RESEARCH CENTER

FIELD
Applied Mathematics, Computation and Simulation

Activity Report 2013

Section highlights of the Team

Edition: 2014-03-20

CAD Team (section vide)

CALVI Project-Team

2.2. Highlights of the Year

The Selalib project has made important progress in its development as it prepares for a release in 2014 with new additions in terms of capabilities and contributors.

CONCHA Project-Team

2.2. Highlights of the Year

MICMAC Project-Team (section vide)

SCIPORT Team (section vide)

SIMPAF Project-Team

2.2. Highlights of the Year

A. Gloria was awarded an ERC Starting Grant.

BACCHUS Team

2.2. Highlights of the Year

- In the context of the first contract supported by European Space Agency on uncertainty quantification (UQ), we applied some innovative UQ techniques in the challenging issue of predicting phenomena associated to the atmospheric reentry. In particular, we focused on the characterization of free-stream conditions in flight experiments, and the prediction of the radiative heat flux in high enthalpy facilities.
- In 2013 we have organized or contributed to the organization of three international conferences held at Inria or on the applied science campus of the Université de Bordeaux I : the Second ECCOMAS Young Investigators Conference (http://yic2013.sciencesconf.org), the EUROPEAN WORKSHOP on High Order Nonlinear Numerical Methods for Evolutionary PDEs (http://honom2013.bordeaux.inria.fr/), and the International Workshop on Uncertainty Quantification in fluids Simulation (http://boquse2013.bordeaux.inria.fr/) ;
- We have finally succeded in proposing Residual Distribution schemes that are *uniformly* accurate independently of the Reynolds number laminar, and turbulent compressible flow equations, with a stunning convergence to steady state down to machine zero ;
- We have shown the applicability of stabilized finite elements to the simulation of free surface water waves described by Boussinesq modes. We have demonstrated that residual based stabilization operators do not degrade the accuracy of the underlying finite element scheme, and used this to construct non oscillatory schemes for wave propagation, breaking, and runup ;
- We have developed an algorithm for the robust construction of curved simplicial meshes in two and three dimensions. Starting from a classical (straight) mesh, we are able to curve the boundary elements then the volumic ones and keep the boundary layer structures, even for meshes designed for turbulent simulations ;
- We developed a multiresolution strategy applied to a semi-intrusive scheme recently introduced in the context of uncertainty quantification (UQ) analysis for compressible fluids problems. This is one of the first global schemes in literature permitting an adaptive refinement in the coupled physical/stochastic space .
- `PaMPA` remeshed a coarse mesh of 27 millions of elements up to a fine mesh comprising more than 600 millions of elements, in 34 minutes, on 240 processors of the Avakas cluster at MCIA Bordeaux.
- François Pellegrini published a book on software law ; co-authored with Sébastien Canevet, associate professor at Université de Poitiers.

CAGIRE Team

2.2. Highlights of the Year

AeroSol has been successufully tested on the Turing machine of the IDRIS computing center. This was a pre-requisite for the subsequent simulation of the targeted flow configuration.

DEFI Project-Team

2.2. Highlights of the Year

G. Allaire received the 2013 Dargelos Prize of AX, the alumni association of Ecole Polytechnique.

GAMMA3 Project-Team (section vide)

IPSO Project-Team

2.3. Highlights of the Year

- A. Debussche was the main organizer of the thematic semester “Perspectives in Analysis and Probability" organized by the Lebesgue Center in Nantes and Rennes from april to september 2013 (see: http://www.lebesgue.fr/content/sem2013-perspectives-analysis-and-probability).
- E. Faou received the Blaise Pascal prize (GAMNI/SMAI and French Academy of Sciences).
- G. Vilmart defended his Habilitation to supervise research (HDR) in Mathematics, [12], July.
- G. Vilmart receives the “Prix Bretagne Jeune Chercheur 2013” from the Region Bretagne, December.

MC2 Project-Team

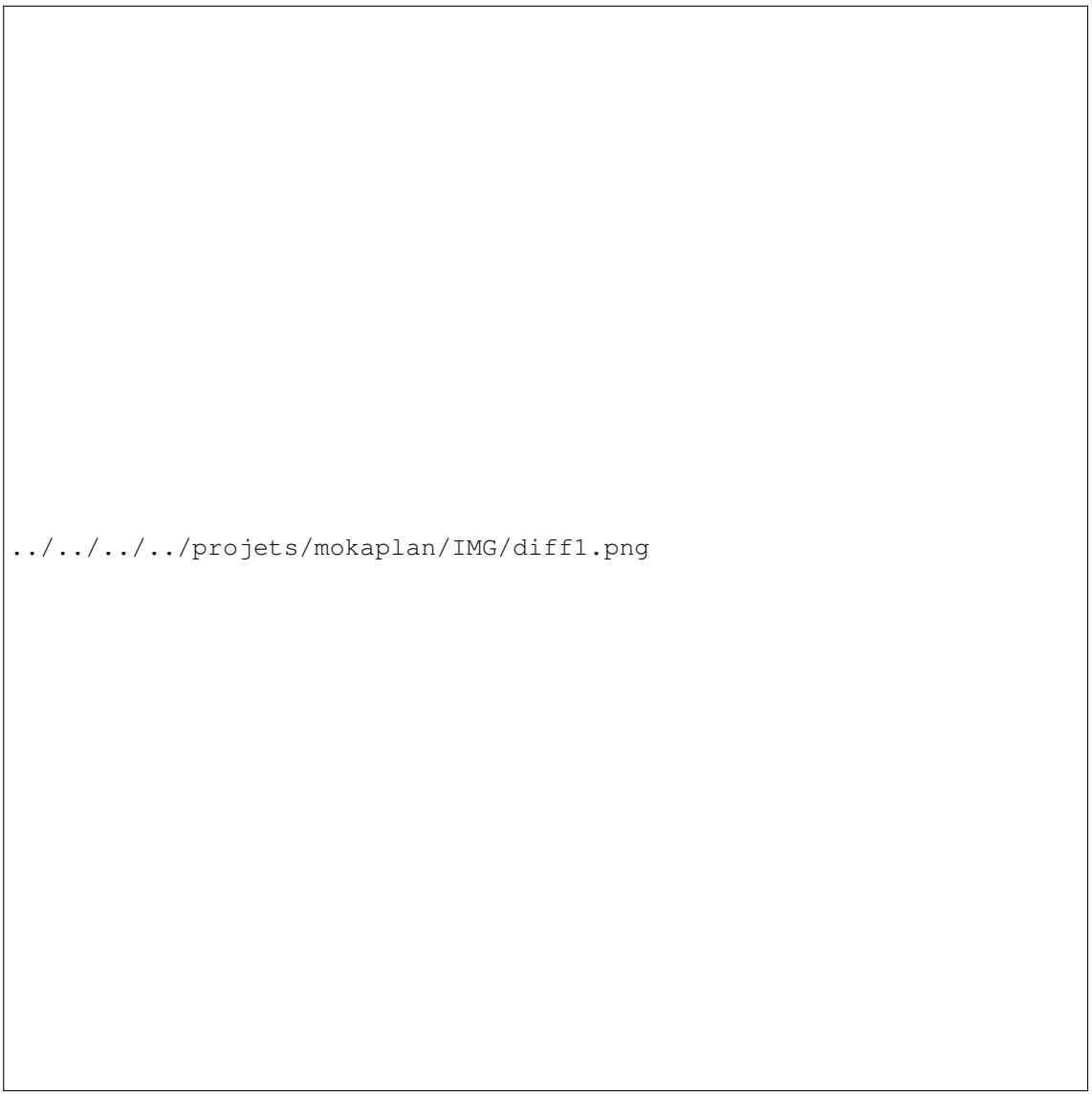
2.2. Highlights of the Year

- In collaboration with the Bordeaux cancer therapy of Bordeaux (Bergonie) the MC2 team has developped an adaptive radiotherapy technique to follow automatically organs using the low resolution control scanners. This method is helpful in order to avoid the overdose in high risk organs. Thanks to image processing it was shown that the movement of organs is much more important than predicted before and a better control is necessary. This work continues with the design of automatic tools to follow organ movements.
- In collaboration with Rajat Mittal (John Hopkins) accurate numerical simulations were performed using the NaSCar code to improve the energetic efficiency of underwater submarine robots. As these robots are propelled in the water using fish like models, the used flippers were modified maximizing their energy and therefore minimizing their energy consumption.
- As the final step of the PREDIT Caravaje, the optimized form of an actuator was designed using adjoint methods. It should be implemented in a car body in order to reduce drag forces and consequently the fuel consumption/pollution. The results are published.
- Numerical simulations were performed to reproduce the soap bubbles experiments performed by Hamid Kellay team (Loma). Simulations are allowed by a change of metrics between a plane and an hemisphere using a stereographic projection. The results in accordance with the experiments were published in Nature scientific reports.

MOKAPLAN Exploratory Action

2.2. Highlights of the Year

The paper [6] resolves numerically the Monge-Ampère formulation of the Optimal Tansportation problem with quadratic cost with the correct "second boundary value" boundary conditions. It is worth pointing that this has been an open problem for a while. The same paper proposes a fast and robust Newton method (empirically linear) which can be applied to degenerate cases. This potentially means progress in many applications of Optimal Mass Transportation. The method has, for instance, been reimplemented in [72] by TU Eindhoven researchers in collaboration with Philips Lightning Labs to simulate the design of reflectors. In 2013, the method was the topic of invited presentations at the Collège de France applied math seminar, at MSRI (UC Berkeley) special program on Optimal Mass Transportation and at SIAM annual conference on PDE analysis.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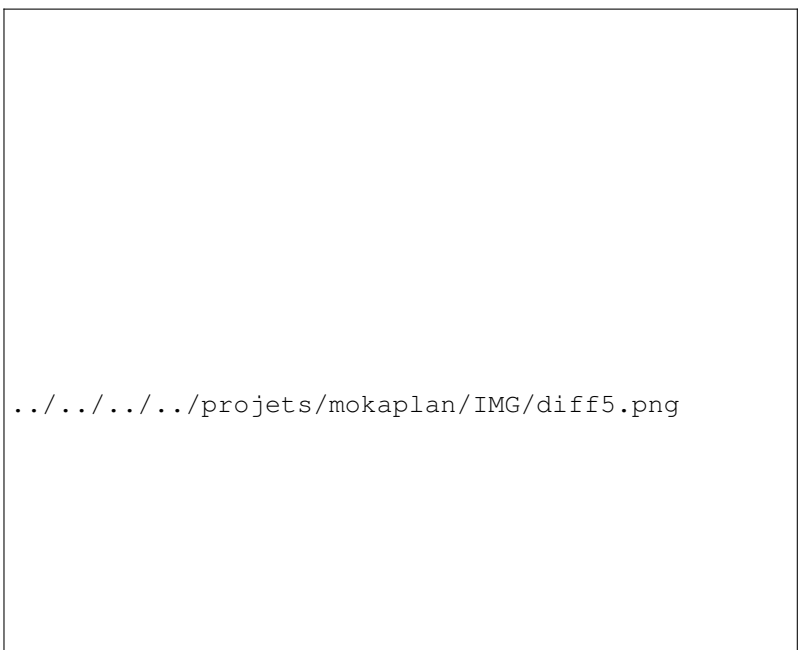
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NACHOS Project-Team (section vide)

NANO-D Team (section vide)

OPALE Project-Team

2.3. Highlights of the Year

Opale now participates in the KIC EIT ICT Labs activity, IMS - Intelligent Mobility and Transportation Systems, “Multimodal Mobility". In this area, a new contract with Autoroute Trafic on "Design and validation of traffic flow models on processed data" has been set up.

In the area of multi-disciplinary optimization, technical collaboration with research and industrial partners (Arcelor Mittal) have been enforced and new axes (nanoelectronics with CEA/LETI Grenoble) developed.

Régis Duvigneau defended his habiltation thesis (HdR).

POEMS Project-Team (section vide)

APICS Project-Team (section vide)

BIPOP Project-Team (section vide)

COMMANDS Project-Team

2.3. Highlights of the Year

In collaboration with L. Giraldi and M. Zopello, we started in 2013 to study the optimal swimming strategies for micro-swimmers. Our approach allows us to solve the optimal control problem without making restrictive assumptions on the shape of the swimming movements. The first numerical results on the 3-link swimmer indicate the existence of a periodic stroke with a better displacement speed than the canonical stroke presented by Purcell in 1977. Further directions include optimal design of micro-swimmers and comparing our simulations to the movement of live micro-organisms.

In collaboration with CNES, a trajectory optimization problem for Ariane 5 was studied and analyzed by HJB approach. In this study, the flight model is considered in dimension 6 without simplification. The problem consists in maximizing the payload to steer the launcher from the launch base (Kourou) to the GEO orbit. The mission includes ballistic phases and the optimization also encompasses the intermediate GTO orbit parameters. The optimization criterion is the mass of the payload to be injected on the GEO.

Finally, the team completed 3 PhD and 4 patents in 2013.

CORIDA Project-Team

2.2. Highlights of the Year

Marius Tucsnak has been nominated Senior Member of the Institut Universitaire de France.

George Weiss visited our team in the frame of the “Chercheur d’excellence” program of Région Lorraine.

DISCO Project-Team

2.2. Highlights of the Year

Frédéric Mazenc in June 2013 for his presentation of the paper was awarded by the *IEEE Control Systems Society* the *Best Presentation of Session Presenter*.

Sorin Olaru got the Best paper award at the 17th International Conference on System Theory, Control and Computing .
BEST PAPERS AWARDS :
[55] **ACC**. F. MAZENC, T. DINH, S.-I. NICULESCU.
[52] **ICSTCC 2013**. C. KOITI IDE, S. OLARU, P. RODRIGUEZ-AYERBE, A. RACHID.

GECO Project-Team

2.2. Highlights of the Year

We edited two volumes on two different and challenging subjects, that is hybrid systems with constraints [12] and sub-Riemannian geometry [13].

I4S Project-Team

2.2. Highlights of the Year

- Prize Bretagne Jeune Chercheur 2013 for Michael Doehler.
- PEGASE 2 launch

Maxplus Project-Team (section vide)

MCTAO Project-Team (section vide)

NECS Project-Team

2.2. Highlights of the Year

In 2013, Carlos Canudas de Wit, leader of the NECS team, has become:

- President Elect of the European Control Association EUCA (http://www.euca-control.org/);
- IEEE CSS distinguished lecturer;
- Associate Editor of IEEE Transactions on Control System Technology (since January 2013) and of IEEE Transactions on Control of Network Systems (since June 2013).

NON-A Project-Team

2.3. Highlights of the Year

- The Implicit Lyapunov Function (ILF) method for non-asymptotic (finite-time and fixed-time) stability analysis of ordinary differential equations has been developed in [75]. The new principles for design of non-asymptotic controls based on ILF are presented.
- New developments for interval estimation of time-delay systems [22], [56] and control of systems with unknown time-varying input delays based on interval predictors [34], [76].
- New results for control of linear [59] or nonlinear [73] systems using asynchronous sampling.
- New book on fault detection and isolation in aerospace systems [86].
- New application has been addressed dealing with the networked control of haptic systems.
- New concrete application of homogeneous, finite-time control, to a pneumatic actuator [36].
- A patent with Airbus has been deposed for a fault detection in actuators of an airplane [87].

CLASSIC Project-Team (section vide)

DOLPHIN Project-Team

2.2. Highlights of the Year

BEST PAPER AWARD :

[62] **GECCO - Genetic and Evolutionary Computation Conference - 2013**. M. NOUREDINE, T. V. LUONG, B. KARIMA, T. EL-GHAZALI.

GEOSTAT Project-Team

2.2. Highlights of the Year

- Hicham Badri, PhD student in GEOSTAT (thesis under way cosupervised by H. Yahia and D. Aboutajdine) received the University Mohammed V best Master student award.
- The paper *Reconstructing an image from its edge representation* by Suman K. Maji, H. Yahia and H. Badri [19] is ranked in the top ten entries in the list of most downloaded papers of Elsevier's Digital Signal Processing journal.
- The paper *An efficient solution to sparse linear prediction analysis of speech* by V. Khanagha and K. Daoudi [15] is ranked in the top ten entries, 13th over 100, in the list of most downloaded papers in 2013 of the EURASIP Journal on Audio, Speech, and Music Processing.
- GEOSTAT and DYNBIO (LEGOS, CNRS UMR 5566, Toulouse) teams have computed daily ocean dynamics at super resolution over a large area around the Algunas current near South Africa using low resolution altimetry data and high resolution Sea Surface Temperature (SST) data for the year 2006. The computed ocean dynamics over a one year time interval is the result of the propagation of low resolution ocean dynamics derived from altimetry across the scales of a multiresolution analysis computed on the SST singularity exponents. The resulting turbulent ocean dynamics has been made into a movie with the help of Inria DIRCOM team (C. Blonz, P.-O. Gaumin) [1].
- Researchers of GEOSTAT have been invited to two speaker sessions, firstly in one of the best international conference in computational biomedecine: EMBC 2013, [21], and second during the India-CEFIPRA workshop in ICST "Challenges in overcoming complexity, from big data to cyberphysical systems", April 4 - 5, 2013, New Delhi- India [22].
- Paper *Fast Multi-Scale Detail Decomposition via Accelerated Iterative Shrinkage* [24] accepted at SIGGRAPH ASIA 2013 conference (technical brief).

[1] http://geostat.bordeaux.inria.fr/exj1309/annee2006_SHORTER_2ipj.mov (size $\sim$ 800 Mo).

MISTIS Project-Team

2.2. Highlights of the Year

2.2.1. European project HUMAVIPS.

The European project HUMAVIPS – Humanoids with Auditory and Visual Abilities in Populated Spaces – is a 36-month FP7 STREP project coordinated by Radu Horaud and which started in 2010. The project addressed multimodal perception and cognitive issues associated with the computational development of a social robot. The objective was to endow humanoid robots with audiovisual (AV) abilities: exploration, recognition, and interaction, such that they exhibit adequate behavior when dealing with a group of people. Research and technological developments emphasized the role played by multimodal perception within principled models of human-robot interaction and of humanoid behavior. The HUMAVIPS project was successfully terminated in January 2013.

An article about *Integrating Smart Robots into Society* refers to HUMAVIPS. The article stresses the role of cognition in human-robot interaction and refers to HUMAVIPS as one of the FP7 projects that has paved the way towards the concept of audio-visual robotics. The article was published in HORIZON, which is Europe's Research & Innovation Magazine.

2.2.2. Best Paper Award at IEEE MMSP'13.

The paper addresses the problem of aligning visual and auditory data using a sensor that is composed of a camera-pair and a microphone-pair. The original contribution of the paper is a method for audio-visual data aligning through estimation of the 3D positions of the microphones in the visual centred coordinate frame defined by the stereo camera-pair. Please consult http://www.mmsp2013.org/mmsp2013_awards.php and .
BEST PAPERS AWARDS :
[41] **MMSP 2013 - IEEE International Workshop on Multimedia Signal Processing**. V. KHALIDOV, F. FORBES, R. HORAUD.

MODAL Project-Team

2.2. Highlights of the Year

- The team developed an extended version of the Rmixmod package allowing to cluster simultaneous mixed categorical and continuous data (see Section [Rmixmod package for mixed data]).
- The full understanding of cross-validation procedures in density estimation has been tackled with new results in terms of risk estimation and model selection (Section [Resampling procedures]).

REALOPT Project-Team

2.2. Highlights of the Year

Our scientific contributions have been recognized by prestigious journals such as Mathematical Programming, EURO Journal on Computational Optimization, INFORMS Journal on Computing, European Journal of Operational Research, Transportation Science, European Journal of Combinatorics, and Combinatorica, as well as by our participations to prime scientific meetings. In particular, François Vanderbeck was invited as a keynote speaker at the European/American Operations Research Conference in Rome (his presentation was "Extended formulations, Column Generation, and stabilization: synergies in the benefit of large scale applications" which is a subject central to our team work this year); Arnaud Pêcher was invited speaker at the International Conference in Discrete Mathematics, India.

Our methodology of combining an extended formulation approach with Dantzig-Wolfe decomposition has proved able to handle the very large scale instances of railway fret transportation applications (as shown by the very competitive results obtained by Ruslan Sadykov) as well as power production planning at EDF (Jinil Han has managed to solve the Roadef Challenge Instances in a few minutes, while Boris Detienne develops a robust approach on that basis). The Samba associated-team project with Brasil has been at the core of our methodological research effort with a one-month-visit of Professor Uchoa, and a one-year-stay of his PhD student, Hugo Kramer. New industrial collaborative project have started: working on the dimensioning of a logistic fleet with Exeo-Solution (Pierre Pesneau is leading this project), on planning operations in wineries with Ertus Consulting, and on packing and cutting problems with Renault and Saint-Gobain (Francois Clautiaux is an expert on those).

The team is very fortunate to have made very successful appointments: a university professor, Francois Clautiaux, an assistant professor, Boris Detienne and an expert engineer, Issam Tahiri, to be appointed by the center of excellence - labex CPU. Let us also mention that the team is organizing the annual conference of the French Operation Research society (ROADEF) taking place in Bordeaux in February 2014.

SELECT Project-Team (section vide)

SequeL Project-Team

2.2. Highlights of the Year

- In 2013, Crazy Stone won the 6th edition of the UEC Cup and the first edition of the Denseisen. Crazy Stone is a Go-playing program developed by Rémi Coulom since 2005, based on the Monte Carlo Tree Search method. The UEC Cup is the most important international computer-Go competition, organized yearly by the University of Electro-Communications in Tokyo, Japan. The Denseisen is a match between the winner of the UEC Cup and a top Japanese profesionnal Go player. This year Crazy Stone won a game with 4 stones of handicap against 9-dan profesionnal player Yoshio Ishida.
- The International Machine Learning Society selects SEQUEL to organize the 32^{nd} International Conference on Machine Learning in 2015 at Lille. ICML is the most important conference in the field of machine learning.

SIERRA Project-Team

2.2. Highlights of the Year

- Visit of Prof. Michael Jordan (U.C. Berkeley) and of his research group.
- Recruitment of two researchers: Alexandre d'Aspremont (DR2 CNRS) and Simon Lacoste-Julien (Inria Starting researcher position).
- Start of a collaboration with Microsoft Research (within the joint MSR/Inria lab).

TAO Project-Team

2.3. Highlights of the Year

2.3.1. Extensions of Multi-Armed Bandits and Monte-Carlo Tree Search

Risk Avoidance Exploration might exert a toll on the agent/system safety in real-world contexts (e.g., controlling a power system or a robot). Risk adverse criteria have been pioneered in MAB, together with multi-objective reinforcement learning – see [12] and [19].

Continuous Options The Rapid Action Value Estimate (RAVE) has been extended to continuous settings [27].

2.3.2. Information Theory and Natural Gradient

Information-geometric Optimization: convergence results. Theoretical guarantees have been obtained for continuous optimization algorithms in the framework of *information geometry* (IGO). Previous improvement guarantees for gradient descent-based methods were valid only for infinitesimally small step sizes. Information geometry and using the *natural gradient* provide improvement guarantees for finite step sizes as is the case in practice [22]. Along the same lines, geodesics in statistical manifolds have been used for estimation of distribution optimization algorithms.

Neural Network Training is a hard optimization problem, sensitive to the problem representation and the optimization trajectory. Within a Riemannian geometry framework, the use of intrinsic Riemannian gradient has been shown to support an affine transformation-invariant optimization approach, with significant robustness improvements at the same cost as the state of the art [66]. This Riemannian approach has been applied to recurrent neural nets, with very satisfactory results on difficult symbolic sequences with non-local dependencies [65]. In the related field of stacked restricted Boltzman machines, we have shown that the layer-wise approach supporting the celebrated deep learning approach yields *globally optimal* results provided the inference (as opposed to generative) model is rich enough, with quantitative estimates [60]. This result is the first of its kind on layerwise deep learning.

ALEA Project-Team

2.2. Highlights of the Year

- Pierrick Legrand was finalist of the Humies award (Human-Competitive Results Produced by Genetic and Evolutionary Computation) for his work on "Evolving estimators of the pointwise Holder exponent with Genetic Programming" at Genetic and Evolutionary Computation Conference (GECCO) July 6-10, 2013 In Amsterdam. The jugging committee was:
  - Erik Goodman
  - Una-May O'Reilly
  - Wolfgang Banzhaf
  - Darrell Whitley
  - Lee Spector

  The regularity of a signal can be numerically expressed using Holder exponents, which characterize the singular structures a signal contains. In particular, within the domains of image processing and image understanding, regularity-based analysis can be used to describe local image shape and appearance. However, estimating the Holder exponent is not a trivial task, and current methods tend to be computationally slow and complex. This work presents an approach to automatically synthesize estimators of the pointwise Holder exponent for digital images. This task is formulated as an optimization problem and Genetic Programming (GP) is used to search for operators that can approximate a traditional estimator, the oscillations method. Experimental results show that GP can generate estimators that achieve a low error and a high correlation with the ground truth estimation. Furthermore, most of the GP estimators are faster than traditional approaches, in some cases their runtime is orders of magnitude smaller. This result allowed us to implement a real-time estimation of the Holder exponent on a live video signal, the first such implementation in current literature. Moreover, the evolved estimators are used to generate local descriptors of salient image regions, a task for which a stable and robust matching is achieved, comparable with state-of-the-art methods. In conclusion, the evolved estimators produced by GP could help expand the application domain of Holder regularity within the fields of image analysis and signal processing.
- The IRSES FP7 Marie Curie project ACOBSEC presented by the team ALEA was accepted.

  Over the last decade, Human-Computer Interaction (HCI) has grown and matured as a field. Gone are the days when only a mouse and keyboard could be used to interact with a computer. The most ambitious of such interfaces are Brain-Computer Interaction (BCI) systems. The goal in BCI is to allow a person to interact with an artificial system using only brain activity. The most common approach towards BCI is to analyse, categorize and interpret Electroencephalography (EEG) signals, in such a way that they alter the state of a computer. The objective of the present project is to study the development of computer systems for the automatic analysis and classification of mental states of vigilance; i.e., a person's state of alertness. Such a task is relevant to diverse domains, where a person is expected or required to be in a particular state. However, this problem is by no means a trivial one. In fact, EEG signals are known to be highly noisy, irregular and tend to vary significantly from person to person, making the development of general techniques a very difficult scientific endeavour.
  List of Beneficiaries
  - Beneficiary 1 (coordinator) Institut National de Recherche en Informatique et Automatique Inria France
  - Beneficiary 2 Universite Victor Segalen Bordeaux II UB2 France
  - Beneficiary 3 Instituto de Engenharia de Sistemas e Computadores, Investigacao e Desenvolvimento em Lisboa INESC-ID Portugal
  - Beneficiary 4 Universidad de Extremadura UNEX Spain
  - Partner 5 Instituto Tecnologico de Tijuana ITT Mexico
  - Partner 6 Centro de Investigacion Cientifica y educacion Superior de Ensenada, Baja California CICESE Mexico

ASPI Project-Team (section vide)

CQFD Project-Team

2.2. Highlights of the Year

The paper *Optimal stopping for predictive maintenance of a structure subject to corrosion* [7] was nominated winner of the 2012 SAGE Best Paper Award by the editorial board of Journal of Risk and Reliability.

MATHRISK Project-Team

2.2. Highlights of the Year

- AA. Sulem has been invited for a Plenary talk at IFIP TC 7 Conference on System Modelling and Optimization, Klagenfurt, Austria. September 2013 - http://ifip2013.uni-klu.ac.at/

- The paper of B. Jourdain with S. Méléard and W. Woyczynski "Lévy flights in evolutionary ecology", *Journal of Mathematical Biology*, has been honored by the prize La Recherche - Mathématiques 2013 - http://www.leprixlarecherche.com/palmares-2013

REGULARITY Project-Team

2.2. Highlights of the Year

J. Lévy Véhel was a finalist at the 2013 Humies competition in Amsterdam.

TOSCA Project-Team (section vide)