des chercheurs reconnues au plus haut niveau international, et portera sur trois thèmes scientifiques interdisciplinaires :

- **Mathématiques discrètes et algorithmique.** Il réunit des chercheurs du LIGM et du LAMA (Marne et Créteil), qui ont développé des approches complémentaires ; les recherches dans le domaine de l'imagerie trouvent des valorisations auprès du CHU Henri Mondor.
- **Phénomènes en grande dimension.** Il réunit également des chercheurs du LIGM et du LAMA (Marne et Créteil), avec une approche permettant de développer des coopérations nouvelles.
- **Modèles probabilistes et modèles déterministes.** Il rapproche des chercheurs du LAMA et du CERMICS, qui ont constitué des groupes de travail communs depuis déjà plusieurs années.

L'Université Paris-Est possède une visibilité large sur ces thèmes, dont les enjeux sont fortement reconnus sur le plan international, et qui ne se retrouvent pas dans les universités du centre de Paris. Ce laboratoire d'excellence est une opportunité unique pour conforter la place du PRES sur ces thématiques dans le paysage francilien.

La notoriété des animateurs scientifiques de ces trois thèmes sera un atout, permettant notamment de favoriser les collaborations au meilleur niveau. Parmi eux, on compte deux membres senior de l'Institut Universitaire de France (Jean-Yves Thibon en Sciences et technologies de l'information et de la communication et Bernard Host, lauréat 2005 du prix "Charles-Louis de Saulx de Freycinet" de l'Académie des Sciences, en mathématiques), plusieurs membres ou anciens membres juniors (Stéphane Jaffard et Etienne Sandier, en mathématiques). Philippe Biane a reçu les prix Rollo-Davidson (London Math. Soc. 1995) et Lecomte (Académie des Sciences, 1998), Hugues Talbot a partagé en 2005 la récompense de la "Society of Australian

Engineers” et le prix DuPont 2006.

L’animation scientifique sera réalisée au quotidien par un bureau (un animateur et des adjoints répartis dans les établissements et les équipes), assisté d’un conseil scientifique extérieur (consulté fréquemment, en dehors de ses réunions, par voie électronique) et indépendant de l’ensemble des établissements constituant la tutelle des laboratoires. Une gestion par projets sera mise en place. Elle permettra une organisation souple autour d’objectifs validés par le bureau. Les projets pourront réunir des chercheurs, appartenant à des unités de recherche différentes, travaillant en collaboration pour une durée déterminée. Un objectif est aussi de faire émerger de nouvelles thématiques communes à différentes équipes.

Rappelons que les thèmes présentés ici bénéficient déjà du soutien financier de plusieurs programmes (ANR, projets européens principalement) qui ont reconnu leur importance. Les moyens supplémentaires attribués au laboratoire d’excellence serviront :

- à financer une dizaine de séjours courts de jeunes scientifiques étrangers ( 3 à 6 mois, pour des jeunes ayant eu leur doctorat depuis moins de 5 ans,
- à financer le séjour d’une année de chercheurs prestigieux, autour desquels sera organisée une année thématique,
- à financer des bourses de Master internationales : le laboratoire d’excellence utilisera pour cela le réseau de laboratoires avec lesquels des collaborations régulières sont institués pour avoir accès à un pool d’étudiants brillants : Montréal, Haifa, Santiago du Chili, King’s College et l’Imperial College de Londres, University College (London), CSIRO (Australie), Université de Rome 3, d’Osaka, d’Oslo, de Rome, l’ETH de Zürich.
- à financer des jeunes chercheurs sur un poste de 6 ans sur des thèmes transverses
- à organiser des événements scientifiques majeurs dans les thèmes retenus dans le projet.

La reconnaissance liée au laboratoire d’excellence permettra un accroissement du nombre de bourses de thèse affectées par les établissements porteurs dans les équipes composant le présent projet.

La constitution de ce projet en laboratoire d’excellence sera ainsi un moyen majeur, s’additionnant aux moyens dégagés par les financements ANR et européens, permettant d’avancer vers

- la constitution d’une force de recherche cohérente et dont les thèmes présentent une forte originalité, au moyen d’une synergie approfondie entre les équipes de trois laboratoires de pointe du PRES UPE,
- l’implication de ces équipes dans des coopérations européennes et internationales de tout premier plan,
- l’attraction dans les formations de master et doctorat des meilleurs étudiants, français, européens, et non-européens.

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# 1 Presentation of the research laboratories members of the Bézout project

Etienne Bézout (1730-1783) is a famous mathematician from Seine-et-Marne (region located at the near east from Paris), whose name is linked with Euclid's algorithm, and studied algebraic curves. His courses in mathematics played a key role in the development of science in France in the late 18th century.

## 1.1 The LIGM (Laboratoire d'Informatique Gaspard-Monge)

The Gaspard-Monge computer science research laboratory (LIGM) is supported jointly by the French National Center for Scientific Research (CNRS), by the University Paris-Est de Marne-la-Vallée (UPEMLV), by ESIEE Paris and by l'École des Ponts ParisTech (ENPC). The computer science research laboratory IMAGINE of the engineer school École des Ponts ParisTech has joined it since october 2009. The number of permanent researchers working at LIGM is 68 (10 CNRS, 32 UPEMLV, 16 ESIEE, 6 ENPC, and 4 from other institutions). The number of Ph.D. students is about 70. The Gaspard-Monge computer science research laboratory carries out research in computer science. The themes of research include theoretical computer science, analysis of natural languages, image and signal processing, the common link being the use of formalized methods that aim to accurately describe the phenomena under study. The computer science research laboratory is composed of five teams that can be identified thanks to their research themes which are at the origin of the projects of the laboratory. These themes are :

- Algebraic combinatorics and symbolic computation
- Algorithmics
- Algorithms, architectures, image analysis and computer graphics
- Computational linguistics
- Signal and communications

The computer science research laboratory is a centre of scientific activity which is developing thanks to the contacts established between the University Paris-Est de Marne-la-Vallée and the different engineer schools (ENPC, ESIEE) on the campus. Researchers from the laboratory take an important part in the preparation of the Postgraduate Diploma (they teach courses and supervise students). They are members of the MSTIC Ph.D. School of University Paris-Est. The University Paris-Est Marne-la-Vallée is also involved in developing international collaborations, which implies exchanging researchers, trainees and postdocs.

## 1.2 The LAMA (Laboratoire d'Analyse et de Mathématiques Appliquées)

The LAMA is a joint unit between CNRS, University Paris-Est Créteil (UPEC) and University Paris-Est Marne-la-Vallée (UPEMLV). It has 85 members (26 full professors, 37 assistant

professors, 19 PhD students, 3 persons for the administrative and technical staff). The research teams work on the following subjects :

- Analysis : Dynamics, wavelets Multifractal Analysis , real and complex analysis
- Partial differential equations : Models from fluid dynamics, elliptic and parabolic PDEs, Homogenisation techniques
- Analysis in large dimension : geometric and probabilistic aspects : functional inequalities, entropy and isoperimetry, statistical mechanics, géométric inequalities and convexity singular values of random matrices, signal processing and reconstruction
- Curvature related problems : minimal surfaces and surfaces with constant mean curvature in dimension 3, and in homogeneous, spaces, stationary lagrangian surfaces, Hypersurfaces with mean constant curvature, and asymptotically hyperbolic manifolds, semilinéaires equations of Allen-Cahn type, first eigenvalue of the Laplacian, extremal metrics in Kähler geometry, conformal geometry and nonlinear analysis
- Probability and statistics : Systems of particules en interaction, random walks in random media, stochastic partial differential equations, numerical probabilities and financial mathematics, limit theorems , statistic.
- Reliability, statistical methods for industry : Bayesian networks, Statistics of extreme values, other statistical studies

### 1.3 The CERMICS (Centre d'Enseignement et de Recherche en Mathématiques et Calcul Scientifique)

CERMICS is a laboratory of École des Ponts ParisTech, hosting joint research teams with INRIA and University of Marne-la-Vallée. It is hosting 13 permanent researchers among whom 9 have a HdR, 5 to 10 visitors per year (among whom 3 professors are invited by INRIA), 6 PostDoc, 20 PhD students , 2 secretaries. It is located at École des Ponts ParisTech in Champs-sur-Marne. The scientific activity of CERMICS covers several domains in scientific computing, numerical analysis, modelling, and optimization.

CERMIC has 22 permanent researchers and PhD students, among the following teams :

- PDEs and materials ,
- fluid Dynamics,
- Optimization and systems,
- Applied Probabilities,
- Molecular and multiscale simulation.

## 2 Masters and PhDs

Investigations performed by UPE show that the former students of our masters have no problems finding jobs : 18 months after obtaining their diploma, 87% have obtained a position. After the master “mathematics and applications” ,some students start a PhD thesis. The others are either

financial engineers, informaticians, or consultants. On the average, they obtained an employment after 6 months.

## **2.1 Master of Computer Science of Université Marne-la-Vallée Paris-Est**

The master has been totally renewed at the moment of the conception of the proposal for the renewal of its certification. The new version of the formation is starting with promotion 2009-2011.

The results of the Master of Computer Science are excellent. The number of students is around 50 a year, among them about 10 are in the Science option. The success rate is around 90% in second year. From OFIPE, the organism in charge of the evaluation of the teaching programmes of the university, depending on years, 95 to 100% of graduate students in Engineering find a job in a company; for graduate students in the Science option, 30% of them start a PhD thesis, while 60% go to industry.

There are five courses in the new version of the master :

- Information Systems and Web Applications,
- Softwares and Networks,
- Signal and Images,
- Computational Linguistic, and
- Algorithms - Bioinformatics - Combinatorics.

Except the last one, which is clearly devoted to research, the other courses aim to teach student for an insertion in the world of industry as well as in the world of research. Except the first one, these courses reflect the domains of research of the Computer Science Laboratory Gaspard-Monge; the wealth of the master lies therefore in the expertise of the members of the labs. The expected amount of students is about 25 by course, excepted for the last one, where 10 students are expected. The amount of courses for each student is about 300 hours for the first year, and 250 hours for the second year, when there is more time for professional training (in industry or university). Inside each course, a core curriculum contains technical lessons as well as more theoretical ones. This makes this formation very specific, compared to engineering schools. This blend gives to the students the ability to consider problems under many perspectives which is certainly enriching for their professional qualifications. In addition to University professors, some courses are delivered, for technical topics, by people coming from companies, but also, for more theoretical topics, by researchers (members of CNRS or ESIEE). Through optional lessons, inside one course, every student can acquire expertise in a more specific topic – software or network, signal processing or image analysis – and, depending on its objectives, to emphasize the technical or theoretical aspects of the formation.

In collaboration with ESIEE, an international master is opening. It aims to attract the best foreign students and allows them to become experts in the fields of digital image and distributed real time systems. After a common core focused on fundamentals of both fields during the first

year, the second year splits into two courses, one about digital imaging corresponding to the "Signal and Images" course (specifically the image analysis and synthesis side of the course), the second one about distributed real time systems, which is also a component of the "Software and Network" course.

## 2.2 Master of Mathematics of Université Paris-Est

This master includes two specialties.

- The master **Mathematics and Applications** produces high level mathematicians motivated by teaching and/or (academic and industrial) research, and market finance. indeed, modeling of financial markets requires sophisticated mathematical tools. The finance track produces specialists in quantitative analysis, structuration and trading of complex financial products.
- In the **Mathematical Engineering, informatics and statistics track**, the main focus is put on random models (probability and statistics) but other aspects of applied mathematics are also present in M1 (optimization, modeling and numerical analysis). A mandatory requirement for actual applications is a thorough knowledge of informatic tools; therefore the cursus includes specific courses in this subject, together with application projects, which allow the students to handle theoretical notions within realistic situations, to develop their autonomy, their initiative, and to make the acquisition of a good informatic practice. The **actuary studies track** students are specifically formed for actuary engineering professions within insurance and bank groups.

Courses that are specific to each track are supplied by nonacademic persons, who work in the specific subject (about one third of the curriculum is spent by the students in a professional framework).

## 2.3 Doctoral school MSTIC (Mathématiques, Sciences et Techniques de l'Information et de la Communication)

The Doctoral School MSTIC is the administrative structure to which the PhD students are affiliated, in the case where their advisor is a researcher in one of the laboratories of the doctoral school. These laboratories are involved in the following scientific domains :

- fundamental and applied mathematics (analysis, algebra, geometry, probabilities theory, statistics...)
- information, communication sciences and technics (including signal and image processing, automatics,...)

In Doctoral School MSTIC, there are

- 11 laboratories
- 240 PhD students
- 250 researchers

## 3 From discrete mathematics to algorithmic

### 3.1 Scientific context

#### 3.1.1 Discrete models of computation

One of the main challenges in modern computer science is to develop automated techniques for the verification of complex computing objects such as circuits and programs. To support this objective, a thorough examination of both finite and infinite formal models which naturally appear in this context is required. Our project subscribes to this line of research and proposes to study particular models associated with programs, electronic devices, or natural language data. Let us review the main directions of research. Challenging developments in automata theory are under consideration :

- distance automata, which can be applied to natural language processing or combinatorial optimization,
- multidimensional subshifts, dynamical systems associated to transducers, trees and timed automata, tree-subshifts of finite type, timed automata,
- topological and symbolical dynamical systems (cellular automata), ergodic theory and its interactions with additive combinatorics,
- finite automata with potentially infinite inputs which are not necessarily linearly ordered,
- distance automata, which can be applied to natural language processing or combinatorial optimization, kernel methods in automata theory and classification algorithms.

Infinite models for software verification will be the object of further advances :

- algorithmic methods for infinite graphs, by extending algorithmic methods from finite graphs to graphs of stack automata,
- structures associated with recursive programs, aspects related to the control flow of systems.

Another direction of research is the development of new algorithms which provide efficient performances on average situations, in the case of uniform or nonuniform distributions on inputs, and the study of combinatorics on words including the theory of codes.

#### 3.1.2 Algorithmic for computational biology

This thema involves different research directions.

- The design of radiation treatment is using computer tomography that detects the exact location of the tumor and the organs at risk. Our algorithmic interest is concerned with computational aspects of minimizing the total setup time of a treatment for new generation multi-leaf collimator settings (rotating beam head and orthogonal multi-leaf collimators).
- The *Consecutive-Ones Property* (C1P) of matrices is playing an important role in combinatorial optimization ; we are interested in designing efficient algorithms for identifying minimum size and developing fast algorithms for finding minimal sets of rows or columns that prevent the matrix from having the C1P.

- The availability of complete genome sequences plays an important role for the analysis of similarities and differences between genomes. But extracting pertinent information from them faces a huge challenge due to the large size of data. The efficiency of existing algorithms to deal with the notion of *absent words* in DNA sequences (also called *unwords* or *forbidden words*) has to be reviewed, by exploring deterministic or probabilistic techniques, as well as with the use of parallel models of computation if necessary.
- Protein interactions identified on a genome-wide scale are commonly visualized as protein interaction graphs, where proteins are vertices and interactions are edges. In this context, the study of pattern matching problems in graphs has become more and more important, and the term *graph motif* plays a central role. Given a multiset of colors (the motif) and a vertex-colored graph (the target graph), we are interested in designing efficient parameterized algorithms for a connected subgraph of the target graph that is exactly colored by the motif.
- We are interested in problems related to the the PERMUTATION PATTERN problem. Given two permutations  $\sigma$  and  $\pi$ , the problem is to decide whether  $\sigma \preceq \pi$ . Although the PERMUTATION PATTERN problem is NP-hard, a challenging problem is to decide whether it is polynomial-timesolvable but may be polynomial-time solvable.

### 3.1.3 Image and signal processing

Let us review the main research directions in this area.

- We have developed new approaches to obtain a complete three-dimensional reconstruction of an object from a series of images taken around the object.
- Algorithm-architecture adequacy consists in simultaneously studying the algorithmic and architectural aspects by taking into account the constraints (resources, response time...) while optimising the implementation and reducing development time.
- We are concerned with the simulation of the illumination of a scene, the simulation of the participating mediums and the simulation of the light/matter interactions, with applications to virtual reality and augmented reality.
- Discrete geometry and computational geometry take part of the theoretical study of the models of spatial objects which can be handled by computers, as well as transformations that can be applied to these models.
- We propose new operators applying to spatial data, images or geometrical models, which preserve topology or modify it in a controlled way.
- We develop new image segmentation methods by a series of approaches based on minimisation of global, rather than local, performance indexes.
- Automatic learning is used to perform tasks in computer vision that are intractable by conventional methods (detection of objects, recognition of handwriting, segmentation, indexing, image mining).
- We contribute to the evolution and the enrichment of the field of mathematical morphology, both on theoretical and algorithmic aspects, as well as by developing various applications.

- In large-size image processing problems (3D or 3D+t) arising in various application areas such as functional MRI, Positron Emission Tomography, microscopy imaging or satellite imaging, one needs to solve optimization problems involving a large number of variables by resorting to efficient data representations. The objective is to achieve better performances and to relax some restrictive assumptions.
- We develop classification techniques based on multifractal attributes, which are widely used in signal and image processing for physiological data (heartbeat intervals, EEG, medical imaging). Interactions with the teams located at CHU Henri Mondor are under consideration. These methods rely heavily on wavelet techniques; an expertise on the subject has been developed by the group of Pesquet at LIGM, specifically for applications in signal and image processing and we will develop interactions between these two groups.

### **3.1.4 Algebraic Combinatorics and Computer Algebra**

These research themes are centred around combinatorial and algorithmic aspects of various questions of pure or applied mathematics, most of the time connected with representation theory. We develop computational methods which are systematically implemented in computer algebra software.

### **3.1.5 Kernel methods**

Kernel methods are widely used in learning and classification techniques. They usually involve vectors which represent the signatures of the patterns. The rank of an experiment is compared with a witness through the scalar product of their signatures. These methods rely on formal language theory. Actually, to handle speech recognition or computational biology, the patterns are not fixed-size objects, and, therefore, any signature by a fixed-length vector is not relevant. That is the reason why Cortes, Haffner, and Mohri have recently introduced the notion of rational kernels, which consists in computing the rank of an experiment with a weighted transducer. A weighted transducer is a two-tape automaton which associated to a pair of words, typically a witness and an experiment, a weight, that is a scalar value computed along the paths labeled by the pair of words. This notion opens a number of questions, practical or theoretical. How to find a efficient algorithm for transducer synthesis? Is it possible to define a positive and negative learning process? How to ensure the convergence or the quality of the learning or the classification process? How to characterize the languages which can be defined as intersection of half-spaces defined by kernel methods? Is it possible to define kernels with infinite vectors, that is, as compact operators? Transducer over infinite words are they pertinent for this modelization?

## **3.2 Researchers in charge of the scientific animation**

### **3.2.1 Jean Berstel**

Prof. Jean Berstel (University Paris-Est) received his PhD in 1967 and his Doctorat d'État in 1972, both at the University of Paris. He got his first assistant professorship position at the University Strasbourg in 1970. He became professor in computer science at the University of Paris 6 in 1973, and moved to University of Marne-la-Vallée in 1995, where he is Professor Emeritus since 2005. His research areas are automata theory, formal languages, noncommutative power series, combinatorics on words. He participated in several European projects in theoretical computer science, and supervised about a dozen of PhD students. He has co-authored several textbooks on formal languages, codes and automata, and he co-edited the series of Lothaire's books on combinatorics on words. He published more than 100 research papers. He received a doctor honoris causa award from the University of Turku in 2005.

### **3.2.2 Philippe Biane**

Dr. Philippe Biane received his PhD in 1985 at Université Paris 7 and his Habilitation à diriger des recherches in 1992 at Université Paris 6. He is Directeur de Recherche at CNRS. His research area concerns probabilities, stochastic calculus, operator algebra and probabilities and theory of representations. He published about 60 research papers, supervised 4 PhD students. He is a member of editorial committee of "Probability Theory and Related Fields", of program committee of Emile Borel Center, of editorial committees of IHES publications and Rendiconti Del Seminario del Università di Padova. He received the Rollo-Davidson price (London Math. Soc. 1995), Lecomte price (Académie des Sciences, 1998), and has been invited to the International Mathematicians Congress (2002).

### **3.2.3 Maxime Crochemore**

Prof. Maxime Crochemore (University Paris-Est and King's College London) received his PhD in 1978 and his Doctorat d'état in 1983 at the University of Rouen. He got his first professorship position at the University Paris-Nord in 1985 where he acted as President of the Department of Mathematics and Computer Science for two years. He became professor at the University Paris 7 in 1989 and was involved in the creation of the University of Marne-la-Vallée where he is Professor, Emeritus from 2007. He also created the Computer Science research laboratory of this university in 1991 and was the director until 2005. From 2004 to 2006, he was Deputy Scientific Director of the Information and Communication Department of CNRS. Prof. Crochemore was Senior Research Fellow from 2002 to 2007 and is presently Professor at King's College London. His research area in algorithmics comprises text processing, text compression, automata theory, computational genomics. He is a world leader on combinatorial pattern matching. He has been the recipient of several French grants on string algorithmics and bio-informatics. He participated

in a good number of international projects in algorithmics and supervised more than twenty PhD students. He has co-authored several textbooks on algorithms and published more than 150 articles, among which 132 are referenced on the DBLP Bibliography Server as of June 2010.

### **3.2.4 Bernard Host**

Prof. Bernard Host (University of Marne la Vallée) received his Thèse d'État in 1979 at the University Paris-Nord. he became full professor in Marseille in 1990. Since 1996 he his professor at the University of Marne la Vallée. His research area comprises topological and symbolics dynamics and ergodic theory. He is particularly interested in interactions with additive combinatorics. He is involved in different international cooperations , in particular with the CMM of the University of Chili (coordinator of a PICS project). In 2005 he received the prize "Charles-Louis de Saulses de Freycinet" decerned by the French Academy of Sciences. He is Senior member of the Institut Universitaire de France.

### **3.2.5 Stéphane Jaffard**

Professor Stéphane Jaffard's (University Paris Est Créteil Val-de Marne) main subjects of study are harmonic analysis, signal processing, wavelets and fractals. He is author or co-author of 55 articles in international journals and one book, and supervised 11 PhD students. He is a member of the editorial board of several journals (Applied and Computational Harmonic Analysis, Journal of Fourier Analysis and Applications, Constructive Approximation). He has been the coordinator of an "Hubert Curien Project" (research in cooperation with Tunisia) during 6 years. He has been a member of the "Institut Universitaire de France". He is the former president of the SMF (French Mathematical Society).

### **3.2.6 Renaud Keriven**

Renaud Keriven is professor of Computer Science at Ecole des Ponts ParisTech where he heads the IMAGINE group and associate professor at Ecole Polytechnique. He received the M.S. degree from Ecole Polytechnique in 1988, obtained his Ph.D. from the Ecole des Ponts ParisTech in 1997 on Level Sets Method in Stereo and Computer Vision, and his HDR ("Habilitation a Diriger les Recherches") from Paris-Est University in 2006 on Shape Optimization in Computer Vision. From 2002 to 2007, he was assistant director of the INRIA Odyssée team (leader Pr. O. Faugeras) at Ecole Normale Supérieure, Paris. He has published in the most prestigious journals and conferences of image processing, computer vision and medical image analysis. Professor Keriven serves as chair and regular reviewer for the most important journals and conferences of his domain. His work on stereo-vision received the "best paper award" at the European Conference in Computer Vision (1998) and he received a honorable mention from the European Union (Cor Bayen award) in 1999. His research interests include 3D photography, Multiview Stereovision, Shapes and Shape priors in Computer Vision, Discrete and continuous

optimization in Computer Vision and Generic Programming on Graphics Processing Units. His H-index is 21, and his most cited paper scores 480 citations.

### 3.2.7 Dominique Perrin

Dominique PERRIN is Professor (CE) at University of Paris-Est Marne-la Vallée since 1993 and Director of ESIEE Paris since 2004. He graduated from Ecole Polytechnique in 1968, holds a PhD from Université de Paris (1970) and a Thèse d'État from University Paris 7 (1975). In the past, he has been President of Université de Marne-la-Vallée (1997-2002), Associate Professor at Ecole Polytechnique (1989-2002), Professor at Université Paris 7 (1983-93), and Vice President for research (87-92), Professor at Université de Rouen (1977-83), Stagiaire, Attaché, Chargé de Recherches at CNRS (1970-77??), Professor at Universidad de Chile (1972-73). He is the author or editor of 8 books among which Theory of Codes, Academic Press, 1984 (with Jean Berstel), Combinatorics on Words, Cambridge University Press, 1983, Algebraic Combinatorics on Words, Cambridge University Press 2002 (with Jean Berstel), Infinite Words, automata, semigroups and games, Elsevier, 2004 (with Jean-Eric Pin), Applied Combinatorics on Words, Cambridge University Press, 2005 (with Jean Berstel), Codes and Automata, Cambridge University Press, 2009 (with Jean Berstel and Christophe Reutenauer). He is the author of more than 100 scientific journal papers in the fields of automata theory, variable-length codes and combinatorics on words. He is also President ad honorem of Université de Marne-la-Vallée (since 2002), Member of Academia Europea (since 1989), Member of editorial board of Theoretical Computer Science (North Holland), Semigroup Forum (Springer), Int. J. of Algebra and Computation (World Scientific), et Advances in Applied Mathematics (Academic Press). He has been Visiting Scientist at IBM Yorktown (summers 1989, 90, 91) and Almaden (summers 1992, 93).

### 3.2.8 Hugues Talbot

Hugues Talbot has been an associate professor of computer science at ESIEE and a member of the computer science institute at Paris-Est University since 2004. He graduated from Ecole Centrale de Paris in 1989 and received the PhD in mathematical morphology in 1993 from Ecole des Mines de Paris. He was a visiting scientist at MIT, Cambridge, USA, from 1991 to 1992, a research engineer at Isover Saint Gobain, Rantigny, France, between 1990 and 1994, and a principal research scientist at CSIRO, Mathematical and Information Sciences in Sydney, Australia from 1994 to 2004. He is the author of over 70 articles, and has edited or authored 7 books in the fields of computer science, image analysis and computer vision. He shared the 2005 society of Australian engineers award and the 2006 DuPont prize for his work on the automated diagnosis of melanoma.

### 3.2.9 Jean-Yves Thibon

Jean Yves Thibon received the M.S. degree in mathematics and the Ph.D. degree in computer science from the University of Paris VII : Denis Diderot, Paris, France, in 1981 and 1987, respectively. Since 1992, he has been a Full Professor of computer science at the University Paris-Est Marne-la-Vallée, where he is heading a research team working in algebraic combinatorics and computer algebra. He is a Senior Member of the Institut Universitaire de France since 2008. His research interests include symmetric functions, computer algebra, representation theory, combinatorial Hopf algebras, quantum groups, and invariant theory. He is one of the three managing editors of the journal *Séminaire Lotharingien de Combinatoire* and a regular organizer of the eponym seminar. He is a Member of the Editorial Board of the *Journal of Algebra*, of the *International Journal of Combinatorics*, and of the Standing Committee of the international conference *Formal Power Series and Algebraic Combinatorics*. He has been involved in several national and international projects in combinatorics. He has published some 120 research papers, of which 97 are referenced in *Mathematical Reviews*.

### 3.2.10 Stéphane Vialette

Stéphane Vialette (Université Paris-Est) received his PhD in 2001 at the LIAFA University Paris 7. He was a postdoctoral fellow in computational molecular biology at the LGM Ecole Normale Supérieure from 2001-2003, and he became assistant professor in the bioinformatic group at the LRI Université Paris-Sud 11 in 2003. Since 2007 he joined the computer science laboratory at the Université Paris-Est as a full time CNRS researcher. His research area includes algorithmic (polynomial-time approximation and parameterized complexity) for high-order intervals, biological network matchings and comparative genomics. He supervised two PhD students. He has co-authored a MIT textbook on combinatorics for comparative genomics, and published 25 journal papers and 31 papers in international conferences (54 are referenced on the DBLP bibliography Server as of June 2010).

## 3.3 Perspectives of french and international collaborations

Let us first mention all the collaborations with the biomedical scientific domain, which are natural within the PRES Université Paris-Est. Besides, several centers have a focus on research similar to ours and have strong relations with us.

- In France, this includes LIAFA (Paris 7) for automata and for enumerative combinatorics, LIX (Polytechnique) for combinatorics and LaBRI (Bordeaux) for automata and bio-informatics, INRIA (Roquencourt and Sophia-Antipolis) for image processing and analysis.
- Numerous links exist with research centers like LACIM (Montréal) for combinatorics, CTCS (Aachen) for logic and automata, Haifa for bio-informatics, King's College London for bio-informatics and algorithms, Warsaw for algorithms, McMaster (Hamilton, Ontario) for stringology, Palermo for bio-informatics and automata.

- Several international initiatives include researchers from our group : séminaire Lotharingien de combinatoire (Wien, Bologne, Marne-la-Vallée), the AutoMathA project (European Science Foundation),
- In the domain of biomedical image analysis, we developed strong links with both academic and industrial partners, in France and abroad : Henri Mondor Hospital and Faculty of Medicine (Créteil), University College (London), CSIRO (Australia), Siemens Corporate Research (Princeton), General Electric Healthcare (Buc), Sanofi (Toulouse).
- Let us mention an intense and increasing cooperation with the "Centro de Modelamiento Matemático" (Chile university, Santiago , UMI 2807), and in particular with Prof. Alejandro Maass.

We propose to extend these cooperations by new initiatives including Special Years on selected topics : regular cost functions, symbolic dynamics and automata, kernel methods for automata...

We will invite Marteen de Hoop, professor at Purdue University in June 2010. He is an internationally recognized specialist in the analysis of seismic images, and the inverse problems related with them ; the methods he developed combine pseudodifferential operators, wavelet analysis and multifractal imaging.

## 4 Phenomena in high dimension

### 4.1 Scientific context

This program will bring together internationally leading researchers from the LAMA and LIGM, concerned with several disciplines : probability theory, statistics, high-dimensional geometry, convexity, combinatorics, mathematical physics and theoretical computing.

#### 4.1.1 Geometry in high dimension

- The research in Asymptotic Geometric Analysis is focused on the search for phase transitions and threshold behavior in high-dimensional normed spaces.
- In the area of Isoperimetric principles it will be important to investigate further the interplay between geometric inequalities, mass transportation and probabilistic and semi-group tools.
- Reconstruction of signals, exact reconstruction or approximate reconstruction is a very active subject in particular in statistic, after the recent great discovery from E. Candes et T.Tao (2005) about compressive sensing. Compressed sensing interacts with statistics, approximation theory, random matrix theory and asymptotic combinatorics. Surprisingly it also interacts strongly with High Dimensional Geometry. The dual problem may be formulated as a linear error correcting code problem.

### **4.1.2 High Dimensional random matrices.**

The study of the behavior of the singular values of high dimensional random matrices when the entries are not i.i.d. is quite open, in particular in the important case of the empirical covariance matrix of a random high dimensional vector. The main questions of universal principles as in the classical "ensemble" in random matrix theory are still open.

## **4.2 Researchers in charge of the scientific animation**

### **4.2.1 Djalil Chafaï**

Djalil Chafaï received his PhD in 2002 and his Habilitation à Diriger des Recherches in 2008 from Université de Toulouse. Before joining Université Paris-Est Marne-la-Vallée, he has been working for various institutions including Centre National de Recherches Météorologiques, Oxford University, and Institut National de la Recherche Agronomique. His main scientific activities cover three areas of pure and applied mathematics : analysis, probability theory, and statistics. His most recent works concern the analysis and geometry of Markov processes in relation with random matrix theory or partial differential equations. He has co-supervised 1 PhD and has currently two PhD students. He is the author or co-author of two books and more than 20 research papers. He is currently preparing a new book on high dimensional phenomena, in collaboration with three other researchers of LAMA.

### **4.2.2 Philippe Loubaton**

Philippe Loubaton received the M.Sc and the Ph.D. degrees from Ecole Nationale Supérieure des Télécommunications, Paris, France, in 1981 and 1988, respectively. From 1982 to 1986, he was a member of the technical staff of Thomson-CSF/RGS, where he worked in digital communications. From 1986 to 1988, he worked with the Institut National des Télécommunications as an Assistant Professor of Electrical Engineering. In 1988, he joined the Ecole Nationale Supérieure des Télécommunications, Paris, France, working in the Signal Processing Department. Since 1995, he has been Professor of Electrical Engineering at Marne la Vallée University, Champs sur Marne, France. After some works on two parameter stationary stochastic processes and linear system theory, his present research interests are in statistical signal processing, digital communications with a special emphasis performance analysis of large communication systems and statistics of large random matrices. Philippe Loubaton served as associate editor for the IEEE Transactions on Signal Processing (1998-2001, 2002-2005), for the IEEE Communications Letters (2001-2003), and is presently associate editor for Eurasip Signal Processing and Traitement du Signal. He was a member of the IEEE Signal Processing for Communications technical committee (1998-2004), and a nominated member of the french national university council from 2000 to 2009. He is the author or co-author of more than 70 journal papers and 100 conference papers. Philippe Loubaton is IEEE Fellow.

### 4.2.3 Alain Pajor

Alain Pajor is graduate from University Pierre et Marie-Curie (Paris VI), Habilitation à diriger des recherches (1989). He is professor of mathematics at University Paris-Est Marne-la-Vallée since 1992. He has supervised 6 PhD students, and he is the author or co-author of about 60 research papers. He was involved in many international research programs and in particular head of the Research Training Network "Phenomena in High Dimensions" 2004-2008 (6th European Marie-Curie Programme). His research area comprises Asymptotic Geometric Analysis and its connection with Random Matrix Theory and Reconstruction of signals.

## 4.3 Perspectives of national and international collaboration

### 4.3.1 Invited researchers

- Professor Pietro Caputo, University Roma 3, 2010-2011, UPEMLV funding

## 5 From probabilistic to deterministic models

### 5.1 Scientific context

#### 5.1.1 Mathematical Finance

The main activities concern theoretical results, modeling and numerical calculus motivated by mathematical finance problems. The research team produced **the software Premia** which contains numerical algorithms as well as theoretical background and bibliography concerning the recent contributions in this area. It is intended to be a benchmark for the algorithms presented in the recent literature as well as an instrument for the training of students in masters of mathematical finance. It represents also a bridge between the academic word and professionals - a consortium of five french and three foreign banks are support the project by a means of a fee paid each year. In return we present each year a new version of the software containing new algorithms and recent bibliography and we discuss with our professional partners the axes of development for the following year. Our theoretical contribution to the research in this area concerns stopping time problems (related to American option pricing and hedging), applications of Malliavin calculus to sensitivity computations (the so called Greeks), models with jumps and approximation schemes.

#### 5.1.2 Link between Stochastic Differential Equations and deterministic Partial Differential Equations.

There are several significant topics :

- Backward Stochastic Differential equations (BSDE's) this is a generalization of the well known Feynman Kac formula which gives a stochastic representation for the solution of non linear Partial Differential Equations.
- Optimal stopping problems for continuous diffusion processes but also for jump type diffusions.
- Control and stochastic control. BSDE's turn out to be a central instrument in this area.
- Approximation problems : discretization of stochastic differential equations, high order schemes, stochastic approximation, numerical methods in high dimensional problems.
- Applications of Malliavin calculus to the study of the regularity and to density estimates for the solution of a Stochastic Differential Equation - which corresponds to the fundamental solution of the Cauchy problem.

### 5.1.3 Markovian dynamics and evolution equations

This theme brings together researchers from several disciplines : probability theory, statistics, partial differential equations, numerical analysis. The modeling of stochastic evolution phenomena plays a crucial role in most fields of applications of mathematics. Discrete and continuous Markov processes are at the heart of such models, and their study is still under active development. Markov Chains Monte Carlo is one of the most useful algorithm available to date. The long time behavior of Markov processes is related to fundamental aspects of stochastic analysis and metric geometries. The dynamics itself may involve partial differential equations of various types, with or without jumps. On the numerical side, the simulation and estimation of Markov processes is a key point in all their applications, and offers a wide range of open questions for mathematicians. Attention will also be paid to the Ginzburg-Landau model in supraconductivity since it plays an important role in mathematical analysis, , and a central one in supraconductivity. The techniques developed for it lead to powerful new techniques in order to study other nonlinear and non-convex models, in material sciences and homogeneization.

The main areas of this theme are as follows :

- Monte Carlo Markov Chains algorithms
- Diffusions with singular dynamics or boundary conditions
- Collective phenomena : oscillators, interacting particle systems
- Piecewise Deterministic Markov Processes
- Ginzburg-Landau model

## 5.2 Researchers in charge of the scientific animation

### 5.2.1 Vlad Bally

Prof. Vlad Bally received his PhD in 1986 from the University of Bucharest and his Habilitation in 1992 from the University Paris VI. He worked as a researcher in the Center of Mathematical Statistics of the Roumanian Academy up to 1990, benefits of a post doctoral fellowship and a

invited professor position in the University Paris VI in the period 1990-1993 and between 1993 and 2001 he occupied a professor position in the University of Maine. Between 2001-2003 he benefits of a detachment in the team Math-fi of INRIA and then he joined the University of Marne la Vallée as a professor. He worked in topics of stochastic calculus as Markov Processes, Approximation Schemes, Backward Stochastic Differential Equations, Stochastic PDE's and Malliavin Calculus. He has supervised 7 PhD students and he is the author or co-author of about 45 research papers.

### **5.2.2 François Bouchut**

François Bouchut received his PhD in 1992 and "habilitation à diriger des recherches" in 1998, both from University of Orléans. He has been employed by CNRS since 1991, and is "directeur de recherches" since 2004. He arrived in Marne-la-Vallée in 2009 after working ten years at the Ecole Normale Supérieure de Paris. He has been working on the analysis of hyperbolic partial differential equations, and on their numerical approximation. At the level of mathematical analysis, he has worked for example on questions related to uniqueness and stability for linear transport equations with discontinuous coefficients, and on the structural analysis of relaxation models. He has been involved in two long term collaboration projects. The first concerns gravity driven debris flows in collaboration with the Institut de Physique du Globe de Paris, since 2002. He is the coordinator of an ANR project on this subject, running from 2006 to 2010. The second project is on ocean and atmosphere circulation in collaboration with the Laboratoire de Météorologie Dynamique UMR 8539, since 2003. He is a team manager of an ANR project starting in 2010 on this subject, with the aim to develop efficient numerical methods for solving shallow water type models over the sphere with applications in meteorology. He has more than 70 journal publications, and is the author of one book, coauthor of two other books. He is member of the editorial board of Journal of Hyperbolic Differential Equations, Communications in Mathematical Science, Mathematical Models and Methods in Applied Science. He has supervised 2 PhD students. He is currently the director of the LAMA.

### **5.2.3 Robert Eymard**

Robert Eymard is now professor of mathematics at University Paris-Est Marne-la-Vallée, and is the head of Doctoral School Mathématiques, Sciences et Techniques de l'Information et de la Communication. His research domain mainly concerns finite volumes for physical and engineering problems. He coauthored the book "finite volume methods" in the Handbook for Numerical analysis, with T. Gallouët and R. Herbin (2000). He is involved in research collaborations with WIAS Institut (Berlin), Technical University (Bratislava) and doctoral courses in Cambodia and Indonesia. He has supervised 17 PhD students, and he is the author or co-author of about 60 research papers.

#### 5.2.4 Nicolas Fournier

Nicolas Fournier's main subject of study are probability theory (statistical mechanics, stochastic calculus of variations) and partial differential equations of kinetic equations (uniqueness and regularization properties). He received his PhD at Paris 6 in 1999, then spent 5 years as assistant professor in University Poincaré (Nancy), where he obtained his habilitation à diriger des recherches in 2004. He is now Professor at Université Paris Est since 2005. He is the author or co-author of more than 40 research papers. He supervises the ANR project MADCOF (2009-2012).

#### 5.2.5 Benjamin Jourdain

B. Jourdain (Ecole des Ponts ParisTech) received his PhD in 1998 and his habilitation à diriger des recherches in 2002. He is researcher at Cermics, professor at Ecole des Ponts and also assistant professor at Ecole Polytechnique. His research areas are -probabilistic particle methods for nonlinear PDEs with applications to polymeric fluids, quantum chemistry and molecular simulation, -numerical methods in finance (variance reduction, discretization of SDEs). He has supervised 4 PhDs and is the author or co-author of 2 books and 40 research articles.

#### 5.2.6 Damien Lambertson

Prof. Damien Lambertson received his PhD in 1983 and his Habilitation à Diriger des Recherches in 1992 from University Pierre et Marie Curie (Paris 6). Before joining the University of Marne-la-Vallée, he held a research position at Ecole des Ponts. He has been Professor at Marne-la-Vallée since 1993. He contributed to the development of research in mathematical finance in the laboratory and has been in charge of the DEA (now master recherche) since 1995. He is currently "directeur de l'UFR de mathématiques". His research interests are in stochastic calculus and its applications in finance, and especially optimal stopping problems and American options. He has supervised 12 PhD students and has been a member of the steering committee of a European network on advanced mathematical methods for finance. He is associate editor of *Mathematical Finance* and co-editor of ESAIM Probability and Statistics. He is the author or co-author of one book and about 30 research papers.

#### 5.2.7 Régis Monneau

Régis Monneau received his PhD in 1999 and his "Habilitation à diriger les recherches" in 2002 at Paris 6 University. He is researcher at CERMICS at the Ecole des Ponts ParisTech. His research area is in nonlinear partial differential equations, free boundary problems and their applications, including modeling, analysis, numerical analysis and simulations. He has been the leader of a french ACI project (2003-2007) on the dynamics of dislocation curves in crystal.

He has supervised 5 PhD students and 4 post-doc students. He has published more than 70 articles.

### **5.3 Perspectives of national and international collaboration**

#### **5.3.1 Invited researchers**

- Professor A. Tagaushi, from Osaka University Japan, september to december, 2010, with personal funding

#### **5.3.2 Congresses and workshops**

- "Malliavin Calculus for jump processes", november, 2010.

The Mathfi project (INRIA-UPEMLV-Ecole des Ponts) has acquired a strong recognition in mathematical finance and numerical probability. On the national level, it has regular interactions with teams working in related subjects in Ile de France (Paris 6-Paris 7, Paris-Dauphine, Paris 13, Evry, Ecole polytechnique) and outside (INRIA Sophia-Antipolis et Nancy, Brest). CERMICS has been the leading group of two ANR projects concerning numerical probabilities. The group has been a driving force of the AMaMeF project (Advanced Mathematical Methods for Finance). Collaborations started with foreign centers (London School of Economics, Imperial College, ETH Zürich, Barcelonne, Oslo, Rome, Osaka) are expected to develop.

## **6 Leadership of the excellency laboratory**

### **6.1 Scientific animation**

The scientific animation will be performed by a board, assisted by a scientific committee whose members won't belong to the PRES and will be independent from the direction group.

The board is composed of one head, assisted by one member of each laboratory. It takes the daily decisions concerning the use of the means. It will be closely involved with the scientific responsables of each team, in order to develop the collaborations, organize the meetings, and make invitations. It meets once a year, but can be consulted at any occasion by email. This will allow to include in the committee internationally recognized researchers

### **6.2 Means required and their use**

A part of the means given to the laboratory of excellency will be used for invitations of both young researchers (less than 5 years after their PhDs) and confirmed researchers. Our purpose is to have each year devoted, in turns to one of the subjects on which the project is focused. A group of people would come to UPE centered around one or two senior researchers who would be invited for 6 months or one year (typically a sabbatical leave), and would give a doctoral

or postdoctoral course, and would take part in the animation of a conference and workshops. The younger researchers will play an active role of coordination with the PhD students of the laboratory.

On the other hand, we believe that it is very important to attract brilliant students before they start their PhD. In this spirit, we ask for two or three fellowships each year that would be given to foreign students that would allow them to come to UPE and spend a year attending the M2 (we note that it is now possible to have PhD fellowships and postdocs, but not fellowships at that level, so that the money obtained from the laboratoire d'excellence would fill a gap in the french research funding); the idea would of course be to have them stay afterwards and do their PhD at UPE. Having a few extremely brilliant students regularly in our M2 would also help the M2 to keep its position among the M2 of mathematics and informatics in Ile-de-France.

We also wish to obtain long term funding (up to 6 years) for young researchers already having their PhD on the transversal themes that we mentioned. Indeed, these medium term positions are a very efficient way to confort collaborations between the different themes of the laboratory. This apparatus would give us serious scientific ground to obtain each year (from alternative fundings, inside and outside UPE) 2 or 3 PhD fellowships on the subjects of the laboratoire d'excellence, and also 2 Postdocs, specifically on the theme chosen during the that specific year.