



RESEARCH CENTER

FIELD

**Applied Mathematics, Computation  
and Simulation**

Activity Report 2014

**Section Software**

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## BACCHUS Team

### 4. New Software and Platforms

#### 4.1. AeroSol

**Participants:** Simon Delmas [Cagire], Damien Genet [Bacchus], Maxime Mogé [Cagire], Yann Moguen [Cagire], Vincent Perrier [Corresponding member], Mario Ricchiuto [Bacchus].

The AeroSol software is jointly developed in teams Bacchus and Cagire. It is a high order finite element library written in C++. The code has been designed so as to allow for efficient computations, with continuous and discontinuous finite elements methods on hybrid and possibly curvilinear meshes. The work of the team Bacchus is focused on continuous finite elements methods, while the team Cagire is focused on discontinuous Galerkin methods. However, everything is done for sharing the largest part of code we can. More precisely, classes concerning IO, finite elements, quadrature, geometry, time iteration, linear solver, models and interface with PaMPA are used by both of the teams. This modularity is achieved by mean of template abstraction for keeping good performances. The distribution of the unknowns is made with the software PaMPA, developed within the team Bacchus and the team Castor.

The work performed this year in the BACCHUSteam has focused on the experimentation of parallelisation solutions on heterogenous machines, and in particular on the study of efficient solution for shared memory parallelism. In particular, in the framework of the PhD of D. Genet, the coupling with runtime systems such as StarPU (Inria team Runtime) and DAGuE (University of Tennessee), has been compared to a more classical OpenMP implementation. This initial work, done for scalar problems, will be now extended to systems of equations.

#### 4.2. COCA

**Participants:** Mario Ricchiuto [corresponding member], Gregory Perrot.

COCA(CodeOxydationCompositesAutocicatrisants) is a Fortran 90 code for the simulation of the oxidation process in self-healing composites COCA solves the discrete finite element equations relative to the oxidation (chemistry) and flow (potential) models. Time integration is performed with an implicit approach (Backward Euler or second order backward differencing). The linear algebraic systems arising in the discretization are solved with the MUMPS library. Physical outputs of interest can be obtained to use COCA as a numerical closure for continuous mechanics solvers in order to perform numerical strain tests for self-healing composites.

#### 4.3. RealfluidS

**Participants:** Pietro Marco Congedo, Héloïse Beaugendre [corresponding member], Cécile Dobrzynski, Quentin Viville, Leo Nouveau.

RealfluidS is a software dedicated to the simulation of inert or reactive flows. It is also able to simulate multiphase, multimaterial, MHD flows and turbulent flows (using the SA model). There exist 2D and 3D dimensional versions. The 2D version is used to test new ideas that are later implemented in the 3D one. This software implements the more recent residual distribution schemes. The code has been parallelized with and without overlap of the domains. The uncertainty quantification library RobUQ has been coupled to the software. A partitioning tool exists in the package, which uses Scotch. Recently, the code has been developed for taking into account real-gas effects, in order to use arbitrarily complex equations of state. Further developments concerning multiphase effects are under way.

#### 4.4. MMG3D

**Participants:** Cécile Dobrzynski [corresponding member], Algiane Froehly.

MMG3D is a tetrahedral fully automatic remesher. Starting from a tetrahedral mesh, it produces quasi-uniform meshes with respect to a metric tensor field. This tensor prescribes a length and a direction for the edges, so that the resulting meshes will be anisotropic. The software is based on local mesh modifications and an anisotropic version of Delaunay kernel is implemented to insert vertices in the mesh. Moreover, MMG3D allows one to deal with rigid body motion and moving meshes. When a displacement is prescribed on a part of the boundary, a final mesh is generated such that the surface points will be moved according this displacement. MMG3D is/was used in gamma3 team, at EPFL (maths department), Dassault Aviation, Lemma (a french SME), Renault etc. MMG3D can be used in FreeFem++ (<http://www.freefem.org>), a free software which eases the solving of PDEs and in Gmsh (<http://geuz.org/gmsh/>).

Version 5.0 of MMG3D allows the modification of the surface triangulation based on cubic Bezier patches. A. Froehly, ingenieur in the FUI Rodin, is working on this new version.

More details can be found on <http://www.math.u-bordeaux1.fr/~doj/logiciels/mmg3d.php>.

## 4.5. ORComp

**Participants:** Pietro Marco Congedo [Corresponding member], Maria-Giovanna Rodio.

The ORComp platform is a simulation tool permitting to design an ORC cycle. Starting from the solar radiation, this platform computes the cycle providing the best performance with optimal choices of the fluid and the operating conditions. It includes RobUQ, a simulation block of the ORC cycles, the RealfluidScore for the simulation of the turbine and of the heat exchanger, the software FluidProp (developed at the University of Delft) for computing the fluid thermodynamic properties.

## 4.6. sDEM

**Participants:** Pietro Marco Congedo [Corresponding member], Maria-Giovanna Rodio.

The sDEM platform is a simulation tool permitting to simulate multiphase flows with transition modelling. In particular, the code relies on the formulation of a DEM method, the use of a complex thermodynamics, the possibility to model cavitating phenomena. Moreover, the method has been generalized in order to take into account directly uncertainty, thus proposing the so-called Stochastic DEM (sDEM) method. This is one of the first stochastic semi-intrusive scheme, permitting to consider uncertainties in multiphase flows including heat and mass transfer terms. This software is developed together with the University of Zurich.

## 4.7. PaMPA

**Participants:** Cédric Lachat, François Pellegrini [Corresponding member], Cécile Dobrzynski.

PaMPA (“Parallel Mesh Partitioning and Adaptation”) is a middleware library dedicated to the management of distributed meshes. Its purpose is to relieve solver writers from the tedious and error prone task of writing again and again service routines for mesh handling, data communication and exchange, remeshing, and data redistribution. It is based on a distributed data structure that represents meshes as a set of *entities* (elements, faces, edges, nodes, etc.), linked by *relations* (that is, computation dependencies).

PaMPA interfaces with Scotch for mesh redistribution, and with MMG3D for parallel remeshing of tetrahedral elements. Other sequential remeshers can be plugged-in, in order to handle other types of elements.

Version 1.0 of PaMPA allows users to declare distributed meshes, to declare values attached to the entities of the meshes (e.g. temperature attached to elements, pressures to the faces, etc.), to exchange values between overlapping entities located at the boundaries of subdomains assigned to different processors, to iterate over the relations of entities (e.g. iterate over the faces of elements), to remesh in parallel the areas of a mesh that need to be emeshed, and to redistribute evenly the remeshed mesh across the processors of the parallel architecture.

PaMPA is already used as the data structure manager for two solvers being developed at Inria: Plato (team PUMAS) and AeroSol (teams BACCHUS and CAGIRE).

Following expressions of interest from industrial partners, a formal industrialization process of PaMPA has been started, under the auspices of the *Direction du Transfert Technologique* (DTI) at Inria. In this context, much work was directed towards improving the robustness of the code, by including it into a continuous integration framework based on Jenkins.

## 4.8. RobUQ

**Participants:** Pietro Marco Congedo [Corresponding member], Maria Giovanna Rodio, Kunkun Tang.

The RobUQ platform has been conceived to solve problems in uncertainty quantification and robust design. It includes the optimization code ALGEN, and the uncertainty quantification code NISP. It includes also some methods for the computation of high-order statistics, efficient strategies for robust optimization, the Simplex2 method. Some methods are developed in partnership with the Stanford University (in the framework of the associated team AQUARIUS). Other methods are developed in the context of ANR UFO.

## 4.9. Scotch

**Participant:** François Pellegrini [corresponding member].

parallel graph partitioning, parallel static mapping, parallel sparse matrix block ordering, graph repartitioning, mesh partitioning.

Scotch (<http://www.labri.fr/~pelegri/scotch/>) is a software package for parallel and sequential sparse matrix ordering, parallel and sequential graph partitioning, as well as sequential static mapping and remapping, without and with fixed vertices, and mesh and hypergraph partitioning.

The initial purpose of Scotch was to compute high-quality static mappings of valued graphs representing parallel computations onto target architectures of arbitrary topologies. This allows the mapper to take into account the topology and heterogeneity of the target architecture in terms of processor speed and link bandwidth. This feature, which was meant for the NUMA machines of the 1980's, has not been widely used in the past because machines in the 1990's became UMA again thanks to hardware advances. Now, architectures become NUMA again, and these features are regaining popularity.

The Scotch package consists of two libraries: the sequential Scotch library, and the parallel PT-Scotch library (for "*Parallel Threaded Scotch*") that operates according to the distributed memory paradigm, using MPI. Scotch was the first full 64-bit implementation of a general purpose graph partitioner.

Version 6.0, released on December 2012, offers many new features: static mapping with fixed vertices, static remapping, and static remapping with fixed vertices. Several critical algorithms of the formerly strictly sequential Scotch library can now run in a multi-threaded way. All of these features, which exist only in the sequential version, will be available to the parallel PT-Scotch library in the upcoming release 6.1, the development of which has been pursued this year. Also, Scotch has been integrated into the Jenkins continuous integration framework that is used for other projects of the team, such as PaMPA and AeroSol.

Scotch has been integrated in numerous third-party software, which indirectly contribute to its diffusion. It is natively available in several Linux and Unix distributions, as well as on some vendors platforms (SGI, etc).

## 4.10. SLOWS

**Participants:** Luca Arpaia, Andrea Filippini, Maria Kazolea, Mario Ricchiuto [corresponding member].

SLOWS (“*Shallow-water FLOWS*”) is a C-platform allowing the simulation of free surface shallow water flows with friction. Arbitrary bathymetries are allowed, defined either by some complex piecewise analytical expression, or by  $xyz$  data files, the classical Manning model for friction is used, and an Exner model is implemented for sediment transport. For non-hydrostatic propagation the enhanced Boussinesq equations of Madsen and Sorensen are used. The equations are discretized with a residual based approach which is an adaptation of the schemes developed for aeronautics applications. Due to the inherent unsteadiness of these flows, the time discretization plays an important role. Three different approaches are available, based on conditionally depth-positivity preserving implicit schemes, or on conditionally depth-positivity preserving genuinely explicit discretizations, or on an unconditionally depth-positivity preserving space-time approach. Newton and frozen Newton loops are used to solve the implicit nonlinear equations. The linear algebraic systems arising in the discretization are solved with the MUMPS library. This year implicit and explicit (extrapolated) multistep higher order time integration methods have been implemented, and a mesh adaptation technique based on simple mesh deformation has been also included. The current mid-term objective is to merge SLOWS with the TUCWave code developed by M. Kazolea during her PhD to obtain the first (worldwide) non-hydrostatic dynamically adaptive unstructured mesh Boussinesq code for wave propagation in the near shore region.

#### 4.11. Nomesh

**Participants:** Cécile Dobrzynski [corresponding member], Algiane Froehly.

Nomesh is a software allowing the generation of third order curved simplicial meshes. Starting from a "classical" mesh with straight elements composed by triangles and/or tetrahedra, we are able to curve the boundary mesh. Starting from a mesh with some curved elements, we can verify if the mesh is valid, that means there is no crossing elements and only positive Jacobian. If the curved mesh is non valid, we modify it using linear elasticity equations until having a valid curved mesh.



## CAGIRE Team

# 5. New Software and Platforms

## 5.1. AeroSol

**Participants:** Hamza Belkhayat Zougari [Cagire], Simon Delmas [Cagire], Damien Genet [Bacchus], Francois Pellegrini [Bacchus], Vincent Perrier [Cagire, correspondant], Mario Ricchiuto [Bacchus].

The software AeroSol is jointly developed in the team Bacchus and the team Cagire. It is a high order finite element library written in C++. The code design has been carried for being able to perform efficient computations, with continuous and discontinuous finite elements methods on hybrid and possibly curvilinear meshes.

The work of the team Bacchus is focused on continuous finite elements methods, while the team Cagire is focused on discontinuous Galerkin methods. However, everything is done for sharing the largest part of code we can. More precisely, classes concerning IO, finite elements, quadrature, geometry, time iteration, linear solver, models and interface with PaMPA are used by both of the teams. This modularity is achieved by means of template abstraction for keeping good performances.

The distribution of the unknowns is made with the software PaMPA, developed within the team Bacchus and the team Castor.

At the end of 2013, Aerosol had the following features

- **development environment** use of CMake for compilation (gcc, icc and xlc), CTest for automatic tests and memory checking, lcov and gcov for code coverage reports. Development of a CDash server for collecting the unitary tests and the memory checking. Beginning of the development of an interface for functional tests. Optional linking with HDF5, PAPI, with dense small matrices libraries (BLAS, Eigen)
- **In/Out** link with the XML library for handling with parameter files. Parallel reader for GMSH, with an embedded geometrical pre-partitioner. Writer on the VTK-ASCII legacy format (cell and point centered). Parallel output in vtu and pvtu (Paraview) for cell-centered visualization, and XDMF/HDF5 format for both cell and point centered visualization.
- **Quadrature formula** up to 11th order for Lines, Quadrangles, Hexaedra, Pyramids, Prisms, up to 14th order for tetrahedron, up to 21st order for triangles. Gauss-Lobatto type quadrature formula for lines, triangles, quadrangles and hexaedra.
- **Finite elements** up to fourth degree for Lagrange finite elements and hierarchical orthogonal finite element basis (with Dubiner transform on simplices) on lines, triangles, quadrangles, tetrahedra, prisms, hexaedra and pyramids. Finite element basis that are interpolation basis on Gauss-Legendre points for lines, quadrangles, and hexaedra, and triangle (only 1st and 2nd order)
- **Geometry** elementary geometrical functions for first order lines, triangles, quadrangles, prisms, tetrahedra, hexaedra and pyramids.
- **Time iteration** explicit Runge-Kutta up to fourth order, explicit Strong Stability Preserving schemes up to third order. Optimized CFL time schemes: SSP(2,3) and SSP(3,4). CFL time stepping. Implicit integration with BDF schemes from 2nd to 6th order
- **Linear Solvers** link with the external linear solver UMFPack, PETSc and MUMPS. Internal solver for diagonal and block-diagonal matrices.
- **Memory handling** discontinuous and continuous, sequential and parallel discretizations based on PaMPA for generic meshes, including hybrid meshes.

- **Models** Perfect gas Euler system, real gas Euler system (template based abstraction for a generic equation of state), scalar advection, Waves equation in first order formulation, generic interface for defining space-time models from space models. Diffusive models: isotropic and anisotropic diffusion, compressible Navier-Stokes.
- **Numerical schemes** continuous Galerkin method for the Laplace problem (up to fifth order) with non consistent time iteration or with direct matrix inversion. Explicit and implicit discontinuous Galerkin methods for hyperbolic systems, diffusive and advection-diffusion problems. Beginning of optimization by stocking the geometry for advection problems. SUPG and Residual distribution schemes.
- **Numerical fluxes** centered fluxes, exact Godunov' flux for linear hyperbolic systems, and Lax-Friedrich flux. Riemann solvers for Low Mach flows.
- **Boundary conditions** Periodic boundary conditions, time-dependent inlet and outlet boundary conditions.
- **Parallel computing** Mesh redistribution, computation of Overlap with PaMPA. collective asynchronous communications (PaMPA based). Asynchronous point to point communications. Tests on the cluster Avakas from MCIA, and on Mésocentre de Marseille, and PlaFRIM. Tuer-1 Turing (Blue-Gene).
- **C++/Fortran interface** Tests for binding fortran with C++.
- **Instrumentation** Aerosol can give some traces on memory consumption/problems with an interfacing with the PAPI library. Tests have also been performed with VTUNE and TAU.

This year, the following features were added

- **In/Out** Ability of saving the high order solution and restarting from it. Computation of volumic and probe statistics. Ability of saving averaged layer data in quad and hexa meshes. Ability of defining user defined output visualization variables.
- **Geometry** handling of high order meshes.
- **Time iteration** Newton method for stationary problems. Implicite unstationary time iterator non consistent in time for stationary problems. Implementation of in house GMRES and conjugate gradient based on Jacobian free iterations.
- **Models** scalar advection-diffusion model
- **Numerical schemes** Optimization of DG schemes for advection-diffusion problems: stocking of the geometry and use of BLAS for all the linear phases of the scheme.
- **Numerical fluxes** Development of a new numerical flux accurate for steady and unsteady computations.
- **Boundary conditions** Adiabatic wall and isothermal wall; Steger-Warming based boundary condition.
- **Instrumentation** Tests with Maqao and Scalasca (VIHPS workshop)
- **Validation** Poiseuille, Taylor-Green vortex. Laplace equation on a ring and Poiseuille flow on a ring. Implementation of volumic forcing based on wall dissipation.

## DEFI Project-Team

# 5. New Software and Platforms

## 5.1. RODIN

**Participant:** Grégoire Allaire [correspondant].

In the framework of the RODIN project we continue to develop with our software partner ESI the codes Topolev and Geolev for topology and geometry shape optimization of mechanical structures using the level set method.

## 5.2. FreeFem++ Toolboxes

### 5.2.1. Shape optimization toolbox in FreeFem++

**Participants:** Grégoire Allaire, Olivier Pantz.

We propose several FreeFem++ routines which allow the users to optimize the thickness, the geometry or the topology of elastic structures. All examples are programmed in two space dimensions. These routines have been written by G. Allaire, B. Boutin, C. Dousset, O. Pantz. A web page of this toolbox is available at [http://www.cmap.polytechnique.fr/~allaire/freefem\\_en.html](http://www.cmap.polytechnique.fr/~allaire/freefem_en.html).

We also have written a C++ code to solve the Hamilton Jacoby equation used in the Level-set shape optimization method. This code has been linked with FreeFem++ routines.

### 5.2.2. Eddy current problems

**Participants:** Zixian Jiang, Mohamed Kamel Riahi.

We developed a FreeFem++ toolbox that solves direct and inverse problems for an axisymmetric and 3D eddy current problems related to non destructive testing of deposits on the shell side of PWR fuel tubes. For the 3-D version, one can refer to <http://www.cmap.polytechnique.fr/~ria> and also to [15].

### 5.2.3. Contact managements

**Participant:** Olivier Pantz.

We have developed a toolbox running under Freefem++ in order to take into account the non-intersection constraints between several deformable bodies. This code has been used to treat contacts between red blood cells in our simulations, but also between genuine non linear elastic structure. It can handle both contacts and self-contacts.

Moreover, a toolbox based on the Penalization method has also been developed.

### 5.2.4. De-Homogenization

**Participant:** Olivier Pantz.

We have developed a code under Freefem++ that implements our De-Homogenization method. It has been used to solve the compliance minimization problem of the compliance of an elastic shape. In particular, it enables us to recover well known optimal Michell's trusses for shapes of low density.

## 5.3. Scilab and Matlab Toolboxes

### 5.3.1. Shape optimization toolbox in Scilab

**Participant:** Grégoire Allaire [correspondant].

Together with Georgios Michailidis, we improved a Scilab toolbox for 2-d shape and topology optimization by the level set method which was originally produced by Anton Karrman and myself. The routines, a short user's manual and several examples are available on the web page: [http://www.cmap.polytechnique.fr/~allaire/levelset\\_en.html](http://www.cmap.polytechnique.fr/~allaire/levelset_en.html)

### 5.3.2. Conformal mapping method

**Participant:** Housseem Haddar [correspondant].

This Scilab toolbox is dedicated to the resolution of inverse 2-D electrostatic problems using the conformal mapping method introduced by Akdumann, Kress and Haddar. The toolbox treats the cases of a simply connected obstacle with Dirichlet, Neumann or impedance boundary conditions or a simply connected inclusion with a constant conductivity. The latest development includes the extension of the method to the inverse scattering problem at low frequencies as introduced by Haddar-Kress (2012).

### 5.3.3. SAXS Utilities

**Participants:** Federico Benvenuto [correspondant], Housseem Haddar.

We developed a scilab and matlab toolboxes that post treat SAXS type measurements to identify size distributions of diluted particles. We treat both axisymmetric measurement and anisotropic ones. The toolbox also simulates SAXS measurements associated with some canonical geometries.

### 5.3.4. Direct Solver for periodic media

**Participants:** Thi Phong Nguyen [correspondant], Housseem Haddar.

This Matlab toolbox solves the scattering from locally perturbed periodic layer using Floquet-Bloch transform and spectral discretization of associated volume integral equation.

## 5.4. Sampling methods for inverse problems

### 5.4.1. Samplings-2d

**Participant:** Housseem Haddar [correspondant].

This software is written in Fortran 90 and is related to forward and inverse problems for the Helmholtz equation in 2-D. It includes three independent components. The first one solves to scattering problem using integral equation approach and supports piecewise-constant dielectrics and obstacles with impedance boundary conditions. The second one contains various samplings methods to solve the inverse scattering problem (LSM, RGLSM(s), Factorization, MuSiC) for near-field or far-field setting. The third component is a set of post processing functionalities to visualize the results

See also the web page <http://sourceforge.net/projects/samplings-2d/>.

- License: GPL
- Type of human computer interaction: sourceforge
- OS/Middleware: Linux
- Programming language: Fortran
- Documentation: fichier

### 5.4.2. Samplings-3d

**Participant:** Housseem Haddar [correspondant].

This software is written in Fortran 90 and is related to forward and inverse problems for the Helmholtz equation in 3-D. It contains equivalent functionalities to samplings-2d in a 3-D setting.

### 5.4.3. Time domain samplings-2d

**Participant:** Housseem Haddar [correspondant].

This software is written in Fortran 90 and is related to forward and inverse problems for the time dependent wave equation in 2-D. The forward solver is based on a FDTD method with PMLs. The inverse part is an implementation of the linear sampling method in a near field setting and the factorization method in a far field setting.

## 5.5. BlochTorreyPDESolver

**Participants:** Jing-Rebecca Li [correspondant], Dang Van Nguyen.

We developed two numerical codes to solve the multiple-compartments Bloch-Torrey partial differential equation in 2D and 3D to simulate the water proton magnetization of a sample under the influence of diffusion-encoding magnetic field gradient pulses.

We coupled the spatial discretization with an efficient time discretization adapted to diffusive problems called the (explicit) Runge-Kutta-Chebyshev method.

The version of the code using Finite Volume discretization on a Cartesian grid is complete (written by Jing-Rebecca Li). The version of the code using linear Finite Elements discretization is complete (written by Dang Van Nguyen and Jing-Rebecca Li).

See the web page <http://www.cmap.polytechnique.fr/~jingrebeccali/> for more details.

## ECUADOR Project-Team

# 5. New Software and Platforms

## 5.1. AIRONUM

**Participant:** Alain Dervieux [correspondant].

Aironum is an experimental software that solves the unsteady compressible Navier-Stokes equations with  $k - \epsilon$ , LES-VMS and hybrid turbulence modelling on parallel platforms, using MPI. The mesh model is unstructured tetrahedrization, with possible mesh motion. See <http://www-sop.inria.fr/tropics/aironum>

- Version: v 1.0
- Programming language: Fortran95 (mostly). About 100,000 lines.

Aironum was developed by Inria and University of Montpellier. It is used by Inria, University of Montpellier and University of Pisa (I). Aironum is used as an experimental platform for:

- Numerical approximation of compressible flows, such as upwind mixed element volume approximation with superconvergence on regular meshes.
- Numerical solution algorithms for the implicit time advancing of the compressible Navier-Stokes equations, such as parallel scalable deflated additive Schwarz algorithms.
- Turbulence modelling such as the Variational Multiscale Large eddy Simulation and its hybridization with RANS statistical models.

## 5.2. TAPENADE

**Participants:** Laurent Hascoët [correspondant], Valérie Pascual, Ala Taftaf, Jan Hueckelheim [Queen Mary University of London].

Tapenade is an Algorithmic Differentiation tool that transforms an original program into a new program that computes derivatives of the original program. Algorithmic Differentiation produces analytical derivatives, that are exact up to machine precision. Adjoint-mode AD can compute gradients at a cost which is independent from the number of input variables. Tapenade accepts source programs written in Fortran77, Fortran90, or C. It provides differentiation in the following modes: tangent, vector tangent, adjoint, and vector adjoint. Documentation is provided on <http://www-sop.inria.fr/tropics/tapenade.html>, in Inria technical report RT-0300, and in [9].

- Version: v3.9, r5092, February 2014
- ACM: D.3.4 Compilers; G.1.0 Numerical algorithms; G.1.4 Automatic differentiation; I.1.2 Analysis of algorithms
- AMS: 65K10; 68N20
- APP: IDD.N.FR.001.040038.002.S.P.2002.000.10600
- Keywords: algorithmic differentiation, adjoint, gradient, optimisation, inverse problems, static analysis, data-flow analysis, compilation
- Programming language: Java

Tapenade implements the results of our research about models and static analyses for AD. Tapenade can be downloaded and installed on most architectures. Alternatively, it can be used as a web server. Higher-order derivatives can be obtained through repeated application.

Tapenade performs sophisticated data-flow analysis, flow-sensitive and context-sensitive, on the complete source program to produce an efficient differentiated code. Analyses include Type-Checking, Read-Write analysis, and Pointer analysis. AD-specific analyses include:

- **Activity analysis:** Detects variables whose derivative is either null or useless, to reduce the number of derivative instructions.
- **Adjoint Liveness analysis:** Detects the source statements that are dead code for the computation of derivatives.
- **TBR analysis:** In adjoint-mode AD, reduces the set of source variables that need to be recovered.

Tapenade is not open-source. Academic usage is free for one year. Other usages require a paying license, as detailed on the web page. Ten industrial licences have been sold. Tapenade has been downloaded several hundred times, and the web tool served several thousands of true connections (robots and crawlers excluded) The tapenade-users mailing list is over one hundred registered users.

## **GAMMA3 Project-Team**

### **3. New Software and Platforms**

#### **3.1. BLGEOL-V1 software**

**Participants:** Patrick Laug [correspondant], Houman Borouchaki.

BLGEOL-V1 software can generate hex-dominant meshes of geologic structures complying with different geometric constraints: surface topography (valleys, reliefs, rivers), geologic layers and underground workings. First, a reference 2D domain is obtained by projecting all the line constraints into a horizontal plane. Different size specifications are given for rivers, outcrop lines and workings. Using an adaptive methodology, the size variation is bounded by a specified threshold in order to obtain a high quality quad-dominant mesh. Secondly, a hex-dominant mesh of the geological medium is generated by a vertical extrusion, taking into account the surfaces found (interfaces between two layers, top or bottom faces of underground workings). The generation of volume elements follows a global order established on the whole set of surfaces to ensure the conformity of the resulting mesh.



**IPSO Project-Team (section vide)**

**MATERIALS Team (section vide)**

## MC2 Team

# 5. New Software and Platforms

## 5.1. eLYSe

**Participant:** Olivier Saut.

eLYse is a numerical platform used for our computations in Biology (tumor growth), micro-fluidics and complex Newtonian fluid flows. The platform is divided in two libraries : one is devoted to the modelling equations and the other one includes the numerical solvers. For example, we are able to treat (in 2D and 3D) transport equations, diffusion equations, Navier-Stokes equations, Maxwell system and the interaction fluid-structure by level-set and penalization methods. The solvers are based on finite volume methods on cartesian grids and allow parallel computations. See also the web page <http://www.math.u-bordeaux1.fr/~osaut/pages/eLYSe.html>.

- Version: 0.7
- ACM: ACM J.2 J.3 G.1.8 G.1.10
- AMS: AMS65Z05 35Q92
- Keywords: Modélization and numerical simulations, Finite volume methods, Level Set approach, Penalization method
- APP: En cours
- Type of human computer interaction: console
- OS/Middelware: Platform developped on Mac OS X architecture.
- Required library or software: Petsc (<http://www.mcs.anl.gov/petsc/petsc-as/>) Vtk (<http://www.vtk.org/>) Blitz++ (<http://c2.com/cgi/wiki?BlitzPlusPlus>) (optionnel) Boost (<http://www.boost.org/>)
- Programming language: C++
- Documentation: doxygen.

## 5.2. Kesaco

**Participant:** Olivier Saut.

Kesaco is a set of libraries and programs aiming at applications of mathematical modeling in clinical oncology. It features:

- A library of specialized mathematical model describing the growth of different types of cancers (secondary tumors in the lung, gliomas).
- A set of programs useful to validate mathematical models (compute the various behavior they can produce) and to build databases of numerical simulations.
- Segmentation and registration routines to use medical images directly in our numerical codes.
- Calibration methods to recover the parameters of the models using sequences of medical images. Three techniques are implemented (a genetic algorithm, a technique based on reduced order models, a sensitivity technique).

All these routines are adapted to run on a MP architecture. The webpage may be found at <http://www.math.u-bordeaux1.fr/~osaut/pages/kesaco.html>.

- Version: 0.2
- Keywords: Modélisation and numerical simulations
- APP: En cours
- Type of human computer interaction: console
- OS/Middelware: Platform developped on Mac OS X architecture.
- Required library or software: eLYSe, Insight Toolkit (<http://www.itk.org>)
- Programming language: C++
- Documentation: doxygen.

### 5.3. NaSCar

**Participant:** Michel Bergmann [correspondant].

This code is devoted to solve 3D-flows in around moving and deformable bodies. The incompressible Navier-Stokes equations are solved on fixed grids, and the bodies are taken into account thanks to penalization and/or immersed boundary methods. The interface between the fluid and the bodies is tracked with a level set function or in a Lagrangian way. The numerical code is fully second order (time and space). The numerical method is based on projection schemes of Chorin-Temam's type. The code is written in C language and use Petsc (<http://www.mcs.anl.gov/petsc/petsc-as/>) library for the resolution of large linear systems in parallel.

NaSCar can be used to simulate both hydrodynamic bio-locomotion as fish like swimming and aerodynamic flows such wake generated by a wind turbine.

- Version: 1
- Keywords: numerical analyse, fluid mechanics, langage C, PETSc
- Software benefit : simulate a flow around a deformable obstacle, moving into a fluid.
- APP: En cours
- Patent: non
- Type of human computer interaction: human for the moment
- OS/Middelware: unix, linux, mac os
- Required library or software: PETSc item Programming language: C
- Documentation: in progress

### 5.4. NS-MPI-2D-3D

**Participants:** Charles-Henri Bruneau [correspondant], Khodor Khadra.

The software NS-MPI-2D-3D is a numerical platform devoted to the computation of the incompressible flow around bodies in two or three dimensions modelled by Stokes, Navier-Stokes or Oldroyd-B equations. It is based on finite differences or finite volumes approximations on cartesian grid using the volume penalization method to handle the obstacles. The resolution is achieved by means of the multigrid method. Dirichlet, periodic or artificial boundary conditions are implemented to solve various problems in closed or open domains.

- Version: 3
- Keywords: Numerical simulation of incompressible flows,
- Type of human computer interaction: console
- OS/Middelware: unix, linux, Mac OS X item Programming language: Fortran 95 and MPI
- Documentation: included

## 5.5. Other MC2 codes

- Penalization techniques on cartesian grids to solve incompressible Navier-Stokes equations
  - **Vortex**: sequential, Vortex In-Cell (VIC) scheme : hybrid vortex methods based on the combination of Lagrangian mesh-free schemes and Eulerian grid based schemes on the same flow region.
  - Unstructured body fitted meshes
  - **Richards** : 2D Unstructured finite element code, implicit solver, sequential, to solve the transport-diffusion equations through a porous media including tidal forcing and mechanisms of diagenesis.
  - development inside **FluidBox** software in collaboration with **BACCHUS**. 2D-3D unstructured meshes, Stabilized Finite Elements method (SUPG), RANS turbulence model, parallel: Domain Decomposition and MPI.
- Immersed boundary techniques for:
  - **Compressible flows** : 2D-3D finite volume scheme for compressible Euler equations with solid obstacles on cartesian grids. 3D code parallelized with MPI
  - **Elliptic problems** : 2 2D-3D finite difference scheme for elliptic interface problems, parallelized with PETSc
  - Elmo. C++ Code of Finite Differences on cartesian grid parallelized with PETSC to compute the electropermeabilisation of cells in 2D and 3D.

## MEPHYSTO Team

# 5. New Software and Platforms

## 5.1. Platforms

### 5.1.1. *Modulef*

The numerical method to approximate the constitutive laws for rubber elasticity derived from polymer physics (as used in [15], [25]) are implemented in the Inria software *Modulef* (joint work of M. Vidrascu, projetc-team REO, and A. Gloria).

It is based on

- algorithms from stochastic geometry to generate suitable polymer networks;
- Delaunay tessellation algorithms to deal with steric effects (courtesy of the Inria project-team GAMMA2);
- the introduction of 1-dimensional finite elements for the polymer-chains in *Modulef*.

### 5.1.2. *CMA-ES*

To solve the inverse problem for the reconstruction of an explicit constitutive law from in silico experiments in [25], we relied on the Covariance Matrix Adaptation Evolution Strategy developed in the project-team TAO.

<https://www.lri.fr/~hansen/cmaesintro.html>

### 5.1.3. *FreeFEM++*

The numerical methods proposed in [14] for the approximation of homogenized coefficients were implemented in *FreeFEM++*, a user-friendly PDE-solver.

<http://www.freefem.org/ff++/>

## MOKAPLAN Team

# 5. New Software and Platforms

## 5.1. ALG2 for Monge Mean-Field Games, Monge problem and Variational problems under divergence constraint

### 5.1.1. Platforms

A generalisation of the ALG2 algorithm [53] corresponding to the paper [18] has been implemented in FreeFem++. The scripts and numerical simulations are available at <https://team.inria.fr/mokaplan/augmented-lagrangian-simulations/>.

We still plan to implement a parallel version on Rocquencourt Inria cluster. We are waiting for FreeFem to be installed on the cluster.

## 5.2. Mokabajour

### 5.2.1. Platforms

Following the pioneering work of Caffarelli and Oliker [42], Wang [85] has shown that the inverse problem of freeforming a *convex* reflector which sends a prescribed source to a target intensity is a particular instance of Optimal Mass Transportation. The method developed in [7] has been used by researchers of TU Eindhoven in collaboration with Philips Lightning Labs to compute reflectors [81] in a simplified setting. The industrial motivation is the automatic design of reflector given prescribed source and target illuminance. From the mathematical point of view there is a hierarchy of Optimal Mass Transportation reflector and lenses problems and only the simplest "far field" one can be solved with state of the art Monge-Ampère solvers. We will adapt the Monge-Ampère solvers and also attempt to build real optimized reflector prototypes. We plan on investigating the more complicated near field models and design numerical methods. Finally Monge-Ampère based Optimal Mass Transportation solvers will be made available. This could be used for example in Mesh adaptation.

The web site is under construction <https://project.inria.fr/mokabajour/>, preliminary results are available.

This ADT (Simon Legrand) on the numerical free forming of specular reflectors started in december. We implement different types of MA solvers in collaboration with Quentin Mérigot (CEREMADE), Boris Thibert (LJK Grenoble) and Vincent Duval. See <https://project.inria.fr/mokabajour/>.

## NACHOS Project-Team

# 5. New Software and Platforms

## 5.1. MAXW-DGTD

**Participants:** Alexandra Christophe-Argenvillier, Loula Fézoui, Stéphane Lanteri [correspondant], Raphaël Léger, Jonathan Viquerat.

MAXW-DGTD is a software suite for the simulation of time domain electromagnetic wave propagation. It implements a solution method for the Maxwell equations in the time-domain. MAXW-DGTD is based on a discontinuous Galerkin method formulated on unstructured triangular (2d case) or tetrahedral (3d case) meshes [19]. Within each element of the mesh, the components of the electromagnetic field are approximated by an arbitrary high order nodal polynomial interpolation method. This discontinuous Galerkin method combines a centered scheme for the evaluation of numerical fluxes at a face shared by two neighboring elements, with an explicit Leap-Frog time scheme. The software and the underlying algorithms are adapted to distributed memory parallel computing platforms thanks to a parallelization strategy that combines a partitioning of the computational domain with message passing programming using the MPI standard. Besides, a peripheral version of the software has been recently developed which is able to exploit the processing capabilities of a hybrid parallel computing system comprising multicore CPU and GPU nodes.

- AMS: AMS 35L50, AMS 35Q60, AMS 35Q61, AMS 65N08, AMS 65N30, AMS 65M60
- Keywords: Computational electromagnetics, Maxwell equations, discontinuous Galerkin, tetrahedral mesh.
- OS/Middleware: Linux
- Required library or software: MPI (Message Passing Interface), CUDA
- Programming language: Fortran 77/95

## 5.2. MAXW-DGFD

**Participants:** Stéphane Lanteri [correspondant], Ludovic Moya, Ronan Perrussel.

MAXW-DGFD is a software suite for the simulation of time-harmonic electromagnetic wave propagation. It implements a solution method for the Maxwell equations in the frequency domain. MAXW-DGFD is based on a discontinuous Galerkin method formulated on unstructured triangular (2d case) or tetrahedral (3d case) meshes. Within each element of the mesh, the components of the electromagnetic field are approximated by an arbitrary high order nodal polynomial interpolation method. The resolution of the sparse, complex coefficients, linear systems resulting from the discontinuous Galerkin formulation is performed by a hybrid iterative/direct solver whose design is based on domain decomposition principles. The software and the underlying algorithms are adapted to distributed memory parallel computing platforms thanks to a parallelization strategy that combines a partitioning of the computational domain with a message passing programming using the MPI standard. Some recent achievements have been the implementation of non-uniform order DG method in the 2d case and of a new hybridizable discontinuous Galerkin (HDG) formulation also in the 2d and 3d cases.

- AMS: AMS 35L50, AMS 35Q60, AMS 35Q61, AMS 65N08, AMS 65N30, AMS 65M60
- Keywords: Computational electromagnetics, Maxwell equations, discontinuous Galerkin, tetrahedral mesh.
- OS/Middleware: Linux
- Required library or software: MPI (Message Passing Interface)
- Programming language: Fortran 77/95



### 5.3. SISMO-DGTD

**Participants:** Nathalie Glinsky, Stéphane Lanteri [correspondant].

SISMO-DGTD is a software for the simulation of time-domain seismic wave propagation. It implements a solution method for the velocity-stress equations in the time-domain. SISMO-DGTD is based on a discontinuous Galerkin method formulated on unstructured triangular (2d case) or tetrahedral (3d case) meshes [4]. Within each element of the mesh, the components of the electromagnetic field are approximated by an arbitrary high order nodal polynomial interpolation method. This discontinuous Galerkin method combines a centered scheme for the evaluation of numerical fluxes at a face shared by two neighboring elements, with an explicit Leap-Frog time scheme. The software and the underlying algorithms are adapted to distributed memory parallel computing platforms thanks to a parallelization strategy that combines a partitioning of the computational domain with a message passing programming using the MPI standard.

- AMS: AMS 35L50, AMS 35Q74, AMS 35Q86, AMS 65N08, AMS 65N30, AMS 65M60
- Keywords: Computational geoseismics, elastodynamic equations, discontinuous Galerkin, tetrahedral mesh.
- OS/Middleware: Linux
- Required library or software: MPI (Message Passing Interface)
- Programming language: Fortran 77/95

## NANO-D Project-Team

### 4. New Software and Platforms

#### 4.1. SAMSON

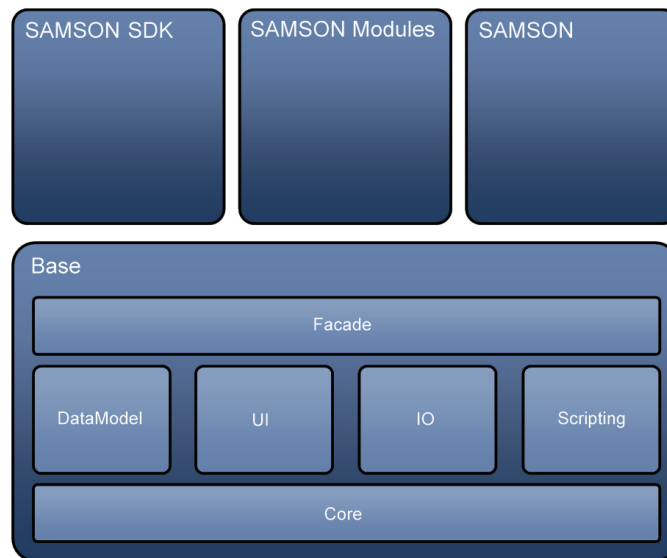


Figure 3. SAMSON's architecture.

A major objective of NANO-D is to try and integrate a variety of adaptive algorithms into a unified framework. As a result, NANO-D is developing SAMSON (Software for Adaptive Modeling and Simulation Of Nanosystems), a software platform aimed at including all developments from the group, in particular those described below.

The objective is to make SAMSON a generic application for computer-aided design of nanosystems, similar to existing applications for macrosystem prototyping (CATIA, SolidWorks, etc.).

The current architecture of SAMSON is visible in Figure 3. The code is organized into four main parts: a) the Base (in which “Core” contains, in particular, the heart of the adaptive algorithms: signaling mechanisms specifically designed for SAMSON), b) the Software Development Kit (SDK: a subset of the base that will be provided to module developers), c) Modules, and d) the SAMSON application itself.

Similar to the concept of Mathematica *toolboxes*, for example, the goal has been to make it possible to personalize the user interface of SAMSON for potentially many distinct applications. For example, we may want to personalize the interface of SAMSON for crystallography, drug design, protein folding, electronics, material science, nano-engineering, etc., by loading different modules at startup, depending on the user application domain.

## OPALE Project-Team

# 5. New Software and Platforms

## 5.1. NUM3SIS

**Participant:** Régis Duvigneau [correspondant].

The Opale project-team has initiated a few years ago the development of NUM3SIS (<http://num3sis.inria.fr>), which is a modular platform devoted to scientific computing and numerical simulation. It is not restricted to a particular application field, but is designed to host complex multidisciplinary simulations. Main application fields are currently Computational Fluid Dynamics (by Opale project-team), Computational Electro-Magnetics (by Nachos project-team) and pedestrian traffic simulation (by Opale project-team). Some components of the platform are also used by the Tosca project-team for CO2 market simulation and wind simulation in collaboration with Ciric (Inria-Chile).

NUM3SIS provides innovative software tools to overcome some limitations encountered by classical monolithic simulation codes. In particular, the platform is based on abstract concepts commonly used in scientific computing, such as mesh, fields, finite-elements, linear solvers etc, that can be implemented in plugins. A fast prototyping of algorithms can be achieved using a visual programming interface. A component is dedicated to deployment on parallel architectures. Moreover, the platform relies on a "store" system to foster exchange of plugins, scripts or data.

This work is being carried out with the support of one engineer in the framework of an ADT (Action de Développement Technologique) program.

## 5.2. FAMOSA

**Participant:** Régis Duvigneau [correspondant].

Opale team is developing the software platform FAMOSA (C++), that is devoted to multidisciplinary design optimization in engineering. It integrates the following components:

- an optimization library composed of various algorithms : several descent methods from steepest-descent method to quasi-Newton BFGS method (deterministic, smooth), the Multi-directional Search Algorithm (deterministic, noisy), the Covariance Matrix Adaption Evolution Strategy (semi-stochastic, multi-modal) and the Efficient Global Optimization method (deterministic, multi-modal). It also contains the Pareto Archived Evolution Strategy to solve multi-objective optimization problems ;
- an evaluation library managing the performance estimation process (communication with external simulation tools) ;
- a metamodel library that contains tools to build a database and kriging models that are used to approximate the objective function for different purposes;
- a scenario library that allows to use the previous components to achieve various tasks:
  - Construct a design of experiments ;
  - Construct a metamodel ;
  - Find the design that minimizes a cost functional ;
  - Find the Pareto front for two cost functionals
  - Play a Nash game to find the equilibrium between two criteria ;
  - Apply a multiple gradient descent strategy to improve simultaneously two criteria.

The FAMOSA platform is employed by Opale project-team to test its methodological developments. The platform is also used by the Fluid Mechanics Laboratory at Ecole Centrale de Nantes for hydrodynamic design applications and ONERA for multidisciplinary design optimization (MDO). Moreover, it is presently tested by Peugeot Automotive industry for external aerodynamic design purpose.

### 5.3. Plugins for AXEL

**Participant:** Régis Duvigneau [correspondant].

Opale team is developing plugins in the framework of the algebraic modeler Axel, in collaboration with the Galaad project-team. These developments correspond to two research axes :

- isogeometric analysis and design. In particular, two simulation tools for heat conduction and compressible flows have been implemented, in conjunction with some deterministic and semi-stochastic optimization algorithms for optimum-shape design ;
- geometrical modeling for design optimization.

### 5.4. Integration platform for multidiscipline optimization applications

**Participants:** Toan Nguyen, Laurentiu Trifan.

A prototype software integration platform is developed and tested for multidiscipline optimization applications. It is based on a workflow management system called YAWL (<http://www.yawlfoundation.org>). The goal is to design, develop and assess high-performance distributed scientific workflows featuring resilience, i.e., fault-tolerance and exception-handling capabilities. The platform is used to experiment new resilience algorithms, including monitoring and management of application-level errors. Errors include time-outs and out of bounds data values. They can be added and modified by the users. The platform is tested against use-cases provided by the industry partners in the OMD2 project supported by the French Agence Nationale de la Recherche. For example, an optimization of a car air-conditioning pipe was implemented and deployed on the Grid5000 infrastructure. It also takes into account run-time errors related to resource consumption, e.g., memory overflow, to automatically and dynamically relocate the applications tasks involved on the various clusters. This work was Laurentiu Trifan's PhD thesis, defended in October 2013.

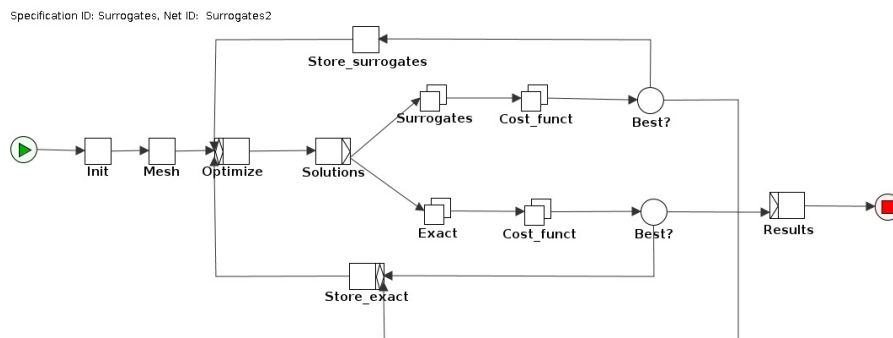


Figure 1. Testcase deployment on the Grid5000 infrastructure.

## POEMS Project-Team

# 5. New Software and Platforms

## 5.1. Software

### 5.1.1. *XLiFE++*

**Participants:** Eric Lunéville, Nicolas Kielbasiewicz, Colin Chambeyron.

XLiFE++ is a Finite Element library in C++ based on philosophy of the previous library MELINA in Fortran but with new capabilities (boundary elements, discontinuous Galerkin methods, more integrated tools -in particular mesh tools - and high performance computing skills, multithread and GPU computation). It is licensed under LGPL and developed in the context of the European project SIMPOSIUM (FP7/ICT, leader CEA/LIST, from september 2011 to august 2014). There are also academic partners: IRMAR, University of Rennes and LAMA, University of Marne-la-Vallée.

After 3 years of work, the development of the finite element library XLiFE++ reached a milestone in 2014 with the first downloadable public release, after an important effort to improve the user interface and to complete the last major developments necessary for this output: essential boundary conditions, mesh construction, Dirichlet-to-Neumann maps ... among others. In June 2014, a day was organized to present to a wider audience the features of this library. We now provide support to the users (patches, new developments...).

### 5.1.2. *COFFEE*

**Participant:** Stéphanie Chaillat.

COFFEE is a 3D BEM-accelerated FMM solver for linear elastodynamics (full implementation, 30 000 lines of Fortran 90). The 3-D elastodynamic equations are solved with the boundary element method accelerated by the multi-level fast multipole method. The fundamental solutions for the infinite space are used in this implementation. A boundary element-boundary element coupling strategy is also implemented so multi-region problems (strata inside a valley for example) can be solved.

## APICS Project-Team

# 5. New Software and Platforms

## 5.1. RARL2

**Participant:** Martine Olivi [corresponding participant].

Status: Currently under development. A stable version is maintained.

This software is developed in collaboration with Jean-Paul Marmorat (Centre de mathématiques appliquées (CMA), École des Mines de Paris).

RARL2 (Réalisation interne et Approximation Rationnelle L2) is a software for rational approximation (see Section 3.3.2.2) <http://www-sop.inria.fr/apics/RARL2/rarl2.html>.

The software RARL2 computes, from a given matrix-valued function in  $\overline{H}^{2m \times l}$ , a local best rational approximant in the  $L^2$  norm, which is *stable and of prescribed McMillan degree* (see Section 3.3.2.2). It was initially developed in the context of linear (discrete-time) system theory and makes an heavy use of the classical concepts in this field. The matrix-valued function to be approximated can be viewed as the transfer function of a multivariable discrete-time stable system. RARL2 takes as input either:

- its internal realization,
- its first  $N$  Fourier coefficients,
- discretized (uniformly distributed) values on the circle. In this case, a least-square criterion is used instead of the  $L^2$  norm.

It thus performs model reduction in case 1) and 2) and frequency data identification in case 3). In the case of band-limited frequency data, it could be necessary to infer the behavior of the system outside the bandwidth before performing rational approximation (see Section 3.2.2). An appropriate Möbius transformation allows to use the software for continuous-time systems as well.

The method is a steepest-descent algorithm. A parametrization of MIMO systems is used, which ensures that the stability constraint on the approximant is met. The implementation, in Matlab, is based on state-space representations.

The number of local minima can be large so that the choice of an initial point for the optimization may play a crucial role. In this connection, two methods can be used: 1) An initialization with a best Hankel approximant. 2) An iterative research strategy on the degree of the local minima, similar in principle to that of RARL2, increases the chance of obtaining the absolute minimum by generating, in a structured manner, several initial conditions.

RARL2 performs the rational approximation step in our applications to filter identification (see Section 4.5) as well as sources or cracks recovery (see Section 4.2). It was released to the universities of Delft, Maastricht, Cork, Brussels and Macao. The parametrization embodied in RARL2 was also used for a multi-objective control synthesis problem provided by ESTEC-ESA, The Netherlands. An extension of the software to the case of triple poles approximants is now available. It is used by FindSources3D (see Section 5.6).

## 5.2. RGC

**Participant:** Fabien Seyfert [corresponding participant].

Status: A stable version is maintained.

This software is developed in collaboration with Jean-Paul Marmorat (Centre de mathématiques appliquées (CMA), École des Mines de Paris).

The identification of filters modeled by an electrical circuit that was developed by the team (see Section 4.5) led us to compute the electrical parameters of the underlying filter. This means finding a particular realization  $(A, B, C, D)$  of the model given by the rational approximation step. This 4-tuple must satisfy constraints that come from the geometry of the equivalent electrical network and translate into some of the coefficients in  $(A, B, C, D)$  being zero. Among the different geometries of coupling, there is one called “the arrow form” [57] which is of particular interest since it is unique for a given transfer function and is easily computed. The computation of this realization is the first step of RGC. Subsequently, if the target realization is not in arrow form, one can nevertheless show that it can be deduced from the arrow-form by a complex-orthogonal change of basis. In this case, RGC starts a local optimization procedure that reduces the distance between the arrow form and the target, using successive orthogonal transformations. This optimization problem on the group of orthogonal matrices is non-convex and has many local and global minima. In fact, there is not even uniqueness of the filter realization for a given geometry. Moreover, it is often relevant to know all solutions of the problem, because the designer is not even sure, in many cases, which one is being handled. The assumptions on the reciprocal influence of the resonant modes may not be equally well satisfied for all such solutions, hence some of them should be preferred for the design. Today, apart from the particular case where the arrow form is the desired form (this happens frequently up to degree 6) the RGC software is not guaranteed to provide a solution. In contrast, the software Dedale-HF (see Section 5.4), which is the successor of RGC, is guaranteed to solve this constraint realization problem.

### 5.3. PRESTO-HF

**Participant:** Fabien Seyfert [corresponding participant].

Status: Currently under development. A stable version is maintained.

PRESTO-HF: a toolbox dedicated to lowpass parameter identification for microwave filters <http://www-sop.inria.fr/apics/Presto-HF>. In order to allow the industrial transfer of our methods, a Matlab-based toolbox has been developed, dedicated to the problem of identification of low-pass microwave filter parameters. It allows one to run the following algorithmic steps, either individually or in a single shot:

- determination of delay components caused by the access devices (automatic reference plane adjustment),
- automatic determination of an analytic completion, bounded in modulus for each channel,
- rational approximation of fixed McMillan degree,
- determination of a constrained realization.

For the matrix-valued rational approximation step, Presto-HF relies on RARL2 (see Section 5.1). Constrained realizations are computed by the RGC software. As a toolbox, Presto-HF has a modular structure, which allows one for example to include some building blocks in an already existing software.

The delay compensation algorithm is based on the following assumption: far off the passband, one can reasonably expect a good approximation of the rational components of  $S_{11}$  and  $S_{22}$  by the first few terms of their Taylor expansion at infinity, a small degree polynomial in  $1/s$ . Using this idea, a sequence of quadratic convex optimization problems are solved, in order to obtain appropriate compensations. In order to check the previous assumption, one has to measure the filter on a larger band, typically three times the pass band.

This toolbox is currently used by Thales Alenia Space in Toulouse, Thales airborne systems and a license agreement has been recently negotiated with TAS-España. XLIM (University of Limoges) is a heavy user of Presto-HF among the academic filtering community and some free license agreements are currently being considered with the microwave department of the University of Erlangen (Germany) and the Royal Military College (Kingston, Canada). A time-limited license has been bought by Flextronics for testing purposes.

### 5.4. Dedale-HF

**Participant:** Fabien Seyfert [corresponding participant].

Status: Currently under development. A stable version is maintained.

Dedale-HF is a software dedicated to solve exhaustively the coupling matrix synthesis problem in reasonable time for the filtering community. Given a coupling topology, the coupling matrix synthesis problem (C.M. problem for short) consists in finding all possible electromagnetic coupling values between resonators that yield a realization of given filter characteristics. Solving the latter problem is crucial during the design step of a filter in order to derive its physical dimensions as well as during the tuning process where coupling values need to be extracted from frequency measurements (see Figure 3 ).

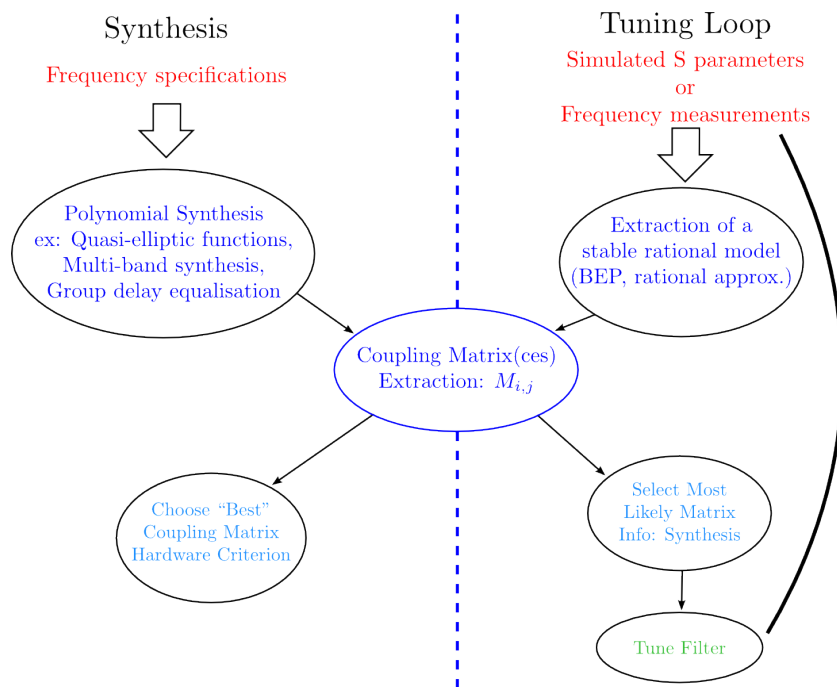


Figure 3. Overall scheme of the design and tuning process of a microwave filter.

Dedale-HF consists in two parts: a database of coupling topologies as well as a dedicated predictor-corrector code. Roughly speaking each reference file of the database contains, for a given coupling topology, the complete solution to the C.M. problem associated to particular filtering characteristics. The latter is then used as a starting point for a predictor-corrector integration method that computes the solution to the C.M. corresponding to the user-specified filter characteristics. The reference files are computed off-line using Gröbner basis techniques or numerical techniques based on the exploration of a monodromy group. The use of such continuation techniques, combined with an efficient implementation of the integrator, drastically reduces the computational time.

Access to the database and integrator code is done via the web on <http://www-sop.inria.fr/apics/Dedale/WebPages>. The software is free of charge for academic research purposes: a registration is however needed in order to access full functionality. Up to now 90 users have registered world wide (mainly: Europe, U.S.A, Canada and China) and 4000 reference files have been downloaded.

A license for this software has been sold end of 2011 to TAS-Espagna, in order to tune filters with topologies having multiple solutions. For this, Dedale-HF teams up with Presto-HF.



## 5.5. easyFF

**Participant:** Fabien Seyfert.

Status: A stable version is maintained.

This software has been developed by Vincent Lunot (Taiwan Univ.) during his PhD. He still continues to maintain it.

EasyFF is a software dedicated to the computation of complex, in particular multi-band filtering functions. The software takes as input, specifications on the modulus of the scattering matrix (transmission and rejection), the filter's order and the number of transmission zeros. The output is an "optimal" filtering characteristic in the sense that it is the solution of an associated min-max Zolotarev problem. Computations are based on a Remez-type algorithm (if transmission zeros are fixed) or on linear programming techniques if transmission zeros are part of the optimization [11].

## 5.6. FindSources3D

**Participant:** Juliette Leblond [corresponding participant].

Status: Currently under development. A stable version is maintained.

This software is developed in collaboration with Maureen Clerc and Théo Papadopoulo from the Athena Project-Team, and with Jean-Paul Marmorat (Centre de mathématiques appliquées - CMA, École des Mines de Paris).

FindSources3D<sup>0</sup> is a software dedicated to source recovery for the inverse EEG problem, in 3-layer spherical settings, from point-wise data (see <http://www-sop.inria.fr/apics/FindSources3D/>). Through the algorithm described in [9] and Section 4.2, it makes use of the software RARL2 (Section 5.1) for the rational approximation step in plane sections.

A new release of FindSources3D is now available, which will be demonstrated and distributed, in particular to the medical team we maintain contact with (hosp. la Timone, Marseille). The preliminary step ("cortical mapping") is now solved using expansion in spherical harmonics, along with a constrained approximation scheme.

Another release is being prepared, due to strong interest by the German company BESA GmbH<sup>0</sup>, which develops EEG software for research and clinical applications. A deeper collaboration with this company started last year. Figure 4 shows good results on a two sources distribution recovered by FindSources3D from values of the potential at electrodes on a sphere (scalp) generated by BESA's simulator. There, the localization error is satisfactory, see [28]. Altogether FindSources3D provides suitable initial guess to heavier dedicated recovery tools, including an estimate of the number of sources see Section 6.1.1.

## 5.7. Sollya

**Participant:** Sylvain Chevillard [corresponding participant].

Status: Currently under development. A stable version is maintained.

This software is developed in collaboration with Christoph Lauter (LIP6) and Mioara Joldeş (LAAS).

Sollya is an interactive tool where the developers of mathematical floating-point libraries (libm) can experiment before actually developing code. The environment is safe with respect to floating-point errors, *i.e.* the user precisely knows when rounding errors or approximation errors happen, and rigorous bounds are always provided for these errors.

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<sup>0</sup>CeCILL license, APP version 2.0 (2012): IDDN.FR.001.45009.001.S.A.2009.000.10000

<sup>0</sup><http://www.besa.de/>

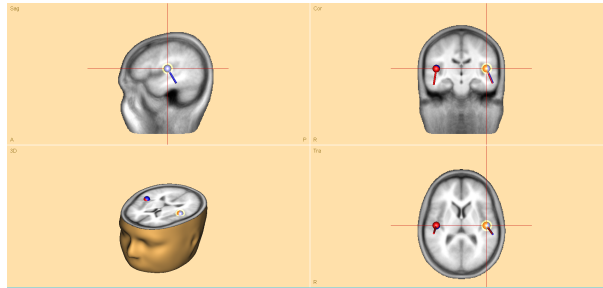


Figure 4. Recovered 2 sources by FindSources3D (courtesy of BESA).

Among other features, it offers a fast Remez algorithm for computing polynomial approximations of real functions and also an algorithm for finding good polynomial approximants with floating-point coefficients to any real function. As well, it provides algorithms for the certification of numerical codes, such as Taylor Models, interval arithmetic or certified supremum norms.

It is available as a free software under the CeCILL-C license at <http://sollya.gforge.inria.fr/>.

## BIPOP Project-Team

# 5. New Software and Platforms

## 5.1. Nonsmooth dynamics: Siconos

**Participants:** Vincent Acary, Maurice Brémond, Olivier Huber, Franck Pérignon.

In the framework of the European project Siconos, Bipop was the leader of the Work Package 2 (WP2), dedicated to the numerical methods and the software design for nonsmooth dynamical systems. The aim of this work is to provide a common platform for the simulation, modeling, analysis and control of abstract nonsmooth dynamical systems. Besides usual quality attributes for scientific computing software, we want to provide a common framework for various scientific fields, to be able to rely on the existing developments (numerical algorithms, description and modeling software), to support exchanges and comparisons of methods, to disseminate the know-how to other fields of research and industry, and to take into account the diversity of users (end-users, algorithm developers, framework builders) in building expert interfaces in Python and end-user front-end through Scilab.

After the requirement elicitation phase, the Siconos Software project has been divided into 5 work packages which are identified to software products:

1. SICONOS/NUMERICS This library contains a set of numerical algorithms, already well identified, to solve non smooth dynamical systems. This library is written in low-level languages (C,F77) in order to ensure numerical efficiency and the use of standard libraries (Blas, Lapack, ...)
2. SICONOS/KERNEL This module is an object-oriented structure (C++) for the modeling and the simulation of abstract dynamical systems. It provides the users with a set of classes to describe their nonsmooth dynamical system (dynamical systems, interactions, nonsmooth laws, ...) and to perform a numerical time integration and solving.
3. SICONOS/FRONT-END. This module is mainly an auto-generated wrapper in Python which provides a user-friendly interface to the Siconos libraries. A scilab interface is also provided in the Front-End module.
4. SICONOS/CONTROL This part is devoted to the implementation of control strategies of non smooth dynamical systems.
5. SICONOS/MECHANICS. This part is dedicated to the modeling and the simulation of multi-body systems with 3D contacts, impacts and Coulomb's friction. It uses the Siconos/Kernel as simulation engine but relies on an industrial CAD library (OpenCascade and pythonOCC) to deal with complex body geometries and to compute the contact locations and distances between B-Rep description and on Bullet for contact detection between meshes.

Further informations may be found at <http://siconos.gforge.inria.fr/>

## 5.2. Simulation of fibrous materials subject to frictional contact

### 5.2.1. MECHE: Modeling Entangling within Contacting hair fibErs

**Participants:** Florence Bertails-Descoubes, Gilles Daviet, Alexandre Derouet-Jourdan, Romain Casati, Laurence Boissieux.

The software MECHE was essentially developed during the MECHE ADT (2009-2011, research engineer: Gilles Daviet), for simulating the dynamics of assemblies of thin rods (such as hair), subject to contact and friction. Currently, this software is extensively used by two PhD students (A. Derouet-Jourdan and R. Casati) and continues to be enriched with new rod models and inversion modules. This software combines a panel of well-accepted models for rods (ranging from reduced coordinates to maximal coordinates models, and including models recently developed by some members of the group) with classical as well as innovative schemes for solving the problem of frictional contact (incorporating the most recent results of the group, as well as the new contact solver we published in [9]). The aim of this software is twofold: first, to compare and analyze the performance of nonsmooth schemes for the frictional contact problem, in terms of realism (capture of dry friction, typically), robustness, and computational efficiency. A first study of this kind was conducted in 2010-2011 onto the different rod models that were available in the software. New studies are planned for evaluating further rod models. Second, we believe such a software will help us understand the behavior of a fibrous material (such as hair) through virtual experiments, thanks to which we hope to identify and understand some important emergent phenomena. A careful validation study against experiments started to be conducted in 2011 in collaboration with physicists from L'Oréal. Once this discrete elements model will be fully validated, our ultimate goal would be to build a continuous macroscopic model for the hair medium relying on nonsmooth laws (which we have started to build in Gilles Daviet's PhD thesis). The core of this software was transferred to L'Oréal in 2011, and to AGT Digital in early 2013, by Gilles Daviet and Florence Bertails-Descoubes. It was also used for generating a number of simulations supporting at least 4 of our research publications.

## COMMANDS Project-Team

### 5. New Software and Platforms

#### 5.1. Bocop

**Participants:** Pierre Martinon [corresponding author], Frédéric Bonnans, Daphné Giorgi, Olivier Tissot.

Web page: <http://bocop.org>

The Bocop project aims to develop an open-source toolbox for solving optimal control problems, with collaborations with industrial and academic partners. Optimal control (optimization of dynamical systems governed by differential equations) has numerous applications in transportation, energy, process optimization, and biology. The software reuses some packages from the COIN-OR library, in particular the well-known nonlinear programming solver Ipopt, features a user-friendly interface and can be deployed on Windows / Mac / Linux.

The project is supported by Inria with the recruitment of Vincent Grelard as developer in 2010-2012, Daphné Giorgi (Oct. 2012-Sept. 2014), and Olivier Tissot since October 2014. The first prototype was released at the end of 2011, Bocop is currently at version 2.0.1 and has been downloaded more than 700 times. The software was first successfully tested on several academic problems, see [55] available on <http://bocop.org>. Starting in 2012, several research collaborations were initiated in fields such as bio-reactors for energy production ([13], [26]), swimming micro-robots ([71]), and quantum control for medical imaging ([35]). Bocop was also featured during our participation in the Imatch "Optimisation and Control" in October 2013, leading to an ongoing contract with the startup Safety Line, on fuel optimization for civil aircrafts.

*Bocop auto-assessment according to Inria notice: A3up4, SO3, SM3, EM3up4, SDL4up5*

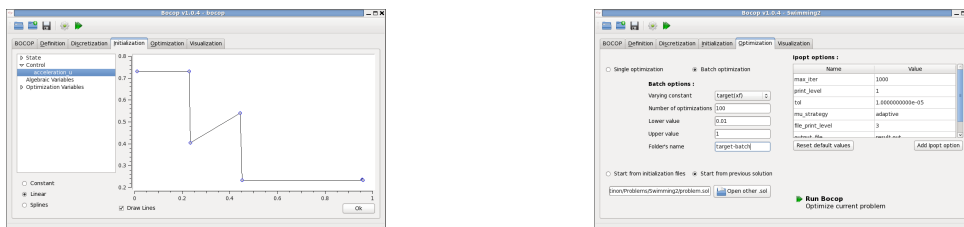


Figure 1. BOCOP

## CORIDA Team

# 5. New Software and Platforms

## 5.1. Simulation of viscous fluid-structure interactions

**Participants:** Takéo Takahashi [correspondant], Jean-François Scheid.

A number of numerical codes for the simulation for fluids and fluid-structure problems has been developed by the team. These codes are mainly written in MATLAB Software with the use of C++ functions in order to improve the sparse array process of MATLAB. We have focused our attention on 3D simulations which require large CPU time resources as well as large memory storage. In order to solve the 3D Navier-Stokes equations which model the viscous fluid, we have implemented an efficient 3D Stokes sparse solver for MATLAB and a 3D characteristics method to deal with the nonlinearity of Navier-Stokes equations. This year, we have also started to unify our 2D fluid-structure codes (fluid alone, fluid with rigid bodies and fluid with fishes).

Another code has been developed in the case of self-propelled deformable object moving into viscous fluid. Our aim is to build a deformable ball which could swim in a viscous fluid. In order to do this we have started a collaboration with a team from the CRAN (Research Centre for Automatic Control). This software solves numerically 3D Stokes equations using finite elements methods. The source code is written for use with MATLAB thanks to a C++ library developed by ALICE.

- Version: v0.5
- Programming language: MATLAB/C++

## 5.2. Fish locomotion in perfect fluids with potential flow

**Participants:** Alexandre Munnier [correspondant], Bruno Pinçon.

SOLEIL is a Matlab suite to simulate the self-propelled swimming motion of a single 3D swimmer immersed in a potential flow. The swimmer is modeled as a shape-changing body whose deformations can be either prescribed as a function of time (simulation of the direct swimming problem) or computed in such a way that the swimmer reaches a prescribed location (control problem). For given deformations, the hydrodynamical forces exerted by the fluid on the swimmer are expressed as solutions of 2D integral equations on the swimmer's surface, numerically solved by means of a collocation method.

SOLEIL is free, distributed under licence GPL v3. More details are available on the project web page <http://soleil.gforge.inria.fr/>.

The next step of SOLEIL (under progress) is to take into account a fluid whose flow is governed by Stokes equations.

- Version: 0.1
- Programming language: Matlab/C++

## 5.3. SUSHI3D : Simulations of Structures in Hydrodynamic Interactions

**Participants:** Jean-François Scheid, Takéo Takahashi.

SUSHI3D is a 3D solver for numerical simulations of Fluid/Structures Interactions. The Navier-Stokes equations are coupled with the dynamics of immersed bodies which can be either rigid or deformable. The deformable body case is handled and designed for fish-swimming. The numerical method used to solve the full differential system is based on a Lagrange-Galerkin method with finite elements.

- Version: 1.0
- Programming language: Matlab/C++

## 5.4. The Vir'Volt prototype

**Participants:** Thomas Chambrion, Bruno Pinçon.

The European Shell Eco Marathon is an annual competition gathering around 200 high schools and universities. The aim of this race is to travel a given distance (changing from year to year, about 16 km in 2013 and 2014) within a given time (39 minutes in 2014). The winning team is the one with the lowest energy consumption (expressed in km/kWh). The EcoMotion Team (EMT) of the École Supérieure des Sciences et Technologies de l'Ingénieur de Nancy (ESSTIN) in France, has been involved for 15 years in the European Shell Eco-Marathon in the categories gasoline, hydrogen and battery electric. In 2014, the prototype *Vir'Volt 3* (see Figure 1) entered the competition in the battery electric category.



Figure 1. *Vir'Volt* prototype during a test run in Geoparc race track near Saint Dié in May 2014 (left) and in the neighborhood of Toul in October 2014 (right).

An automatic speed control was embedded in the vehicle. From the velocity measures and a GPS sensor, the dynamics was identified in real time. This identification was precise enough to detect changes in the slope of the track or in wind direction. This dynamics was then used to compute in real time an optimal pair of lower and upper bounds for the speed. These bounds were computed in real time with an embedded low cost micro-controller. The final performance<sup>0</sup> of 533 km/kWh is in line with the (human driven) performance of the team in the recent years.

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<sup>0</sup><http://s00.static-shell.com/content/dam/shell-new/local/corporate/ecomarathon/downloads/pdf/europe/2014-results/sem-europe-2014-results-prototype-battery-electric-220514.pdf>

## DISCO Project-Team

# 5. New Software and Platforms

## 5.1. OreModules

**Participants:** Alban Quadrat [correspondent], Daniel Robertz [Univ. Aachen], Frédéric Chyzak [Inria Rocquencourt, Algorithms Project].

The OREMODULES package [73], based on the commercial Maple package Ore\_algebra [74], is dedicated to the study of linear multidimensional systems defined over certain Ore algebras of functional operators (e.g., ordinary or partial differential systems, time-delay systems, discrete systems) and their applications in mathematical systems theory, control theory and mathematical physics. OREMODULES is original because it combines the recent developments of the Gröbner bases over some noncommutative polynomial rings [82], [84] and new algorithms of algebraic analysis in order to effectively check classical properties of module theory (e.g., existence of a non-trivial torsion submodule, torsion-freeness, reflexiveness, projectiveness, stably freeness, freeness), it gives their system-theoretical interpretations (existence of autonomous elements or successive parametrizations, existence of minimal/injective parametrizations or Bézout equations) [90], [89], [72] and it computes important tools of homological algebra (e.g., (minimal) free resolutions, split exact sequences, extension functors, projective or Krull dimensions, Hilbert power series). The abstract language of homological algebra used in the algebraic analysis approach carries over to the implementations in OREMODULES: up to the choice of the domain of functional operators which occurs in a given system, all algorithms are stated and implemented in sufficient generality such that linear systems defined over the Ore algebras developed in the Ore\_algebra package are covered at the same time. Applications of the OREMODULES package to mathematical systems theory, control theory and mathematical physics are illustrated in a large library of examples. The binary of the package is freely available at <http://wwwb.math.rwth-aachen.de/OreModules/>.

## 5.2. Stafford

**Participants:** Alban Quadrat [correspondent], Daniel Robertz [Univ. Aachen].

The STAFFORD package of OREMODULES [73] contains an implementation of two constructive versions of Stafford's famous but difficult theorem [96] stating that every ideal over the Weyl algebra  $A_n(k)$  (resp.,  $B_n(k)$ ) of partial differential operators with polynomial (resp., rational) coefficients over a field  $k$  of characteristic 0 (e.g.,  $k = \mathbb{Q}, \mathbb{R}$ ) can be generated by two generators. Based on this implementation and algorithmic results developed in [92] by the authors of the package, two algorithms which compute bases of free modules over the Weyl algebras  $A_n(\mathbb{Q})$  and  $B_n(\mathbb{Q})$  have been implemented. The rest of Stafford's results developed in [96] have recently been made constructive in [93] (e.g., computation of unimodular elements, decomposition of modules, Serre's splitting-off theorem, Stafford's reduction, Bass' cancellation theorem, minimal number of generators) and implemented in the STAFFORD package. The development of the STAFFORD package was motivated by applications to linear systems of partial differential equations with polynomial or rational coefficients (e.g., computation of injective parametrization, Monge problem, differential flatness, the reduction and decomposition problems and Serre's reduction problem). To our knowledge, the STAFFORD package is the only implementation of Stafford's theorems nowadays available. The binary of the package is freely available at <http://wwwb.math.rwth-aachen.de/OreModules/>.

## 5.3. QuillenSuslin

**Participants:** Anna Fabiańska [Univ. Aachen], Alban Quadrat [correspondent].



The QUILLEN-SUSLIN package [78] contains an implementation of the famous Quillen-Suslin theorem [94], [97]. In particular, this implementation allows us to compute bases of free modules over a commutative polynomial ring with coefficients in a field (mainly  $\mathbb{Q}$ ) and in a principal ideal domain (mainly  $\mathbb{Z}$ ). The development of the QUILLEN-SUSLIN package was motivated by different constructive applications of the Quillen-Suslin theorem in multidimensional systems theory [78] (e.g., the Lin-Bose conjectures, the computation of (weakly) left/right/doubly coprime factorizations of rational transfer matrices, the computation of injective parametrizations of flat linear multidimensional systems with constant coefficients, the reduction and decomposition problems, Serre's reduction problem). To our knowledge, the QUILLEN-SUSLIN package is the only implementation of the Quillen-Suslin theorem nowadays available. The binary of the package is freely available at <http://wwwb.math.rwth-aachen.de/QuillenSuslin>.

## 5.4. OreMorphisms

**Participants:** Thomas Cluzeau [ENSIL, Univ. Limoges], Alban Quadrat [correspondent].

The OREMORPHISMS package [76] of OREMODULES [72] is dedicated to the implementation of homological algebraic tools such as the computations of homomorphisms between two finitely presented modules over certain noncommutative polynomial algebras (Ore algebras), of kernel, coimage, image and cokernel of homomorphisms, Galois transformations of linear multidimensional systems and idempotents of endomorphism rings. Using the packages STAFFORD and QUILLEN-SUSLIN, the factorization, reduction and decomposition problems can be constructively studied for different classes of linear multidimensional systems. Many linear systems studied in engineering sciences, mathematical physics and control theory have been factorized, reduced and decomposed by means of the OREMORPHISMS package. The binary of the package is freely available at <http://pages.saclay.inria.fr/alban.quadrat/OreMorphisms/index.html>.

## 5.5. PurityFiltration

**Participant:** Alban Quadrat [correspondent].

The PURITYFILTRATION package, built upon the OREMODULES package, is an implementation of a new effective algorithm obtained in [24] which computes the purity/grade filtration [67], [68] of linear functional systems (e.g., partial differential systems, differential time-delay systems, difference systems) and equivalent block-triangular matrices. This package is used to compute closed form solutions of over/underdetermined linear partial differential systems which cannot be integrated by the standard computer algebra systems such as Maple and Mathematica. For more information, see <http://pages.saclay.inria.fr/alban.quadrat/OreAlgebraicAnalysis/index.html>.

## 5.6. OreAlgebraicAnalysis

**Participants:** Thomas Cluzeau [ENSIL, Univ. Limoges], Alban Quadrat [correspondent], Maris Tõnso [Institute of Cybernetics, Univ. Tallinn].

OREALGEBRAICANALYSIS is a Mathematica implementation of algorithms available in the OREMODULES and the OREMORPHISMS packages (developed in Maple). OREALGEBRAICANALYSIS is based on the implementation of Gröbner bases over Ore algebras available in the Mathematica *HolonomicFunctions* package developed by Christoph Koutschan (RICAM). OREALGEBRAICANALYSIS can handle larger classes of Ore algebras than the ones accessible in Maple, and thus we can study larger classes of linear functional systems. Finally, Mathematica internal design allows us to consider classes of systems which could not easily be considered in Maple such as generic linearizations of nonlinear functional systems defined by explicit nonlinear equations and systems containing transcendental functions (e.g., trigonometric functions, special functions). This package has been developed within the PHC Parrot project CASCAC.

## 5.7. YALTA

**Participants:** Catherine Bonnet [correspondent], Hugo Cavalera, André R. Fioravanti [UNICAMP], Jim Pioche [SciWorks Technologies].

The YALTA toolbox is a Matlab toolbox dedicated to the study of classical and fractional systems with delay in the frequency-domain. Its objective is to provide basic but important information such as, for instance, the position of the neutral chains of poles and unstable poles, as well as the root locus with respect to the delay of the system. The corresponding algorithms are based on recent theoretical results (see, for instance, [70] and [79]) and on classical continuation methods exploiting the particularities of the problem [80], [81].

For classical delay systems, a Pade2 approximation scheme is available as well as a finite-dimensional approximation of the system.

Recently, some optimizations and features have been added. For instance, the main software function has been split into several procedures, allowing some calculus such as finding the position of the neutral chains to be processed independently of more computationnally expensive ones (for instance determining the root locus with respect to the delay of the system). In parallel, software documentation has been rewritten.

Binaries are freely available at <http://yalta-toolbox.gforge.inria.fr/>.

The YALTA GUI (graphical user interface) is a graphical application developed in Python that interacts with the Matlab toolbox 5.7 . User actions are performed through intuitive graphic elements (dialog boxes, icons, menus, scroll bars) in order to capitalize on the functionalities of YALTA. This software, still in development, is based on PyQt, a Python binding of the cross-platform GUI toolkit Qt (C++).

## **GECO Project-Team**

# **5. New Software and Platforms**

## **5.1. IRHD**

We develop a software for reconstruction of corrupted and damaged images, named IRHD (for Image Reconstruction via Hypoelliptic Diffusion). One of the main features of the algorithm on which the software is based is that it does not require any information about the location and character of the corrupted places. Another important advantage is that this method is massively parallelizable; this allows to work with sufficiently large images. Theoretical background of the presented method is based on the model of geometry of vision due to Petitot, Citti and Sarti. The main step is numerical solution of the equation of 3D hypoelliptic diffusion. IRHD is based on Fortran.

## I4S Project-Team

# 5. New Software and Platforms

## 5.1. ISTL

**Participant:** Qinghua Zhang.

ISTL is a software realizing numerical computations of the inverse scattering transform for electrical transmission lines. It provides an efficient solution to experimentally determining the distributed characteristic impedance of an electrical transmission line from the reflection coefficient measured at one end of the line. Its current applications are in the fields of electrical cable fault diagnosis and of civil engineering structure monitoring. In addition to inverse scattering transform algorithms, ISTL includes a numerical simulator generating reflection coefficients of user-specified transmission lines and a graphical user interface. It is registered at Agence pour la Protection des Programmes (APP) under the number IDDN.FR.001.120003.000.S.P.2010.000.30705. See <http://people.rennes.inria.fr/Qinghua.Zhang/istl.html>.

## 5.2. PEGASE

**Participants:** Vincent Le Cam, Mathieu Le Pen, Laurent Mevel, Michael Doehler.

I4S is actually finalizing the setup of a new platform named PEGASE 2.0 as the technological successor of the previous PEGASE platform developed by IFSTTAR.

The new version of PEGASE keeps the best of its previous version in its main vocation, to be a generic high level Wireless Sensor Platform.

- What does not change between PEGASE 1 and 2.0: Based on various feedback from application fields, results from real structures monitored by PEGASE, and due to the rapid obsolescence of electronic devices, the design of the new PEGASE platform has been launched in 2013. Some of the main functions of PEGASE does not change but are reinforced.
  - Software genericity: use of a Linux embedded OS to make any application developed independently from the hardware, to make the user able to manage the system without any physical and heavy operations.
  - Hardware genericity: with a principle of daughter and mother boards, each redundant need is embedded (processing, memory, timing, GPS, energy, etc) which each pluggable daughter board implements a specific function (sensing, 3G, Ethernet, communication, signal processing and relay control).
  - Accurate time synchronization: based on an original GPS and PPS algorithm, PEGASE platform is one of the only board able to time-stamp data from sensors or any event with an accuracy of some micro-seconds Universal Time.
- What's new on PEGASE 2 platform ?

Previous principles are maintained or extended. Full electronic design from scratch occurred in 2014 to maximise its capacities in terms efficiency, cost, energy consumption, etc. Its main characteristics are

- Important software evolutions: the platform embedded a real Linux kernel (not  $\mu$ Linux as previously done for memory size questions). This new kernel allows the perception of PEGASE 2 as real PC (without screen and mouse) providing important functions as MMU, software upgrade.
- Important hardware evolutions and integration

- \* A very advanced GPS module (Ublox Neo 6T) to allow more accurate time synchronization (up to 100 nanoseconds)
- \* An embedded energy harvesting module (and not from a daughter board as previously done) to recover energy from DC sources if available or a solar cell, while managing the low of dis/charging Lithium-Ion battery and the MMPT algorithms
- A Single Development Kit (SDK) fully (re) coded in C++ (and not C-object as proposed before) that permit a real capitalization of software developments and knowledges implemented (such as algorithms for SHM). Based on an UML model
- A major evolution in PEGASE concept consists in providing a generic web-tool to monitor PEGASE platform (whatever is the version) and many others wireless and commercial devices. A reproach addressed to previous concept resides in the fact that PEGASE was too focused on providing a generic wireless platform. But a quite big work was still necessary to monitor the devices. This new concept has been already sold to companies (such as SNCF or Cofiroute) and allows:
  - To create one independent instance of the Supervisor by client
  - Each instance of the Supervisor works 100% in the cloud with a secured access (https + login/password). Thus final users can operate it from anywhere in the world : at instrumented site level as at desk or during travel, etc.
  - For each client, the possibility to create an infinity of instrumentation projects
  - For each instrumentation project, to associate as many sensors as required by the application. Sensors can be PEGASE 1 or PEGASE 2 boards as many others : Labjack devices, some National Instruments acquisition boards, Meteo-France sources...

The list of the devices known by the Supervisor is open and is supposed, year after year, to be completed. Thus, next PEGASE projects aims at providing not only some wireless sensors platform but also a modern, full-clouded, monitoring application. Moreover the 2015 *R&D* program plans to add a very interesting function from the scientific point of view: a Matlab plug-in. The idea consists in linking the data flow managed by supervisor directly and automatically to some Matlab sources codes uploaded on the web platform. The Supervisor will compile the original Matlab files. They are dynamically compiled on an embedded Matlab runtime library on the cloud server. Thus, once the the specifications about data format are written and took into account by developers, scientist can dynamically test and operate its Matlab models uploaded on the Supervisor.

## Maxplus Project-Team

# 5. New Software and Platforms

## 5.1. Boîte à outil Maxplus de SCILAB/Maxplus toolbox of Scilab

Trois chercheurs du groupe (S. Gaubert, J.-P. Quadrat, et G. Cohen) ont développé (à partir d'une première version réalisée par M. Mc Gettrick) la *boîte à outils Maxplus* de Scilab, qui est **téléchargeable librement** parmi les contributions du site **Scilab**, et qui est maintenant intégrée par défaut dans **Scicoslab**. Cette boîte à outils implémente l'ensemble du calcul numérique linéaire max-plus, elle comprend en particulier le stockage creux des matrices, et des algorithmes efficaces pour le calcul de la valeur propre basées sur les itérations sur les politiques. Elle a été utilisées par plusieurs chercheurs, voir notamment [76], [147]. Il faut aussi noter que le groupe de L. Hardouin, du LISA/Istia, a complété la boîte à outils Maxplus en interfaçant leur propre **librairie** C++, qui permet le calcul des séries de transfert de graphes d'événements temporisés.

### *English version*

Three researchers of the team (S. Gaubert, J.-P. Quadrat, and G. Cohen, building on a preliminary version of M. McGettrick) have developed and released the *Maxplus toolbox* of Scilab, which is freely **available** among the contributions on the **Scilab** web site, and which is now included by default in **Scicoslab**. It implements all basic linear algebra functionalities, with a special attention to large sparse matrices, including efficient algorithms for eigenvalue computation based on policy iteration. The software has been used by several researchers in their work, including [76], [147]. It should be noted that the team of L. Hardouin, from LISA/Istia, has completed the toolbox by interfacing their own C++ **library** computing the transfer series of a timed event graph.

## 5.2. Itérations sur les politiques pour les jeux stochastiques à somme nulle/Policy iterations for zero sum stochastic games

L'algorithme d'itérations sur les politiques pour les jeux stochastiques à somme nulle pour le cas de paiements ergodiques (gain moyen par unité de temps), et dégénérés de type "multi-chaîne" a été introduit dans [95]. Plusieurs stages ont permis l'implémentation partielle en Scilab, C ou C++, et le test de ce type d'algorithmes (voir le travail de Vishesh Dhingra [112]), ou de son couplage avec la résolution de systèmes linéaires par des méthodes multigrilles algébriques (stage de Shantanu Gangal en 2007). Le travail de thèse de Sylvie Detournay a permis le développement d'un programme complet. Le code écrit par Sylvie Detournay (en C) a été déposé sur InriaGForge. Pour le moment il n'est accessible qu'aux membres de l'équipe.

### *English version*

The policy iteration algorithm for zero sum repeated games with ergodic payoff (i.e. mean payoff per time unit), and in degenerate "multichain" cases, has been introduced in [95]. Several internships allowed us to implement in Scilab, C or C++, and to test such algorithms (see the work of Vishesh Dhingra [112]), or its combinaison with the resolution of linear systems by algebraic multigrid methods (internship of Shantanu Gangal in 2007). The PhD thesis work of Sylvie Detournay allowed us to develop a complete program. The program written by Sylvie Detournay (in C language) has been posted on InriaGForge. For the moment it can only be seen by members of the team.

## 5.3. TPLib: bibliothèque pour la manipulation de polyèdres tropicaux/TPLib: tropical polyhedra library

TPLib est une bibliothèque écrite en OCaml qui permet de manipuler des polyèdres tropicaux. Elle est distribuée sous license LGPL <https://gforge.inria.fr/projects/tplib>.

Cette bibliothèque implémente notamment des algorithmes permettant de passer d'une représentation externe d'un polyèdre à une représentation interne, ou inversement (voir §6.3.1 pour plus de détails). Elle permet aussi de réaliser d'autres opérations fondamentales, comme le calcul du complexe polyédral associé à un polyèdre donné (au sens de Develin et Sturmfels [108]), ou le calcul de cônes tangents tropicaux. Enfin, elle fournit toutes les primitives permettant d'utiliser les polyèdres tropicaux en tant que domaine abstrait numérique, afin de déterminer des invariants de programmes ou systèmes faisant intervenir les opérations min et max (voir [70]).

TPLib est utilisé dans le logiciel Polymake [128], développé à la Technische Universität Berlin (Allemagne). Ce dernier logiciel constitue une boîte à outils permettant de manipuler des nombreux objets mathématiques (polytopes convexes, complexes polyédraux, graphes, matroïdes, polytopes tropicaux).

Le développement d'interfaces avec d'autres logiciels est désormais facilité grâce à la présence de *bindings* dans le langage C. Grâce à cela, un prototype d'interface a été réalisé entre TPLib et l'outil VerifyTAPN (<https://launchpad.net/verifytapn>), qui permet la vérification de réseaux de Pétri avec arcs temporisés (voir §6.6.4). De même, une interface à la bibliothèque de domaines abstraits numériques APRON [140] est également en cours de développement.

#### *English version*

TPLib is a library written in OCaml, which allows to manipulate tropical polyhedra. It is distributed under LGPL <https://gforge.inria.fr/projects/tplib>.

This library implements algorithms allowing to pass from an external representation of a polyhedron to an internal description, or inversely (see §6.3.1 for more details). Besides, the library allows to perform several fundamental operations over tropical polyhedra, such as computing the associated polyhedral complex (see Develin and Sturmfels [108]), or determining the tropical tangent cone at any point. Finally, it provides all the primitives allowing to use tropical polyhedra as an numerical abstract domain, in order to determine program/system invariants involving the operations min and max (see [70]).

TPLib is used in the software Polymake [128], developed in Technische Universität Berlin (Germany). Polymake is a toolbox allowing to manipulate mathematic objects such as convex polytopes, polyhedral complexes, graphs, matroids, and tropical polytopes.

The development of further interfaces is now easier thanks to the distribution of bindings in C language. Using these bindings, a prototype of interface has been created between TPLib and the model-checker VerifyTAPN (<https://launchpad.net/verifytapn>), which allows the verification of timed-arc Petri Nets (see §6.6.4). An interface to the numerical abstract domain APRON [140] is also under development.

## **MCTAO Project-Team**

# **5. New Software and Platforms**

## **5.1. Hampath**

**Participants:** Jean-Baptiste Caillau, Olivier Cots [corresponding participant], Joseph Gergaud.

Hampath is a software developed to solve optimal control problems but also to study Hamiltonian flow. It has been developed since 2009 by members of the APO team from Institut de Recherche en Informatique de Toulouse, jointly with colleagues from the Université de Bourgogne. It is now updated with McTAO team members. See more on <http://cots.perso.math.cnrs.fr/hampath/>.



## NECS Project-Team

# 5. New Software and Platforms

## 5.1. GTL – Grenoble Traffic Lab

**Participants:** C. Canudas de Wit [contact person], I. Bellicot, P. Bellemain, L. Leon Ojeda, D. Pisarski, A. Kibangou, H. Fourati, F. Morbidi, F. Garin, A. Ladino Lopez, P. Grandinetti, E. Lovisari, R. Singhal, A. Andreev.

The Grenoble Traffic Lab (GTL) initiative, led by the NECS team, is a real-time traffic data Center (platform) that collects traffic road infrastructure information in real-time with minimum latency and fast sampling periods. The main elements of the GTL are: a real-time data-base, a show room, and a calibrated micro-simulator of the Grenoble South Ring. Sensed information comes from a dense wireless sensor network deployed on Grenoble South Ring, providing macroscopic traffic signals such as flows, velocities, densities, and magnetic signatures. This sensor network was set in place in collaboration with Inria spin-off Karrus-ITS, local traffic authorities (DIR-CE, CG38, La Metro), and specialized traffic research centers. In addition to real data, the project also uses simulated data, in order to validate models and to test the ramp-metering; the micro-simulator is a commercial software (developed by TSS AIMSUN ©).

More details at <http://necs.inrialpes.fr/pages/grenoble-traffic-lab.php>

## 5.2. Source-seeking robot

**Participants:** R. Fabbiano [contact person], J. Dumon, Y. Gaudfrin.

The source-seeking algorithms developed in the thesis of Ruggero Fabbiano have been implemented in hardware, with a wheeled robot performing 2-dimensional search. The considered scenario is a source of pollutant in the ocean, where the pollutant can be detected thanks to the fact that it is warmer than water, so that data from an infra-red camera can be used by one or multiple helicopters to move along the ocean surface towards the source. In our experimental equipment, the 2-dimensional movement has been performed with a wheeled vehicle, and the camera was a regular camera, taking pictures of a color-coded image from an actual infra-red image of a pollutant leak. Videos of the experiments are available online: <http://necs.inrialpes.fr/pages/platforms.php>

## **NON-A Project-Team**

# **5. New Software and Platforms**

## **5.1. SLIM**

Multi-robots cooperation can be found as an application in many domains of science and technology: manufacturing, medical robotics, personal assistance, military/security and spatial robots. The market of robots is quickly developing and its capacity is continuously growing. Concerning cooperation of mobile multi-robots, 3 key issues have to be studied: Localization, path planning and robust control, for which Non-A team has worked and proposed new algorithms. Due to the ADT SLIM, we implement our algorithms (localization, path planning and robust control) and integrate them into ROS (Robotic Operating System) as a package, named SLIM.

## **5.2. Blimp**

Scientific research and development on the control of autonomous airship have shown a significant growth in recent years. New applications appear in the areas such as freight carrier, advertising, monitoring, surveillance, transportation, military and scientific research. The control of autonomous airship is a very important problem for the aerial robots research.

The development of Blimp by Non-A is used for experimentation and demonstration of controlling algorithms. The blimp is required to provide some environment information and status of itself, such as surveillance video of surrounding environment, gesture of blimp, altitude of blimp. With these basic information, one could localize blimp with certain algorithm (visual SLAM for example) or implement one controller in order to improve the stability and maneuverability of blimp.

**QUANTIC Team (section vide)**

**CLASSIC Project-Team (section vide)**

## DOLPHIN Project-Team

# 5. New Software and Platforms

## 5.1. Comparing Continuous Optimizers (Coco) Platform

**Participants:** Dimo Brockhoff, Arnaud Liefooghe, Thanh-Do Tran.

The Coco Platform ([coco.gforge.inria.fr](http://coco.gforge.inria.fr)) provides the functionality to automatically benchmark optimization algorithms for unbounded, unconstrained optimization problems in continuous domains. Benchmarking is a vital part of algorithm engineering and a necessary path to recommend algorithms for practical applications. The Coco platform releases algorithm developers and practitioners alike from (re-)writing test functions, logging, and plotting facilities by providing an easy-to-handle interface in several programming languages. The Coco platform has been developed since 2007 and has been used extensively within the “Blackbox Optimization Benchmarking (BBOB)” workshop series since 2009. Overall, 123 algorithms and algorithm variants by contributors from all over the world have been benchmarked with the platform so far and all data is publicly available for the research community (see for example <http://coco.gforge.inria.fr/doku.php?id=bbob-2013-algorithms> for the submissions to BBOB-2013).

Via the ANR project NumBBO, also Dolphin team members are involved in the development of Coco and it is one of the main purposes of NumBBO to extend the Coco platform towards expensive, large-scale, constrained and multiobjective optimization. In order to facilitate these extensions, a complete overhaul of the platform is currently underway—rewriting the whole functionality from scratch in a single language (ANSI C) which will then be called from all other provided languages (Java, python, Matlab/Octave, R) instead of multiple independent implementations which are highly difficult to maintain. A first release of the new code base is expected in the first half of 2015.

For the rewriting of the source code, we also moved to a publicly available open source code repository at <https://code.google.com/p/numbbo/> which, in addition, provides for the first time a bug and feature request tracking system for Coco. As the first Coco-related deliverable of the NumBBO project, the extension towards expensive optimization has been finished this year. Its full functionality will be provided for the first time for the upcoming BBOB special session at the IEEE Congress on Evolutionary Computation (CEC’2015). Coco is also currently extended towards multiobjective optimization in close relation to the PhD topic of Thanh-Do Tran. A first working (but still preliminary) version of the multiobjective Coco has been developed and is expected to be merged with the newly rewritten Coco code just after its first release.

Inria software self-assessment for Coco: [A-4/5, SO-4, SM-3-up4, EM-3, SDL-4-up5][DA-3, CD-3, MS-3, TPM-2]

## 5.2. MO-Mine

**Participants:** Clarisse Dhaenens, Benjamin Fisset, Laetitia Jourdan.

The MO-Mine platform ([mo-mine.gforge.inria.fr](http://mo-mine.gforge.inria.fr)) aims at providing optimization algorithms, and in particular multi-objective approaches, to deal with data-mining classical tasks (Classification, association rules...). The platform is still in development in the context of an Inria ADT.

*MO – Mine<sub>clust</sub>* is the first package of the platform and is dedicated to clustering (unsupervised classification). Indeed, it is well-known that clustering may be seen as a bi-objective optimization problem as the goal is both to minimize distances between data belonging to a same cluster, while maximizing distances between data belonging to different clusters. Several models (objective functions used,...) and engines (optimization algorithms) have been implemented. The framework searches, for a given dataset, the best association of model/engine/parameter without specifying the number of clusters. *MO – Mine<sub>clust</sub>* shows very interesting behavior and shows that the choice of the model and the engine has a great importance in the performance of the method and depends on the dataset to analyze.

Inria software self-assessment for *MO – Mine<sub>clust</sub>*: [A-1, SO-4, SM-3-up4, EM-2, SDL-1, DA-4, CD-4]

### 5.3. Platforms

Grid'5000<sup>0</sup> is a French nation-wide computational grid infrastructure composed of several clusters of processors distributed over 11 sites including Lille. Since 2004, the Dolphin team is the scientific leader of the Grid'5000 site located at Lille. The role of the team is mainly threefold consisting in ensuring (1) the maintenance and evolution of the platform, (2) the local and national coordination of the related activities, and (3) the scientific animation around Grid'5000. Regarding the evolution of the infrastructure, this later has been extended in 2014 with a new powerful storage server hosting mainly the NFS system. In addition, the team has contributed to the 5-year CPER project called "data" proposed by the Inria Lille research center. The project includes a part related to the Grid'5000 platform. From the coordination point of view, Dolphin has participated to the monthly meetings of the national Grid'5000 committee. Finally, regarding the scientific animation, first, Dolphin has organized in December 20<sup>th</sup>, 2014, a training<sup>0</sup> around Grid'5000. Second, Dolphin has participated to the program committee of the Grid'5000 spring school<sup>0</sup> held in Lyon in June 2014. Third, the team has also been involved in the final evaluation of the scientific nation-wide Hemera research project<sup>0</sup> related to Grid'5000.

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<sup>0</sup><https://www.grid5000.fr/>

<sup>0</sup><http://www.lifl.fr/~melab/HTML/Journee-G5K-Lille.htm>

<sup>0</sup><https://www.grid5000.fr/mediawiki/index.php/Grid5000:School2014>

<sup>0</sup><https://www.grid5000.fr/Hemera>

## GEOSTAT Project-Team

# 5. New Software and Platforms

## 5.1. Fluex

**Participants:** Rémi Paties [correspondent], Hussein Yahia, Joel Sudre.

- Previous software engineer Denis Arrivault has delivered the first Fluex package in December 2013, consisting of a core implementation under Gforge of the Microcanonical Multiscale Formalism in the form of C++ classes, for 1D, 2D 3D and 3D+t general signals. The Fluex project is carried on in 2014 by Rémi Paties. Contact: remi.paties@inria.fr.
- The Fluex project has been supported by the FLUEX ADT.

## 5.2. Platforms

### 5.2.1. Plafrim

GEOSTAT has participated financially in the acquisition of a computing server SGI UV2000 for **PLAFRIM** through funding with the OPTAD project (Conseil Région Aquitaine).

## MISTIS Project-Team

# 5. New Software and Platforms

## 5.1. The LOCUS software

**Participant:** Florence Forbes.

**Joint work with:** Senan Doyle (start-up creator) and Michel Dojat from Grenoble Institute of Neuroscience and Benoit Scherrer from Harvard Medical School, Boston, MA, USA.

From brain MR images, neuroradiologists are able to delineate tissues such as grey matter and structures such as Thalamus and damaged regions. This delineation is a common task for an expert but unsupervised segmentation is difficult due to a number of artefacts. The LOCUS software (<http://locus.gforge.inria.fr>) automatically perform this segmentation for healthy brains. An image is divided into cubes on each of which a statistical model is applied. This provides a number of local treatments that are then integrated to ensure consistency at a global level, resulting in low sensitivity to artifacts. The statistical model is based on a Markovian approach that enables to capture the relations between tissues and structures, to integrate a priori anatomical knowledge and to handle local estimations and spatial correlations.

The LOCUS software has been developed in the context of a collaboration between Mistis, a computer science team (Magma, LIG) and a Neuroscience methodological team (the Neuroimaging team from Grenoble Institut of Neurosciences, INSERM). This collaboration resulted over the period 2006-2008 into the PhD thesis of B. Scherrer (advised by C. Garbay and M. Dojat) and in a number of publications. In particular, B. Scherrer received a "Young Investigator Award" at the 2008 MICCAI conference.

The originality of this work comes from the successful combination of the teams respective strengths i.e. expertise in distributed computing, in neuroimaging data processing and in statistical methods.

## 5.2. The P-LOCUS software

**Participants:** Florence Forbes, Flor Vasseur.

**Joint work with:** Senan Doyle (start-up creator) and Michel Dojat.

The Locus software was extended to address the delineation of lesions in pathological brains. Its extension P-LOCUS (<http://p-locus.com>) for lesion detection was realized by S. Doyle with financial support from GRAVIT (Grenoble Alpes Valorisation Innovation Technologies, <http://www.gravit-innovation.org/>) with the goal to create a Start-up. P-LOCUS software analyses, in few minutes, a 3D MR brain scan and performs fully automatic brain lesion delineation using a combined dataset of various 3D MRI sequences. Its originality comes from:

- it is fully automatic: no external user interaction and no training data required
- the possibility to combine information from several images (MR sequences)
- a statistical Bayesian framework for robustness to image artefacts and a priori knowledge incorporation
- a voxel-based clustering technique that uses Markov random fields (MRF) incorporating information about neighboring voxels for spatial consistency and robustness to imperfect image features (noise).
- the possibility to select and incorporate relevant a priori knowledge via different atlases, e.g. tissue and vascular territory atlases
- a fully integrated preprocessing steps and lesion ROI identification



P-LOCUS software was presented at various conferences and used for the BRATS Challenge on tumor segmentation organized as a satellite challenge of the Miccai conference in Nagoya, Japan. A paper published in IEEE trans. on Medical Imaging reports the challenge results [24]. Results are also shown in [47]. The software has been registered at APP in 2013 and is now undergoing industrial development for the creation of a start-up (Pixyl) expected in January 2015.

### 5.3. The PyHRF software

**Participants:** Thomas Perret, Florence Forbes, Thomas Vincent, Aina Frau Pascual.

**Joint work with:** Philippe Ciuciu and Solveig Badillo from Parietal Team Inria and CEA NeuroSpin, Lotfi Chaari and Laurent Risser from INP Toulouse.

As part of fMRI data analysis, the PyHRF package (<http://pyhrf.org>) provides a set of tools for addressing the two main issues involved in intra-subject fMRI data analysis: (i) the localization of cerebral regions that elicit evoked activity and (ii) the estimation of the activation dynamics also referenced to as the recovery of the Hemodynamic Response Function (HRF). To tackle these two problems, PyHRF implements the Joint Detection-Estimation framework (JDE) which recovers parcel-level HRFs and embeds an adaptive spatio-temporal regularization scheme of activation maps. With respect to the sole detection issue (i), the classical voxelwise GLM procedure is also available through NIPY, whereas Finite Impulse Response (FIR) and temporally regularized FIR models are implemented to deal with the HRF estimation concern (ii). Several parcellation tools are also integrated such as spatial and functional clusterings. Parcellations may be used for spatial averaging prior to FIR/RFIR analysis or to specify the spatial support of the HRF estimates in the JDE approach. These analysis procedures can be applied either to volumic data sets or to data projected onto the cortical surface. For validation purpose, this package is shipped with artificial and real fMRI data sets. To cope with the high computational needs for inference, PyHRF handles distributing computing by exploiting cluster units as well as multiple cores computers. Finally, a dedicated viewer is available which handles  $n$ -dimensional images and provides suitable features for exploring whole brain hemodynamics (display of time series, maps, ROI mask overlay). A paper in *Frontiers in Neuroinformatics* gives more details on the current PyHRF functionalities [26]. The 2-year engineer position of Thomas Perret is devoted to this software development.

### 5.4. R packages

**Participants:** Florence Forbes, Stéphane Girard, Gildas Mazo, Alexis Arnaud.

**Joint work with:** Charles Bouveyron (Univ. Paris 5) and Stéthane Dépréaux (LJK).

MISTIS is involved in the development of several R packages available on the CRAN archive. They are dedicated to the construction of copulas and to the classification and clustering of data.

- **PBC** (product of bivariate copulas). <http://cran.r-project.org/web/packages/PBC/> This R package provides tools for building copulas with the PBC model, a class of multivariate copulas based on Products of Bivariate Copulas. Copulas are a useful tool to model multivariate distributions. While there exist various families of bivariate copulas, much fewer has been done when the dimension is higher. To this aim an interesting class of copulas based on products of transformed copulas has been proposed. However the use of this class for practical high dimensional problems remains challenging. Constraints on the parameters and the product form render inference, and in particular the likelihood computation, difficult. In this R package, we propose a new class of high dimensional copulas based on a product of transformed bivariate copulas. No constraints on the parameters refrain the applicability of the proposed class which is well suited for applications in high dimension. Furthermore the analytic forms of the copulas within this class allow to associate a natural graphical structure (see illustration below) which helps to visualize the dependencies and to compute the likelihood efficiently even in high dimension.

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- **FDG** (one-Factor copulas with Durante Generators). <http://cran.r-project.org/web/packages/FDGcopulas/> This R package provides tools for building high-dimensional copulas with the FDG model, a class of multivariate copulas based on one-factor copulas. FDG copulas are a class of copulas featuring an interesting balance between flexibility and tractability. This package provides tools to construct, calculate the pairwise dependence coefficients of, simulate from, and fit FDG copulas. The acronym FDG stands for 'one-Factor with Durante Generators', as an FDG copula is a one-factor copula - that is, the variables are independent given a latent factor - whose linking copulas belong to the Durante class of bivariate copulas (also referred to as exchangeable Marshall-Olkin or semilinear copulas).
  - **HDclassif** (classification and clustering methods for high dimensional data). <http://cran.r-project.org/web/packages/HDclassif/> The HDclassif package is devoted to the clustering and the discriminant analysis of high-dimensional data. The classification methods proposed in the package result from a new parametrization of the Gaussian mixture model which combines the idea of dimension reduction and model constraints on the covariance matrices. The supervised classification method using this parametrization has been called High Dimensional Discriminant Analysis (HDDA). In a similar manner, the associated clustering method has been called High Dimensional Data Clustering (HDDC) and uses the Expectation-Maximization (EM) algorithm for inference. In order to correctly fit the data, both methods estimate the specific subspace and the intrinsic dimension of the groups. Due to the constraints on the covariance matrices, the number of parameters to estimate is significantly lower than other model-based methods and this allows the methods to be stable and efficient in high-dimensional spaces. Experiments on artificial and real datasets show that HDDC and HDDA perform better than existing classical methods on high-dimensional datasets, even with small datasets.
  - **robustDA** (robust mixture discriminant analysis). <http://cran.r-project.org/web/packages/robustDA/> Robust mixture discriminant analysis allows to build a robust supervised classifier from learning data with label noise. The idea of the proposed method is to confront an unsupervised modeling of the data with the supervised information carried by the labels of the learning data in order to detect inconsistencies. The method is able afterward to build a robust classifier taking into account the detected inconsistencies into the labels. An application to object recognition under weak supervision is presented below.
  - **MSST** (Mixtures of multiple scaled Student distributions). The package is not yet available on the CRAN but should be early 2015. It implements more efficiently the models and inference procedures described in [21] and will be used on large data sets of brain MRI in the context of Alexis Arnaud PhD thesis. This is joint work with S. Dépréaux who helped with writing subroutines in C++.

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## MODAL Project-Team

### 5. New Software and Platforms

#### 5.1. BlockCluster package for co-clustering

**Participants:** Serge Iovleff, Vincent Kubicki.

BlockCluster is an R package on top of the coclust C++ library. Maintenance of the CRAN package (<http://cran.r-project.org/web/packages/blockcluster/index.html>) and user assistance on the forum have been ensured.

#### 5.2. clere package for high dimensional regression

**Participants:** Christophe Biernacki, Loïc Yengo, Julien Jacques.

The clere package for R proposes variable clustering in high dimensional linear regression. It is available on CRAN (<http://cran.r-project.org/web/packages/clere/index.html>) and now submitted to an international journal dedicated to software [52].

#### 5.3. Clustericat package for correlated categorical variable

**Participants:** Christophe Biernacki, Matthieu Marbac-Lourdelle, Vincent Vandewalle.

Clustericat is an R package for model-based clustering of categorical data. In this package, the Conditional Correlated Model (CCM), published in 2014 [24], takes into account the main conditional dependencies between variables through extreme dependence situations (independence and deterministic dependence). Clustericat performs the model selection and provides the best model according to the BIC criterion and the maximum likelihood estimates. It is available online on Rforge ([https://r-forge.r-project.org/R/?group\\_id=1803](https://r-forge.r-project.org/R/?group_id=1803)).

#### 5.4. CoModes package for correlated categorical variables

**Participants:** Christophe Biernacki, Matthieu Marbac-Lourdelle, Vincent Vandewalle.

CoModes is another R package for model-based clustering of categorical data. In this package, the Conditional Modes Model (CMM), submitted for publication in 2014 [49], takes into account the main conditional dependencies between variables through particular modality crossings (so-called modes). CoModes performs the model selection and provides the best model according to the exact integrated likelihood criterion and the maximum likelihood estimates. It is available online on Rforge ([https://r-forge.r-project.org/R/?group\\_id=1809](https://r-forge.r-project.org/R/?group_id=1809)).

#### 5.5. CorReg package for correlated variables in regression

**Participants:** Christophe Biernacki, Clément Théry.

The main idea of the CorReg package is to consider some form of sub-regression models, some variables defining others. We can then remove temporarily some of the variables to overcome ill-conditioned matrices inherent in linear regression and then reinject the deleted information, based on the structure that links the variables. The final model therefore takes into account all the variables but without suffering from the consequences of correlations between variables or high dimension. The CorReg package is now available on CRAN (<http://cran.r-project.org/web/packages/CorReg/index.html>) and graphical functionalities have been added in 2014. It has been presented to a conference [32] and is currently written as a research paper [51]. It is a joint work with Gaétan Loridant.

#### 5.6. HDPenReg package for penalized regressions in high dimension

**Participants:** Quentin Grimonprez, Serge Iovleff.

HDPenReg is an R-package based on a C++ code dedicated to the estimation of regression model with l1-penalization. It is now available on CRAN (<http://cran.r-project.org/web/packages/HDPenReg/index.html>). More cross-validation options were added. Maintenance in 2014 concerned bugs correction and documentation updates.

## 5.7. FunFEM package for functional data

**Participant:** Julien Jacques.

FunFEM package for R proposes a clustering tool for functional data. The model-based algorithm clusters the functional data into discriminative subspaces. It is available on CRAN (<http://cran.r-project.org/web/packages/funFEM/index.html>).

## 5.8. FunHDDC package for functional data

**Participant:** Julien Jacques.

FunHDDC package for R proposes a clustering tool for functional data. The model-based clustering algorithm considers that functional data live in cluster-specific subspaces. It is available on CRAN (<http://cran.r-project.org/web/packages/funHDDC/index.html>).

## 5.9. Galaxy-Modal platform

**Participants:** Samuel Blanck, Guillemette Marot.

Galaxy is an open, web-based platform for data intensive biomedical research. Galaxy features user friendly interface, workflow management, sharing functionalities and is widely used in the biologist community. The MPAGENOMICS R package developed by MODAL has been integrated into Galaxy, and the Galaxy-Modal instance has been publicly deployed thanks to the IFB-cloud infrastructure (<http://cloud.france-bioinformatique.fr/>). An APP repository with Galaxy-Modal source code has been created (reference : Galaxy - MPAGENOMICS)

## 5.10. metaMA package for meta-analysis of microarray data

**Participant:** Guillemette Marot.

metaMA is a specialised software for microarrays. It is an R package which combines either p-values or modified effect sizes from different studies to find differentially expressed genes. The main competitor of metaMA is geneMeta. Compared to geneMeta, metaMA offers an improvement for small sample size datasets since the corresponding modelling is based on shrinkage approaches.

This software is routinely used by biologists from INRA, Jouy en Josas (it has been included in a local analysis pipeline) but its diffusion on the CRAN (<http://cran.r-project.org/web/packages/metaMA/index.html>) makes it available to a wider community, as attested by the citations of publications related to the methods implemented in the software.

Maintenance in 2014 concerned documentation updates and users assistance.

## 5.11. metaRNASeq package for meta-analysis of RNA-Seq data

**Participant:** Guillemette Marot.

This is joint work with Andrea Rau (INRA, Jouy-en-Josas). metaRNASeq is a specialised software for RNA-seq experiments. It is an R package which is an adaptation of the metaMA package presented previously. Both implement the same kind of methods but specificities of the two types of technologies require some adaptations to each one. metaRNASeq is now available on CRAN (<http://cran.r-project.org/web/packages/metaRNASeq/index.html>).

## 5.12. MixCluster package for correlated mixed variables

**Participants:** Christophe Biernacki, Matthieu Marbac-Lourdelle, Vincent Vandewalle.

MixCluster is an R package for model-based clustering of mixed data (continuous, binary, integer). In this package, the model, submitted for publication in 2014 [48], takes into account the main conditional dependencies between variables through Gaussian copula. Mixcluster performs the model selection and provides the best model according to Bayesian approaches. It is available online on Rforge ([https://r-forge.r-project.org/R/?group\\_id=1939](https://r-forge.r-project.org/R/?group_id=1939)).

## 5.13. MIXMOD and Rmixmod package for mixed data

**Participants:** Vincent Kubicki, Christophe Biernacki, Serge Iovleff.

MIXMOD (MIXture MODelling) is an important software for the MODAL team since it concerns its main topics: model-based supervised, unsupervised and semi-supervised classification for various data situations. MIXMOD is now a well-distributed software with over 250 downloads/month are recorded for several years. MIXMOD is written in C++ (more than 10 000 lines) and distributed under GNU General Public License. Several other institutions participate in the MIXMOD development since several years: CNRS, Inria Saclay-Île de France, Université de Franche-Comté, Université Lille 1. The software already benefits from several APP depositions and an R package (Rmixmod) has been associated to MIXMOD in 2012. In 2014, it has led to publication in an international journal dedicated to software [23].

## 5.14. MixtComp package for full mixed data

**Participants:** Vincent Kubicki, Christophe Biernacki, Serge Iovleff.

MixtComp (Mixture Computation) is another important software for the MODAL team since it concerns model-based clustering for mixed data. Main difference with the MIXMOD/Rmixmod software is that MixtComp's architecture is able to integrate easily and quickly all new univariate models, under the conditional independence assumption, that will be sequentially available from researches of the MODAL team or others. Currently, central architecture of MixtComp is built and three models (Gaussian, multinomial, Poisson) are implemented with ability to natively manage missing data (completely or by interval). MixtComp stands both as a C++ library and an R package. The code is currently developed internally, and has been field-tested through two contracted partnerships.

## 5.15. MPAgenomics package for multi-patient analysis of genomic markers

**Participants:** Quentin Grimonprez, Guillemette Marot, Alain Celisse.

MPAgenomics is an R package for multi-patients analysis of genomics markers. It enables to study several copy number and SNP data profiles at the same time. It offers wrappers from commonly used packages to offer a pipeline for beginners in R. It also proposes a special way of choosing some crucial parameters to change some default values which were not adapted in the original packages. For multi-patients analysis, it wraps some penalized regression methods implemented in HDPenReg.

MPAgenomics is now available on CRAN (<http://cran.r-project.org/web/packages/MPAgenomics/index.html>). New segmentation methods were added to MPAgenomics. Maintenance in 2014 concerned bugs correction, documentation updates and code factorization.

## 5.16. RankCluster package to cluster ranking data

**Participants:** Christophe Biernacki, Quentin Grimonprez, Julien Jacques.

Rankcluster package for R proposes a clustering tool for ranking data. Multivariate and partial rankings can be also taken into account. It is available on CRAN (<http://cran.r-project.org/web/packages/Rankcluster/index.html>).

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Rankcluster now supports tied ranking data. Maintenance in 2014 concerned bugs correction, documentation updates and addition of parallelism.

### 5.17. rtkpp package: STK++ Integration To R Using Rcpp

**Participant:** Serge Iovleff.

rtkpp is the integration of the library STK++ (see 5.18 ) into R. It is using Rcpp. Some functionalities of the Clustering project provided by the library are available in the R environment as R functions. The rtkpp package includes the header files from the STK++ library (currently version 0.8.2). Thus users do not need to install STK++ itself in order to use it. rtkpp is licensed under the GNU GPL version 2 or later and available on CRAN (<http://cran.r-project.org/web/packages/rtkpp/index.html>).

### 5.18. STK++ release 0.8.4: The Statistical ToolKit

**Participant:** Serge Iovleff.

STK++ is a versatile, fast, reliable and elegant collection of C++ classes for statistics, clustering, linear algebra, arrays (with an API Eigen-like), regression, dimension reduction, etc. STK++ is licensed under the GNU LGPL version 2 or later. See: <http://www.stkpp.org/>

## REALOPT Project-Team

# 5. New Software and Platforms

## 5.1. BaPCod – a generic Branch-and-Price Code

**Participants:** Issam Tahiri [Software Engineer], François Clautiaux, Boris Detienne, Pierre Pesneau, Ruslan Sadykov, François Vanderbeck [correspondant].

BaPCod is a prototype code that solves Mixed Integer Programs (MIP) by application of decomposition and reformulation approach (relying mostly on Dantzig-Wolfe reformulation techniques). The reformulated problem is solved using a branch-and-price-and-cut (column and cut generation) algorithm. This software platform, made of C++ classes, offers a “*black-box*” implementation that does not require user input and is not application specific. The features are

(i) A modeling language to express a compact integer linear programming model of the application on hand.  
(ii) the automation of the Dantzig-Wolfe reformulation process. The user can provide subproblem solvers if available, but he does not need to explicitly define the reformulation, the explicit form of the columns, their reduced cost, or the Lagrangian bounds.

(iii) a default column generation procedure with standard initialization and stabilization [1], [56] [88] [87] [77] and

(iv) a default branching scheme that is generic to all applications [7],

(v) default primal heuristics specially developed for use in a decomposition framework [61], [76], [89].

The prototype software was/is used as background solver in our application studies and local PhD thesis. It also serves as the framework for our comparative study in a Inria associated team project and our transfert projects (the prototype enables us to be very responsive in our industrial contact).

See also the web page <https://wiki.bordeaux.inria.fr/realopt/pmwiki.php/Project/BaPCod>.



## SELECT Project-Team

### 5. New Software and Platforms

#### 5.1. MIXMOD software

**Participants:** Gilles Celeux [Correspondant], Erwan Le Pennec, Benjamin Auder.

Mixture model, cluster analysis, discriminant analysis

MIXMOD is being developed in collaboration with Christophe Biernacki, Florent Langrognet (Université de Franche-Comté) and Gérard Govaert (Université de Technologie de Compiègne). MIXMOD (MIXture MODelling) software fits mixture models to a given data set with either a clustering or a discriminant analysis purpose. MIXMOD uses a large variety of algorithms to estimate mixture parameters, e.g., EM, Classification EM, and Stochastic EM. They can be combined to create different strategies that lead to a sensible maximum of the likelihood (or completed likelihood) function. Moreover, different information criteria for choosing a parsimonious model, e.g. the number of mixture component, some of them favoring either a cluster analysis or a discriminant analysis view point, are included. Many Gaussian models for continuous variables and multinomial models for discrete variable are available. Written in C++, MIXMOD is interfaced with MATLAB. The software, the statistical documentation and also the user guide are available on the Internet at the following address: <http://www.mixmod.org>.

Since 2010, MIXMOD has a proper graphical user interface. A version of MIXMOD in R is now available <http://cran.r-project.org/web/packages/Rmixmod/index.html>.

Erwan Le Pennec with the help of Serge Cohen has proposed a spatial extension in which the mixture weights can vary spatially.

Benjamin Auder contributes to the informatics improvement of MIXMOD. He implemented an interface to test any mathematical library (Armadillo, Eigen, ...) to replace NEWMAT. He contributed to the continuous integration setup using Jenkins tool and prepared an automated testing framework for unit and non-regression tests.

This year, it has been decided to create MIXMODSTORE which proposes companion programs of MIXMOD. As a matter of fact, the program MixmodCombi of Jean-Patrick Baudry (Université Paris 6) and Gilles Celeux which allows a hierarchical clustering derived from a mixture has been associated to Rmixmod.

#### 5.2. BLOCKCLUSTER software

**Participants:** Vincent Brault, Gilles Celeux, Christine Keribin.

Mixture model, Block cluster analysis,

Blockcluster is a software devoted on model-based block clustering. It is developed by MODAL team (Inria Lille). With Parmeet Bathia (Inria Lille), Vincent Brault has added a Bayesian point of view for the binary, categorical and continuous datas with the variational Bayes algorithm. It has been enriched by a full Bayesian version using a Gibbs sampler. This Gibbs sampler coupled with the variational Bayes algorithm provides solutions more stable and less dependent of the starting values of the algorithm. An exact expression of criterion ICL has been provided. This criterion or BIC are used for selecting a relevant block clustering.



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## SEQUEL Project-Team

# 5. New Software and Platforms

## 5.1. Computer Games

**Participant:** Rémi Coulom.

- *Crazy Stone* is a top-level Go-playing program that has been developed by Rémi Coulom since 2005. Crazy Stone won several major international Go tournaments in the past. In 2013, a new version was released in Japan. This new version won the 6th edition of the UEC Cup (the most important international computer-Go tournament). It also won the first edition of the Densenen, by winning a 4-stone handicap game against 9-dan professional player Yoshio Ishida. It is distributed as a commercial product by *Unbalance Corporation* (Japan). 6-month work in 2013. URL: <http://remi.coulom.free.fr/CrazyStone/>
- *Kifu Snap* is an Android image-recognition app. It can automatically recognize a Go board from a picture, and analyze it with Crazy Stone. It was released on Google Play in November, 2013. 6-month work in 2013. URL: <http://remi.coulom.free.fr/kifu-snap/>

## 5.2. Function optimization

**Participant:** Philippe Preux.

### 5.2.1. *yaStoSOO*

We have worked on the efficient implementation of the StoSOO algorithm in order to have a software that can be used for real to optimize real functions, and to be able to experiment with the algorithm, and assess its practical usefulness. This led to *yaStoSOO*, an implementation in C available on the web at <http://www.grappa.univ-lille3.fr/~ppreux/software/StoSOO/>. The code is distributed under the GPL licence.

Thanks to this implementation, we were able to compete in the CEC'2014 competition on Real-Parameter Single Objective optimization at which we ranked honorably (10th out of 17 competitor algorithms). More experimental work is under-way.

## SIERRA Project-Team

# 4. New Software and Platforms

## 4.1. SAG

**Participant:** Mark Schmidt [correspondent].

SAG: Minimizing Finite Sums with the Stochastic Average Gradient.

The SAG code contains C implements (via Matlab mex files) of the stochastic average gradient (SAG) method detailed below, as well as several related methods, for the problem of L2-regularized logistic regression with a finite training set.

The specific methods available in the package are: SGD: The stochastic gradient method with (user-supplied) step-sizes, (optional) projection step, and (optional) (weighted-)averaging. ASGD: A variant of the above code that supports less features, but efficiently implements uniform averaging on sparse data sets. PCD: A basic primal coordinate descent method with step sizes set according the (user-supplied) Lipschitz constants. DCA: A dual coordinate ascent method with a numerical high-accuracy line-search. SAG: The stochastic average gradient method with a (user-supplied) constant step size. SAGlineSearch: The stochastic average gradient method with the line-search described in the paper. SAG-LipschitzLS: The stochastic average gradient method with the line-search and adaptive non-uniform sampling strategy described in the paper.

## 4.2. fMRI

**Participant:** Fabian Pedregosa [correspondent].

We showed that HRF estimation improves sensitivity of fMRI encoding and decoding models and propose a new approach for the estimation of Hemodynamic Response Functions from fMRI data. This is an implementation of the methods described in the paper.

## TAO Project-Team

### 5. New Software and Platforms

#### 5.1. METIS

**Participants:** Olivier Teytaud [correspondent], Jérémie Decock, Jean-Joseph Christophe, Vincent Berthier, Marie-Liesse Cauwet, Jialin Liu, Sandra Cecilia Astete Morales.

**Keywords:** Energy, Optimization, Planning.

Many works in Energy Optimization, in particular in the case of high-scale sequential decision making, are based on one software per application, because optimizing the software eventually implies losing generality. Our goal is to develop with Artelys a platform, METIS, which can be used for several applications. In 2012 we interfaced existing codes in Artelys and codes developed in the TAO team; experiments have been performed and test cases have been designed. A main further work is the introduction of generic tools for stochastic dynamic programming into the platform, for comparison and hybridization with other tools from the UCT-SIG.

Our favorite challenge is the hybridization of “classical” tools (based on constraint satisfaction problems, or mixed integer linear programming or mixed integer quadratic programming), which are fast and accurate, with non-linear solvers which can take care of a sophisticated (non-linear) models.

Metis is the Artelys/Tao contribution to Crystal, which is at the heart of the Post project, which is selected by the European Commission for a 4-years project for energy modeling <http://www.artelys.com/news/120/90/Energy-The-European-Commission-Chooses-Artelys-Crystal>.

#### 5.2. MoGo

**Participants:** Olivier Teytaud [correspondent], Jean-Baptiste Hoock.

**Keywords:**

MoGo and its Franco-Taiwanese counterpart MoGoTW is a Monte-Carlo Tree Search program for the game of Go, which made several milestones of computer-Go in the past (first wins against professional players in 19x19; first win with disadvantageous side in 9x9 Go). Recent results include 7 wins out of 12 against professional players (in Brisbane, 2012) in 7x7, and recently an optimization of the random seed which brings a significant improvement in Go and (unpublished) on the difficult case of phantom-Go. However, the work in the UCT-SIG has now shifted to energy management.

#### 5.3. CMA-ES: Covariance Matrix Adaptation Evolution Strategy

**Participants:** Emmanuel Benazera, Nikolaus Hansen [correspondent].

**Keywords:** Evolutionary Computation, Stochastic Optimization, Real-parameter Optimization.

The Covariance Matrix Adaptation Evolution Strategy (CMA-ES) [65] is considered to be state-of-the-art in continuous domain evolutionary computation [64], and in stochastic optimization at large. It has been shown to be highly competitive on different problem classes even with deterministic continuous algorithms using numerically computed gradients (see the results published on COCO platform). The algorithm is widely used in research and industry as witnessed by hundreds of published applications. We provide source code for the CMA-ES in C, C++11, Java, Matlab, Octave, Python, and Scilab including the latest variants of the algorithm.

Link: [http://www.lri.fr/~hansen/cmaes\\_inmatlab.html](http://www.lri.fr/~hansen/cmaes_inmatlab.html)

#### 5.4. COmparing Continuous Optimizers

**Participants:** Nikolaus Hansen [correspondent], Anne Auger, Marc Schoenauer, Ouassim Ait Elhara, Asma Atamna.

**Keywords:** Evolutionary Computation, Stochastic Optimization, Real-parameter Optimization, Benchmarking, Derivative Free Optimization.

COCO (COMparing Continuous Optimizers) is a platform for systematic and sound comparisons of real-parameter global optimizers. COCO provides benchmark function testbeds (noiseless and noisy) and tools for processing and visualizing data generated by one or several optimizers. The code for processing experiments is provided in Matlab, C, Java, and Python. The post-processing code is provided in Python. The code is under continuous development and has been used for the GECCO 2009, 2010, 2012, and 2013 workshops on “Black Box Optimization Benchmarking” (BBOB) (see Section 6.3). It is now undergoing major changes thanks to the ANR project NumBBO that will add constraint handling and multi-objective benchmarks to the existing platform.

Link: <http://coco.gforge.inria.fr/> and <http://numbbo.gforge.inria.fr/>

## 5.5. MultiBoost

**Participant:** Balázs Kégl [correspondent].

**Keywords:** Multi-class, Multi-label Classification.

The MultiBoost package [63] provides a fast C++ implementation of multi-class/multi-label/multi-task boosting algorithms. It is based on ADABOOST.MH but it also implements popular cascade classifiers, ARC-GV, and FILTERBOOST. The package contains common multi-class base learners (stumps, trees, products, Haar filters). Further base learners and strong learners following the boosting paradigm can be easily implemented in a flexible framework.

Link: <http://multiboost.org>

## 5.6. Grid Observatory

**Participants:** Cécile Germain-Renaud [correspondent], Julien Nauroy, Michèle Sebag.

**Keywords:** Autonomic Computing, Green Computing.

The Grid Observatory (GO) software suite collects and publishes traces of the EGI (European Grid Initiative) grid usage. With the release and extensions of its portal, the Grid Observatory has made a database of grid usage traces available to the wider computer science community since 2008. These data are stored on the grid, and made accessible through a web portal without the need of grid credentials. The GO is fully integrated with the evolution of EGI monitoring. More than 250 users are currently registered. The acquisition has been extended to the University cloud StratusLab hosted by the VirtualData center.

The Green Computing Observatory (GCO) monitors the VirtualData center; it collects data on energy consumption and publishes the data through the Grid Observatory. These data include the detailed monitoring of the processors and motherboards, as well as global site information. The first results on energy saving opportunities have been presented at the Green Days@Luxembourg meeting.

In order to make the GO data readily consistent and complete, as well as understandable for further exploitation, an original approach has been designed, based on a flexible data schema built in collaboration with the users [27]. Its implementation is developed within the FUI project TIMCO.

Link: <http://grid-observatory.org>

## 5.7. Platforms

### 5.7.1. *io.datascience*

This Data as a Service (DaaS) platform is developed in the context of the Center for Data Science and the TIMCO project. Its overall goal is to exploit the advances in semantic web techniques for efficient sharing and usage of scientific data. A related specific software is the Tester for Triplestore (TFT) software suite, which benchmarks the compliance of sparql databases wrt the RDF standard and publishes the results through the SparqlScore service. TFT has been selected for the Semantic Web Challenge [42].

Links: <https://io.datascience-paris-saclay.fr>, <https://github.com/BorderCloud/TFT>, <http://sparqlscore.com>

**ASPI Project-Team (section vide)**

## CQFD Project-Team

# 5. New Software and Platforms

## 5.1. Package PCAmixdata

Mixed data type arise when observations are described by a mixture of numerical and categorical variables. The R package PCAmixdata extends standard multivariate analysis methods to incorporate this type of data. The key techniques included in the package are PCAmix (PCA of a mixture of numerical and categorical variables), PCArot (rotation in PCAmix) and MFAMix (multiple factor analysis with mixed data within a dataset). The MFAMix procedure handles a mixture of numerical and categorical variables within a group - something which was not possible in the standard MFA procedure. We also included techniques to project new observations onto the principal components of the three methods in the new version of the package.

## 5.2. QuantifQuantile: an R package to estimate conditional quantiles using optimal quantization

QuantifQuantile is an R package that allows to perform quantization-based quantile regression. The different functions of the package allow the user to construct an optimal grid of  $N$  quantizers and to estimate conditional quantiles. This estimation requires a data driven selection of the size  $N$  of the grid that is implemented in the functions. Illustration of the selection of  $N$  is available, and graphical output of the resulting estimated curves or surfaces (depending on the dimension of the covariate) is directly provided via the plot function.

## 5.3. Biips: Software for Bayesian Inference with Interacting Particle Systems

Biips is a software platform for automatic Bayesian inference with interacting particle systems. Biips allows users to define their statistical model in the probabilistic programming BUGS language, as well as to add custom functions or samplers within this language. Then it runs sequential Monte Carlo based algorithms (particle filters, particle independent Metropolis-Hastings, particle marginal Metropolis-Hastings) in a black-box manner so that to approximate the posterior distribution of interest as well as the marginal likelihood. The software is developed in C++ with interfaces with the softwares R, Matlab and Octave [53].

## MATHRISK Project-Team

# 5. New Software and Platforms

## 5.1. PREMIA

**Participants:** Antonino Zanette, Mathrisk Research Team, Agnès Sulem [correspondant].

### 5.1.1. Premia: general description

Premia is a software designed for option pricing, hedging and financial model calibration. It is provided with its C/C++ source code and an extensive scientific documentation. <https://www-rocq.inria.fr/mathfi/Premia>

The Premia project keeps track of the most recent advances in the field of computational finance in a well-documented way. It focuses on the implementation of numerical analysis techniques for both probabilistic and deterministic numerical methods. An important feature of the platform Premia is the detailed documentation which provides extended references in option pricing.

Premia is thus a powerful tool to assist Research & Development professional teams in their day-to-day duty. It is also a useful support for academics who wish to perform tests on new algorithms or pricing methods without starting from scratch.

Besides being a single entry point for accessible overviews and basic implementations of various numerical methods, the aim of the Premia project is:

1. to be a powerful testing platform for comparing different numerical methods between each other;
2. to build a link between professional financial teams and academic researchers;
3. to provide a useful teaching support for Master and PhD students in mathematical finance.
  - AMS: 91B28;65Cxx;65Fxx;65Lxx;65Pxx
  - License: Licence Propriétaire (genuine license for the Consortium Premia)
  - Type of human computer interaction: Console, interface in Nsp, Web interface
  - OS/Middleware: Linux, Mac OS X, Windows
  - APP: The development of Premia started in 1999 and 15 are released up to now and registered at the APP agency. Premia 15 has been registered on 18/03/2013 and has the number IDDN.FR.001.190010.012.S.C.2001.000.31000
  - Programming language: C/C++ librairie Gtk
  - Documentation: the PNL library is interfaced via doxygen
  - Size of the software: 280580 lines for the Src part only, that is 11 Mbyte of code, 130400 lines for PNL, 105 Mbyte of PDF files of documentation.
  - interfaces : Nsp for Windows/Linux/Mac, Excel, binding Python, and a Web interface.
  - Publications: [12], [58], [68], [79], [84], [40], [18].

### 5.1.2. Content of Premia

Premia contains various numerical algorithms (Finite-differences, trees and Monte-Carlo) for pricing vanilla and exotic options on equities, interest rate, credit and energy derivatives.

#### 1. Equity derivatives

The following models are considered:

Black-Scholes model (up to dimension 10), stochastic volatility models (Hull-White, Heston, Fouque-Papanicolaou-Sircar), models with jumps (Merton, Kou, Tempered stable processes, Variance gamma, Normal inverse Gaussian), Bates model.

For high dimensional American options, Premia provides the most recent Monte-Carlo algorithms: Longstaff-Schwartz, Barraquand-Martineau, Tsitsklis-Van Roy, Broadie-Glassermann, quantization methods and Malliavin calculus based methods.

Dynamic Hedging for Black-Scholes and jump models is available.

Calibration algorithms for some models with jumps, local volatility and stochastic volatility are implemented.

## 2. Interest rate derivatives

The following models are considered:

HJM and Libor Market Models (LMM): affine models, Hull-White, CIR++, Black-Karasinsky, Squared-Gaussian, Li-Ritchken-Sankarasubramanian, Bhar-Chiarella, Jump diffusion LMM, Markov functional LMM, LMM with stochastic volatility.

Premia provides a calibration toolbox for Libor Market model using a database of swaptions and caps implied volatilities.

## 3. Credit derivatives: Credit default swaps (CDS), Collateralized debt obligations (CDO)

Reduced form models and copula models are considered.

Premia provides a toolbox for pricing CDOs using the most recent algorithms (Hull-White, Laurent-Gregory, El Karoui-Jiao, Yang-Zhang, Schönbucher)

## 4. Hybrid products

A PDE solver for pricing derivatives on hybrid products like options on inflation and interest or change rates is implemented.

## 5. Energy derivatives: swing options

Mean reverting and jump models are considered.

Premia provides a toolbox for pricing swing options using finite differences, Monte-Carlo Malliavin-based approach and quantization algorithms.

### 5.1.3. Premia design

Premia has managed to grow up over a period of fifteen years; this has been possible only because contributing an algorithm to Premia is subject to strict rules, which have become too stringent. To facilitate contributions, a standardized numerical library (PNL) has been developed by J. Lelong under the LGPL since 2009, which offers a wide variety of high level numerical methods for dealing with linear algebra, numerical integration, optimization, random number generators, Fourier and Laplace transforms, and much more. Everyone who wishes to contribute is encouraged to base its code on PNL and providing such a unified numerical library has considerably eased the development of new algorithms which have become over the releases more and more sophisticated. An effort is made to continue and stabilize the development of PNL. J. Ph Chancelier, B. Lapeyre and J. Lelong are using Premia and Nsp for Constructing a Risk Management Benchmark for Testing Parallel Architecture [18].

**Development of the PNL in 2014** (J. Lelong) - Release 1.70. and 1.7.1 of the *PNL* library (<http://pnl.gforge.inria.fr/>).

1. Sampling from new distributions: non central Chi squared, Poisson, Bernoulli.
2. When using quasi Monte Carlo sequences, sampling from any distribution resorts to using the inverse of the cumulative distribution function technique.
3. A CMake module is provided to automatically detect the library when used by third party codes.
4. Add a sparse matrix object with advanced functionalities provided by Blas & Lapack. This new object is handled by the MPI binding.



5. Complete refactoring of the Basis object to considerably speedup the evaluation functions. Multivariate polynomials are represented as tensor products of one variate polynomials. The matrix holding the tensor product now uses a sparse storage which avoids many operations leading to a zero value thus leading to an impressive reduction the computational time.
6. All random number generators are thread-safe.

#### 5.1.4. Algorithms implemented in Premia in 2014

Premia 16 has been delivered to the Consortium Premia in March 2014. In this release we have developed the Haar Wavelets-based approach for quantifying credit portfolio losses, Monte Carlo simulations of Credit Value Adjustment (CVA) using Malliavin techniques, asymptotic and exact pricing options on variance and importance sampling, and multilevel methods for jump models.

It contains the following new algorithms:

##### 5.1.4.1. Commodities, Forex (FX), Insurance, Credit Risk

- Pricing and hedging gap risk. P. Tankov.  
*Journal of Computational Finance. Volume 13 Number 3, Spring 2010.*
- An Optimal Stochastic Control Framework for Determining the Cost of Hedging of Variable Annuities. P. A. Forsyth K.Vetzal
- Haar Wavelets-Based Approach for Quantifying Credit Portfolio Losses.  
J. J. Masdemont, L. O. Gracia. *Quantitative Finance, to appear*
- Cutting CVA's complexity. P. Henry-Labordère. *Risk Magazine 04 Jul 2012*
- Towards a coherent Monte Carlo simulation of CVA. L. Abbas Turki, A.Bouselmi, M.Mikou, *hal-00873200*
- Stochastic local intensity loss models with interacting particle system.  
A. Alfonsi, C. Labart, J. Lelong *Mathematical Finance, to appear*
- Repricing the Cross Smile: An Analytic Joint Density. P. Austing.

##### 5.1.4.2. Equity Derivatives

- On the Fourier cosine series expansion (COS) method for stochastic control problems. R.F.T. Aalber, C.W. Oosterlee and M.J. Ruijter.
- A multifactor volatility Heston model. J.Da Fonseca M. Grasselli C. Tebaldi.  
*Quant. Finance 8 (2008), no. 6, 591–604.*
- General approximation schemes for option prices in stochastic volatility models. K.Larsson, *Quantitative Finance Volume 12, Issue 6, 2012*
- A robust tree method for pricing American options with the Cox-Ingersoll-Ross interest rate model.  
E. Appolloni, L. Caramellino and A. Zanette  
*IMA Journal of Management Mathematics 2014, to appear.*
- A hybrid tree-finite difference approach for the Heston and Bates model model. M. Briani, L. Caramellino and A. Zanette *Preprint ArXiv 1307.7178*
- A Closed-Form Exact Solution for Pricing Variance Swaps with Stochastic Volatility. S. Zhu and G. Lian, *Mathematical Finance, Volume 21, Issue 2, April 2011*
- Asymptotic and exact pricing options on variance. M.Keller-Ressel J.Muhle-Karbe.  
*Finance & Stochastics, Volume 17 (2013), issue 1*
- Importance sampling and Statistical Romberg Method for jump models.  
M.B. Alaya, A. Kebaier and K. Hajji
- Smart expansion and fast calibration for jump diffusions E. Benhamou, E. Gobet and M. Miri,  
*Finance Stochastics Volume 13, Number 4, September, 2009*
- Scaling and multiscaling in financial series: a simple model.  
Andreoli, A., Caravenna, F, Dai Pra, P. Posta, G., *Advances in Applied Probability. (2012), 44(4), 1018-1051.*
- Smooth convergence in the binomial model.  
L.B. Chang, K. Palmer. *Finance Stochastics Volume 11, Number 1, 2007.*

## REGULARITY Project-Team

# 5. New Software and Platforms

## 5.1. FracLab

**Participant:** Jacques Lévy Véhel [correspondant].

FracLab was developed for two main purposes:

1. propose a general platform allowing research teams to avoid the need to re-code basic and advanced techniques in the processing of signals based on (local) regularity.
2. provide state of the art algorithms allowing both to disseminate new methods in this area and to compare results on a common basis.

FracLab is a general purpose signal and image processing toolbox based on fractal, multifractal and local regularity methods. FracLab can be approached from two different perspectives:

- (multi-) fractal and local regularity analysis: A large number of procedures allow to compute various quantities associated with 1D or 2D signals, such as dimensions, Hölder and 2-microlocal exponents or multifractal spectra.
- Signal/Image processing: Alternatively, one can use FracLab directly to perform many basic tasks in signal processing, including estimation, detection, denoising, modeling, segmentation, classification, and synthesis.

A graphical interface makes FracLab easy to use and intuitive. In addition, various wavelet-related tools are available in FracLab.

FracLab is a free software. It mainly consists of routines developed in MatLab or C-code interfaced with MatLab. It runs under Linux, MacOS and Windows environments. In addition, a “stand-alone” version (*i.e.* which does not require MatLab to run) is available.

FracLab has been downloaded several thousands of times in the last years by users all around the world. A few dozens laboratories seem to use it regularly, with more than four hundreds registered users. Our ambition is to make it the standard in fractal softwares for signal and image processing applications. We have signs that this is starting to become the case. To date, its use has been acknowledged in roughly three hundreds and fifty research papers in various areas such as astrophysics, chemical engineering, financial modeling, fluid dynamics, internet and road traffic analysis, image and signal processing, geophysics, biomedical applications, computer science, as well as in mathematical studies in analysis and statistics (see <http://fraclab.saclay.inria.fr/> for a partial list with papers). In addition, we have opened the development of FracLab so that other teams worldwide may contribute. Additions have been made by groups in Australia, England, France, the USA, and Serbia.

## TOSCA Project-Team

# 5. New Software and Platforms

## 5.1. Triton

**Participant:** Antoine Lejay [correspondant].

The Triton software aims at providing a toolbox to analyze nearshore waves images recorded by a camera on the beach. More precisely, it aims at estimating the height, length and speed of waves, to find speed and direction of currents, and to reconstruct the bathymetry from these images.

This is a joint work with Rafael Almar (LEGOS, IRD, Toulouse) and with Stanislas Larnier (LAAS-CNRS, Toulouse), a former post-doctoral student in the Tosca team.

- Version: 1.0

## 5.2. SDM

**Participants:** Mireille Bossy [correspondant], Sélim Karia.

The computation of the wind at small scale and the estimation of its uncertainties is of particular importance for applications such as wind energy resource estimation. To this aim, starting in 2005, we have developed a new method based on the combination of an existing Numerical Weather Prediction model providing a coarse prediction, and a Lagrangian Stochastic Model for turbulent flows. This Stochastic Downscaling Method (SDM) requires a specific modelling of the turbulence closure, and involves various simulation techniques whose combination is totally original (such as Poisson solvers, optimal transportation mass algorithm, original Euler scheme for confined Langevin stochastic processes, and stochastic particle methods).

In 2013, the SDM code became the kernel of the wind farm modelling of the Fundacion Inria Chile. In France, its development is pursuing through the collaborative Modéol project on the evaluation of wind potential.

This is a joint work with Antoine Rousseau from the team LEMON.

- Version: 2.0

## 5.3. CarbonQuant

**Participants:** Mireille Bossy [correspondant], Sélim Karia.

CarbonQuant is a simulator project of CO<sub>2</sub> allowances prices on a EU-ETS type market, by an indifference price approach.

It aims to demonstrate the high potentiality of stochastic control solvers, to quantify sensibilities of a carbon market with respect to its design.

See also the web page <http://carbonvalue.gforge.inria.fr>, from where CarbonQuant can be now downloaded for various architectures.

A new version of CarbonQuant is under development that includes a  $N$  players game approche on an auction carbon market.

- Version: 2.0