RESEARCH CENTER

FIELD
Applied Mathematics, Computation and Simulation

Activity Report 2013

Section Software

Edition: 2014-03-20

CAD Team (section vide)

CALVI Project-Team

5. Software and Platforms

5.1. SeLaLib

Participants: Aurore Back, Raphaël Blanchard, Edwin Chacon Golcher, Samuel de Santis, Aliou Diouf, Pierre Navaro, Morgane Bergot, Emmanuel Frénod, Virginie Grandgirard, Adnane Hamiaz, Philippe Helluy, Sever Hirstoaga, Michel Mehrenberger, Laurent Navoret, Nhung Pham, Eric Sonnendrücker.

Under the 'Fusion' large scale initiative, we have continued our work in the development of the ADT Selalib (the Semi-Lagrangian Library), now finishing its third year. This library provides building blocks for the development of numerical simulations for the solution of the fundamental equation of plasma physics: the Vlasov equation. In this context we have continued to add new modules improved interfaces and implemented 'continuous integration' software development techniques to improve code robustness and portability. Furthermore, we continue to involve other researchers within France and abroad to aid in the further development of this software product.

One of the aims of the ADT is to provide numerical building blocks for the GYSELA code developed at CEA Cadarache in collaboration with the Calvi project-team. GYSELA is used by physicists for simulating the development of turbulence in magnetic fusion plasmas in particular in view of the ITER project.

This year many developments have incorporated into Selalib: semi-Lagrangian solvers on curvilinear grids, new models, new fully-Eulerian solvers, new linear solvers for the Poisson or quasineutrality equation. More details are given in the corresponding sections, because we always try to test our new algorithms within Selalib.

Selalib is available on the Inria Forge http://selalib.gforge.inria.fr/

5.2. CLAC

Participants: Philippe Helluy, Michel Massaro, Thomas Strub.

CLAC is a generic Discontinuous Galerkin solver, written in C/C++, based on the OpenCL and MPI frameworks. CLAC means "Conservation Laws Approximation on many Cores".

It is clear now that a future supercomputer will be made of a collection of thousands of interconnected multicore processors. Globally it appears as a classical distributed memory MIMD machine. But at a lower level, each of the multicore processors is itself made of a shared memory MIMD unit (a few classical CPU cores) and a SIMD unit (a GPU). When designing new algorithms, it is important to adapt them to this architecture. Our philosophy will be to program our algorithms in such a way that they can be run efficiently on this kind of computers. Practically, we will use the MPI library for managing the high level parallelism, while the OpenCL library will efficiently operate the low level parallelism.

We have invested for several years now into scientific computing on GPUs, using the open standard OpenCL (Open Computing Language). We were recently awarded a prize in the international AMD OpenCL innovation challenge thanks to an OpenCL two-dimensional Vlasov-Maxwell solver that fully runs on a GPU. OpenCL is a very interesting tool because it is an open standard now available on almost all brands of multicore processors and GPUs. The same parallel program can run on a GPU or a multicore processor without modification.

CLAC is also a joint project with a Strasbourg small company, AxesSim, which develops software for electromagnetic simulations.

Because of the envisaged applications of CLAC, which may be either academic or commercial, it is necessary to conceive a modular framework. The heart of the library is made of generic parallel algorithms for solving conservation laws. The parallelism can be both fine-grained (oriented towards GPUs and multicore processors) and coarse-grained (oriented towards GPU clusters). The separate modules allow managing the meshes and some specific applications. In this way, it is possible to isolate parts that should be protected for trade secret reasons. The open source part of CLAC will be made freely available on the web later on. We have made an APP deposit of the first version of CLAC in October 2012. The versioning of CLAC project is also registered in the Inria Forge http://clac.gforge.inria.fr.

CONCHA Project-Team

5. Software and Platforms

5.1. C++ library Concha

Participants: Roland Becker, Daniela Capatina, Robert Luce, David Trujillo.

The objectives of our library CONCHA are to offer a flexible and extensible software with respect to:

- Numerical methods and
- Physical models.

The aim is to have a flexible code which could easily switch between the different discretizations, in order to provide a toolbox for rapid testing of new ideas.

The software architecture is designed in such a way that a group of core developers can contribute in an efficient manner, and that independent development of different physical applications is possible. Further, in order to accelerate the integration of new members and in order to provide a basis for our educational purposes (see Section 9.2), the software proposes different entrance levels. The basic structure consists of a common block, and several special libraries which correspond to the different fields of applications described in Sections – Hyperbolic solvers, Low-Mach number flow solvers, DNS, and viscoelastic flows. A more detailed description of each special library may be found below. In order to coordinate the cooperative development of the library, Concha is based on the Inria-Gforge.

5.2. User interface and python interface

Participants: Roland Becker, David Trujillo.

Figure 6. Graphical user interface: option panel (left) and process panel (right) of the install tool.

We are confronted with heterogenous backgrounds and levels of implication of the developers and users. It seems therefore crucial to be able to respond to the different needs. Our aim is to facilitate the development of the library, and at the same time, to make it possible that our colleagues involved in physical modeling can have access to the functionality of the software with a reasonable investment of time. Two graphical user interfaces have been developed: one for the installation of the library and another one for the building and execution of projects. They are based on common database and scripts written in python. The scripts can also be launched in a shell. In Figure 6 the user interface of the install tool is shown. The option panel allows to choose the components for conditional compilation and the compilation type (debug and release).

Figure 7. Graphical user interface: project build panel (left) and parameter panel (right) of the project tool.

In Figure 7 the user interface of the project tool is shown. A project consists of a number of sources files and a parameter file used by the C++-executable. The sources define classes derived from the library, which are used to specify certain data such as boundary conditions and employed finite element spaces. The parameter file contains algorithmic information and physical parameters. It is generated from a database by the python utilities.

The tools offered by this development platform are based on a python interface for the library, called pyConcha. It offers a common interface, based on a pluggin-system, which allows the devloppement of command line tools in parallel. This year the consolidation of the interface part of pyConcha has been an important task. The pyConcha library is now a framework rather than a simple interface to Concha C++ library. It allows now creation of plugins, so that each user-programmer can customize pyConcha to his own goals. Previously, two main programs where working: concha-install.py to install library, and concha-project.py for (semi-)end-users. Both are now plugins of pyConcha, and can be launched by pyConcha at startup. A plugin visualization could now be developped in an independant way, and launched by pyConcha on demand.

The structure of pyConcha framework is clearly splitted in various modules(layers): Command Line Interface module, Graphical User Interface module and Handlers modules, see Figure 8 . A great effort has been made for internationalization of pyConcha.

5.3. Euler equations

Participants: Roland Becker, Kossivi Gokpi, Robert Luce, Eric Schall, David Trujillo.

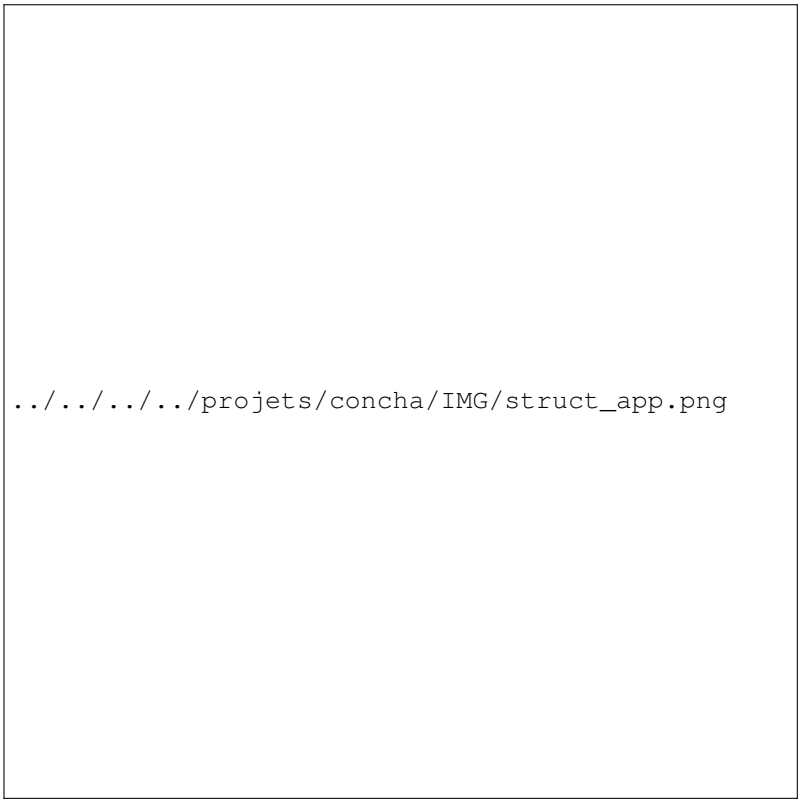


Figure 8. Structure of the pyConcha framework.

Based on the library CONCHA we have developed a solver for hyperbolic PDE's based on DGFEM. So far different standard solvers for the Euler equations such as Lax-Friedrichs, Steger-Warming, and HLL have been implemented for test problems. A typical example is the scram jet test case shown in Figure 9 .

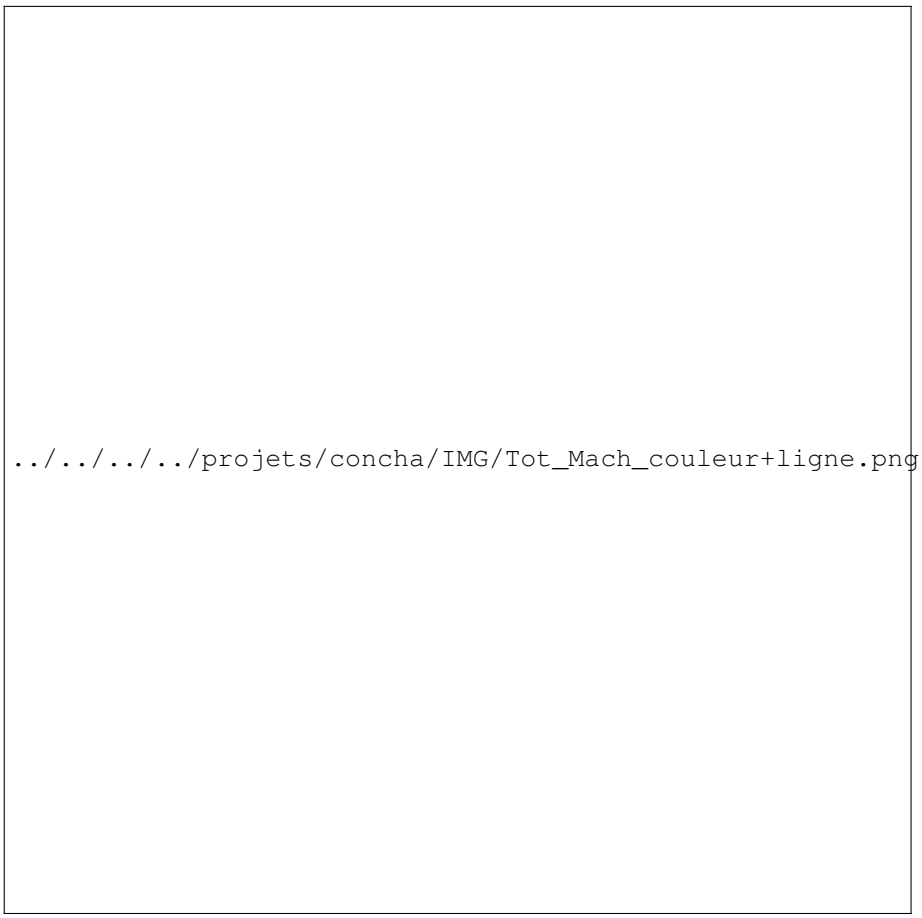


Figure 9. Computed Mach-number distribution for the Scramjet test problem.

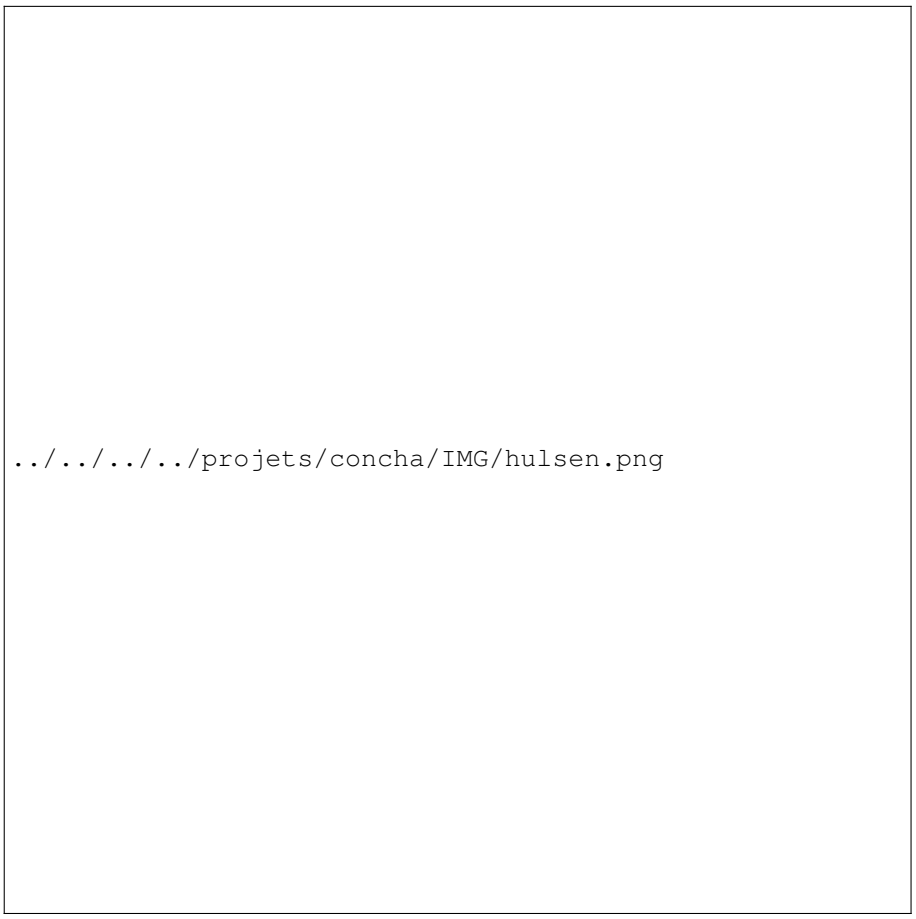
5.4. Incompressible flow solvers

Participants: Roland Becker, Daniela Capatina, Robert Luce, David Trujillo.

We have started the validation of the implementation of different finite element methods for incompressible flows at hand of standard benchmark problems as the Stokes flow around a symmetric cylinder [58] and the stationary flow around a slightly non symmetric cylinder [63], see Figure 10 .

5.5. DNS

Participants: Roland Becker, David Trujillo.


../../../../projets/concha/IMG/hulsen.png


../../../../projets/concha/IMG/cylinderBenchmark.png

For the direct numerical simulation of incompressible turbulent flows, we have started to develop a special solver based on structured meshes with a fast multigrid algorithm incorporating projection-like schemes. The main idea is to use non-conforming finite elements for the velocities with piecewise constant pressures, leading to a special structure of the discrete Schur complement, when an explicit treatment of the convection and diffusion term is used.

5.6. Validation and comparison with other CFD-software

Participants: Roland Becker, Didier Graebling, Eric Schall, David Trujillo.

Validation and comparison with other CFD-software is crucial in order to evaluate the potential of our numerical schemes concerning accuracy, computing time and other practical aspects.

We have compared the Concha library for incompressible and compressible flows. For incompressible flows, we have used a test case proposed by Hulsen and the well-known Schafer-Turek cylinder benchmark in order to validate the accuracy of the Stokes and Navier-Stokes solvers. The viscoelastic code has been compared with PolyFlow for different test configurations.

The compressible Euler code has been compared to the ELSA software developed by ONERA.

For further comparison and validation, it would be important to consider other commercial and research tools such as: *Aéro3* (Inria-Smash), AVBP (CERFACS), Fluent (ANSYS), and OpenFOAM (OpenCfd).

For this purpose we have proposed the ADT-project VALSE in collaboration with a small company involved in aerodynamics (EPSILON Toulouse), which unfortunately has been rejected by Inria.

MICMAC Project-Team (section vide)

SCIPORT Team

5. 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 with MPI as parallel programming concept. The mesh model is unstructured tetrahedrization, with possible mesh motion. See also 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 Hascoet [correspondant], Valérie Pascual, Ala Taftaf.

TAPENADE is an Automatic Differentiation tool that transforms an original program into a new program that computes derivatives of the original program. Automatic 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, ans vector adjoint. Documentation is provided on the web site of the reserch team http://www-sop.inria.fr/tropics/, in Inria technical report RT-0300, and in [13]. TAPENADE runs under most operating systems and requires installation of Java jdk1.6 or upward.

- Version: v3.8, r4996, November 2013
- 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: IDDN.FR.001.040038.002.S.P.2002.000.10600
- Keywords: automatic 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. TAPENADE differentiates computer programs according to the model described in section 3.1 and in [13] Higher-order derivatives can be obtained through repeated application of tangent AD on tangent- and/or adjoint-mode AD.

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 analysis 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. Industrial or commercial usage require a paying license, as detailled on the team's web page. The software has been downloaded several hundred times, and the web tool served several thousands of true connections (not counting robots). The tapenade-users mailing list is over one hundred registered users.

SIMPAF Project-Team

5. Software and Platforms

5.1. ns2ddv-M

Participants: Caterina Calgaro [correspondant (Univ. Lille 1)], Emmanuel Creusé [correspondant (Univ. Lille 1)].

Incompressible Navier-Stokes, Variable Density, Rayleigh-Taylor Instability The NS2DDV-M code is based on a hybrid method coupling FV and FE approaches for solving the variable density Navier-Stokes equation in dimension 2. This original approach for variable density flows is described in [41].

Here is the self-assessment of the team effort following the grid provided by Inria (see : http://www.inria.fr/institut/organisation/instances/commission-d-evaluation): A3, SO3-up4, SM2-up3, EM3, SDL4, DA1, CD4, MS4, TPM4.

Software web site : http://math.univ-lille1.fr/~simpaf/SITE-NS2DDV/home.html

5.2. ns2ddv-C++

Participants: Caterina Calgaro [correspondant (Univ. Lille 1)], Emmanuel Creusé [correspondant (Univ. Lille 1)], Thierry Goudon.

Incompressible Navier-Stokes, Variable Density, Kazhikhov-Smagulov model, Rayleigh-Taylor Instability, avalanches phenomena The NS2DVD-C++ code is based on a hybrid method coupling FV and FE approaches for solving the variable density Navier-Stokes equation in dimension 2. The code is developed around the GetFem++ and the Bamg softwares. It allows in particular mesh refinement strategies so that very relevant simulations can be reached (as the falling droplet with very high density ratios, see for example [38]. The current version of the code consider the additional terms in the Kazhikhov-Smagulov model.

Webpage : http://math.univ-lille1.fr/~simpaf/SITE-NS2DDV

Here is the self-assessment of the team effort following the grid provided by Inria (see : http://www.inria.fr/institut/organisation/instances/commission-d-evaluation): A1, SO3-up4, SM1, EM2, SDL1, DA1, CD4, MS4, TPM1.

5.3. RTcodes

Participants: Pauline Lafitte [correspondant (ECP)], Jean-François Coulombel [(CNRS & Univ. Nantes)], Christophe Besse [(Univ. Lille 1)], Thierry Goudon [(Inria)], Giovanni Samaey [(KU Leuven)].

Radiative Transfer, Radiative shocks, AP schemes

We have developed a set of numerical codes, written in Scilab, to compute the solutions of the system coupling the Euler equations to the radiation through energy exchanges, in the non equilibrium regime. This covers several situations in the hierarchy of asymptotic problems. The code treats the one-dimensional framework. In particular the code can be used to investigate radiative shocks profiles. The main advantage of our numerical codes is that they do not require any refinement near the singularities. The numerical tests show a very good agreement with the theoretical predictions. See reference [48].

Here is the self-assessment of the team effort following the grid provided by Inria (see : http://www.inria.fr/institut/organisation/instances/commission-d-evaluation): A2, SO3, SM2, EM1, SDL1.

5.4. FPcodes

Participants: Pauline Lafitte [correspondant (ECP)], Thierry Goudon [(Inria)], Benjamin Boutin [(Univ. Rennes)].

Fluid-Particles flows, Gravity driven flows, AP schemes

We have developed a numerical code, written in Scilab, to compute the solutions of the two-phase flows equations describing particles interacting with a fluid through friction forces. The code treats one-dimensional situation and is well adapted to describe gravity driven flows in either bubbling or flowing regimes. In particular, it can be used to describe the evolution of pollutants in the atmosphere. The numerical strategy, based on a asymptotic-based scheme, is described in details in [43].

Here is the self-assessment of the team effort following the grid provided by Inria (see : http://www.inria.fr/institut/organisation/instances/commission-d-evaluation): A2, SO3, SM2, EM1, SDL1.

5.5. CLAToolBox

Participants: Christophe Besse [correspondant (Univ. Lille 1)], Pauline Klein [Univ. Besançon].

Absorbant boundary conditions, Schrödinger equation

As a byproduct of the review paper [30], a user-friendly interface is offered [1] to trial and compare various numerical methods to solve the 1D Schrödinger equation with absorbant boundary conditions. We also mention [34] for a numerical investigation of blow-up phenomena in the nonlinear Schrödinger equation.

5.6. SPARCS

Participants: Christophe Besse [Univ. Lille 1], Thierry Goudon [correspondant (Inria)], Ingrid Lacroix-Violet [Univ. Lille 1].

Vlasov-Poisson system, Euler-Poisson system. Back-Trajectory method

SPARCS is the code developed by Thales Alenia Space for the simulation of the charge phenomena the spacecrafts are subject to. The current version of the code, according to the PhD thesis of O. Chanrion and M. Chane-Yook performed in collaboration with the team Caiman at Sophia Antipolis, is specialized to geostationary atmospheres. The model consists in the stationary Vlasov-Poisson system, but where instationary effects are taken into account with the boundary condition for the electric field. We participate, in particular through the post doc of N. Vauchelet, to the elaboration of an improved version of the code which includes parallization optimized procedures, the modelling of the natural difference of potential between different dielectric surfaces of the spacecraft, as well as the possible presence of devices emitting charged particles.

5.7. Code-Carmel3D

Participant: Emmanuel Creusé [correspondant (Univ. Lille 1)].

This numerical code, developed in collaboration between EDF R&D and Lille 1 University, is devoted to the electromagnetic fields computation by the use of finite element methods. This code allows in particular to perform nondestructive control by the use of Foucault currents in steam generator pipes, and should be soon coupled with the thermal simulation of Code-Aster. Code-Carmel3D uses the Salomé platform (mesh-generator and post-processing) and Open Turns (uncertainties computation). It will consequently allow to solve multi-physics problems, both for the temporal and harmonic formulations.

[1] http://math.univ-lille1.fr/~besse/site/recherche/logiciels/index.html

BACCHUS Team

5. Software and Platforms

5.1. AeroSol

Participants: Dragan Amenga-Mbengoué [Bacchus], Simon Delmas [Cagire], Damien Genet [Bacchus], Maxime Mogé [Cagire], Yann Moguen [Cagire], Francois Pellegrini [Bacchus], Vincent Perrier [Corresponding member], Francois Rué [Bacchus], 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.

This year some important features were added including : definition of CMake options for optimization and for using different compilers (GNU gcc, Intel icc, and IBM xlc) ; new element classes (lagrange and hierarchical orthogonal finite element basis for pyramids, Gauss Lagrange elements) ; implicit time integrators (backward Euler, Crank-Nicolson, and BDF from 2nd to 6th order) ; anisotropic diffusion models and (compressible) Navier-Stokes models ; debuggin by looging at memory traces with an interfacing with the PAPI library (tests have also been performed with VTUNE and TAU) ; improvements in schemes robustness and efficiency (Galerkin discretization of advection optimized by stocking most of the geometrical functions and finite elements computations, explicit and implicit version of the DG discretization of diffusion problems, implementation of Taylor-Galerkin stabilization and simplified SUPG stabilization) ; boundary conditions (time dependent, periodic, non reflecting) ; low Mach numerical fluxes for DG ; development of steady and unsteady tests related to all these new features.

5.2. COCA

Participants: Mario Ricchiuto [corresponding member], Gérard Vignoles, 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.

5.3. RealfluiDS

Participants: Dante de Santis, Gianluca Geraci, Pietro Marco Congedo, Rémi Abgrall [corresponding member].

`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 a whatever complex equation of state. Further developments concerning multiphase effects are under way.

5.4. 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 used in particular in GAMMA for their mesh adaptation developments, but also at EPFL (maths department), Dassault Aviation, Lemma (a french SME), 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/). More details can be found on http://www.math.u-bordeaux1.fr/~dobj/logiciels/mmg3d.php.

A new version of MMG3D is under development. The big novelty of this version is the modification of the surface triangulation. A. Froehly, ingenieer in the FUI Rodin, is working on this new version.

5.5. ORComp

Participants: Pietro Marco Congedo [Corresponding member], Rémi Abgrall, Dante de Santis, Maria-Giovanna Rodio.

The ORComp platform is a simulation tool permitting to design an ORC cycle. Starting from the solar radiation, this plateform 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 RealfluiDScode 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.

5.6. PaMPA

Participants: Cédric Lachat, François Pellegrini [Corresponding member], Cécile Dobrzynski, Hervé Guillard [PUMAS], Laurent Hascoët [Tropics].

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.

Following the PhD defense of Cédric Lachat last December, version 1.0 is about to be released publicly under the GPL license. This version 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).

5.7. RobUQ

Participants: Pietro Marco Congedo [Corresponding member], Rémi Abgrall, Gianluca Geraci, Maria Giovanna Rodio, Kunkun Tang, Julie Tryoen.

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.

5.8. Scotch

Participants: François Pellegrini [corresponding member], Sébastien Fourestier.

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

Scotch (http://www.labri.fr/~pelegrin/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 valuated 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, corresponding to the 20th anniversary of Scotch, 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.

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).

5.9. SLOWS

Participants: Mario Ricchiuto [corresponding member], Andrea Filippini.

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 MUMPSlibrary.

5.10. 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. Software and Platforms

5.1. AeroSol

Participants: Dragan Amenga-Mbengoué [Bacchus], Simon Delmas [Cagire], Damien Genet [Bacchus], Maxime Mogé [Cagire], Yann Moguen [Cagire], Francois Pellegrini [Bacchus], Vincent Perrier [Cagire, correspondant], Francois Rué [Bacchus], 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 PaMPAare 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.

This year, Simon Delmas and Yann Moguen were recruited within the team Cagire. Their respective development, low Mach solver for compressible flows and turbulence injection boundary conditions are performed in the library Aerosol. At the end of 2012, Aerosol had the following features

- **development environment** use of CMake for compilation, 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.
- **In/Out** link with the XML library for handling with parameter files. Reader for GMSH, and writer on the VTK-ASCII legacy format (cell and point centered). Parallel GMSH reader, XML paraview files on unstructured meshes (vtu) and parallel XML based files (pvtu).
- **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 and hexaedra. Finite element basis that are interpolation basis on Gauss-Legendre points for lines, quadrangles, and hexaedra.
- **Geometry** elementary geometrical functions for first order lines, triangles, quadrangles, prisms, tetrahedra and hexaedra.
- **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.
- **Linear Solvers** link with the external linear solver UMFPack, PETSc and MUMPS. Internal solver for diagonal matrices.
- **Memory handling** discontinuous and continuous, sequential and parallel discretizations based on PaMPA for generic 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.
- **Numerical schemes** continuous Galerkin method for the Laplace problem (up to fifth order) with non consistent time iteration or with direct matrix inversion. Discontinuous Galerkin methods for hyperbolic systems. SUPG and Residual disribution schemes.
- **Numerical fluxes** centered fluxes, exact Godunov' flux for linear hyperbolic systems, and Lax-Friedrich flux.
- **Parallel computing** Mesh redistribution, computation of Overlap with PaMPA. collective asynchronous communications (PaMPA based). Tests on the cluster Avakas from MCIA, and on Mésocentre de Marseille, and PlaFRIM.
- **C++/Fortran interface** Tests for binding fortran with C++.

This year, the following features were added

- **development environment** Definition of CMake options for optimization and for using different compilers. Currently, the following compilers have been tested: GNU gcc, Intel icc, and IBM xlc. Aerosol can now be linked with HDF5, PAPI, and can use different BLAS implementations like eigen or MKL.
- **In/Out** Point centered visualization for discontinuous approximations. XML binary output for Paraview was added. The link with HDF5 was added for parallel IO for defining XDMF format. A geometrical pre-partitioning was developped for reducing the size ofthe parallel graph in the parallel mesh reading.
- **Pyramids** Mesh reader, Lagrange and hierarchical orthogonal finite element basis were added for pyramids. Geometrical functions for linear pyramids were also added.
- **Finite element** Gauss Lagrange finite element basis (order 1 and 2) for triangles.
- **Time iteration** the following implicit integration schemes were added: backward Euler, Crank-Nicolson, and BDF from 2nd to 6th order.
- **Linear Solvers** Interface with PETSc was tested on a parallel environment. An in house block diagonal solver was developped.
- **Memory handling** Aerosol can now work on hybrid meshes.
- **Models** the generic model interface supports now diffusive models. Anisotropic diffusion and (compressible) Navier-Stokes models were added.
- **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.
- **Parallel computing** Tests were performed on the clusters Pyrene (Université de Pau), poincaré (Maison de la Simulation), and on the Tier-1 cluster Turing (IDRIS).
- **Numerical schemes** The DG discretization of advection problems was optimized by stocking most of the geometrical functions and finite elements computations , and by using BLAS implementations for linear computations. Implicit versions of the DG discretization of advection problems. Development of explicit and implicit version of the DG discretization of diffusion problems. Time dependent boundary conditions, periodic boundary conditions, non reflecting boundary conditions. Development of low Mach numerical fluxes, and development of stationary and unstationary tests for this kind of problem.

DEFI Project-Team

5. 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.

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, 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/~riahi

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

5.3.2. Conformal mapping method

Participant: Houssem 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).

5.4. Sampling methods for inverse problems

5.4.1. Samplings-2d

Participant: Houssem 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/Middelware: Linux
- Programming language: Fortran
- Documentation: fichier

5.4.2. Samplings-3d

Participant: Houssem 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: Houssem 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.

5.4.4. Factorization Method for EIT

Participant: Giovanni Migliorati.

We developed a numerical code that implements the Factorization Method applied to the Continuous Model, in the framework of Electrical Impedance Tomography featuring an inhomogeneous background. The numerical scheme relies on the approximation by the finite element method of the solution to the dipole-like Neumann boundary-value problem. Two regularization techniques are implemented, i.e. the Tikhonov regularization embedding Morozov principle, and the classical Picard Criterion. The code now supports the case of piecewise-wise constant by unknown background.

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.

GAMMA3 Project-Team

3. 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)

MC2 Project-Team

5. 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: Modélization 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-locomation 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 progess

5.4. S-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
  - Electropermeabilization: 2D finite difference scheme, parallelized with PETSc to simulate the electropermeablization of biological cells

MOKAPLAN Exploratory Action

5. Software and Platforms

5.1. CFD based MK solvers

5.1.1. Platforms

The core of the ALG2 algorithm [43] for the CFD formulation of the Optimal Mass Transportation problem and many of its generalization is a Poisson solver. Then each problem calls for different but simple modifications the point wise minimization of a given Lagrangian function. We have written such a FreeFem ALG2 platform and are plan to implement a parallel version on Rocquencourt Inria cluster.

5.2. MA based Optimal Mass Transportation solvers

5.2.1. Platforms

Monotone discretisations of the Monge-Ampère operator (the determinant of a Hessian function) is the core of Monge-Ampère Optimal Mass Transportation solvers but is also a useful tool for convexity constraints in infinite dimensional optimization and JKO gradient flows. We are implementing in F90 and comparing several monotone schemes. These modules could be reused in different applications.

NACHOS Project-Team

5. Software and Platforms

5.1. MAXW-DGTD

Participants: Stéphane Lanteri [correspondant], Loula Fezoui, Ludovic Moya, 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 [16]. Within each element of the mesh, the components of the electromagnetic field are approximated by a 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 muticore 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/Middelware: Linux
- Required library or software: MPI (Message Passing Interface), CUDA
- Programming language: Fortran 77/95

5.2. MAXW-DGFD

Participants: Stéphane Lanteri [correspondant], 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 a 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 paralleization 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/Middelware: Linux
- Required library or software: MPI (Message Passing Interface)
- Programming language: Fortran 77/95

5.3. SISMO-DGTD

Participants: Nathalie Glinsky [correspondant], Stéphane Lanteri.

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 [6]. Within each element of the mesh, the components of the electromagnetic field are approximated by a 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 paralleization 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/Middelware: Linux
- Required library or software: MPI (Message Passing Interface)
- Programming language: Fortran 77/95

5.4. NUM3SIS

Participants: Nora Aissiouene, Thibaud Kloczko [SED [1] team], Régis Duvigneau [OPALE project-team], Thibaud Kloczko [SED team], Stéphane Lanteri, Julien Wintz [SED team].

NUM3SIS http://num3sis.inria.fr is a modular platform devoted to scientific computing and numerical simulation. It is designed to handle complex multidisciplinary simulations involving several fields such as Computational Fluid Dynamics (CFD), Computational Structural Mechanic (CSM) and Computational ElectroMagnetics (CEM). In this context, the platform provides a comprehensive framework for engineers and researchers that speeds up implementation of new models and algorithms. From a software engineering point of view, num3sis specializes and extends some layers of the meta-platform dtk, especially its core and composition layers. The core layer enables the user to define generic concepts used for numerical simulation such as mesh or finite-volume schemes which are then implemented through a set of plugins. The composition layer provides a visual programming framework that wraps these concepts inside graphical items, nodes. These nodes can then be connected to each other to define data flows (or compositions) corresponding to the solution of scientific problems. NUM3SIS provides a highly flexible, re-usable and efficient approach to develop new computational scenarios and takes advantage of existing tools. The team participates to the development of the NUM3SIS platform through the adaptation and integration of the MAXW-DGTD simulation software. This work is being carried out with the support of two engineers in the framework of an ADT (Action de Développement Technologique) program.

5.5. Medical Image Extractor

Participants: Stéphane Lanteri, Julien Wintz [SED team].

[1] Service d'Experimentation et de Développement

Medical Image Extractor http://num3sis.inria.fr/software/apps/extractor provides functionalities needed to extract meshes from labeled MR or PET-CT medical images. It puts the emphasis on consistence, by generating both boundary surfaces, and volume meshes for each label (ideally identifying a tissue) of the input image, using the very same tetreahedrization. As this process requires user interaction, images and meshes are visualized together with tools allowing navigation and both easy and accurate refinement of the generated meshes, that can then be exported to serve as an input for other tools, within a multidisciplinar software toolchain. Using both DTK http://dtk.inria.fr and NUM3SIS SDKs, Medical Image Extractor comes within NUM3SIS'framework. Using cutting edge research algorithms developped by different teams at Inria, spread among different research topics, namely, visualization algorithms from medical image processing, meshing algorithms from algorithmic geometry, it illustrates the possibility to bridge the gap between software that come from different communities, in an innovative and highly non invasive development fashion.

NANO-D Team

4. 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. Software and Platforms

5.1. NUM3SIS

Participants: Régis Duvigneau [correspondant], Nora Aïssiouene, Babett Lekouta.

The Opale project-team has initiated a few years ago the development of NUM3SIS (http://num3sis.inria.fr), which is 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 programing 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 two engineers 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 appplications tasks involved on the various clusters. This work was Laurentiu Trifan's PhD thesis, defended in October 2013 [37]. (See Fig. 1 .)

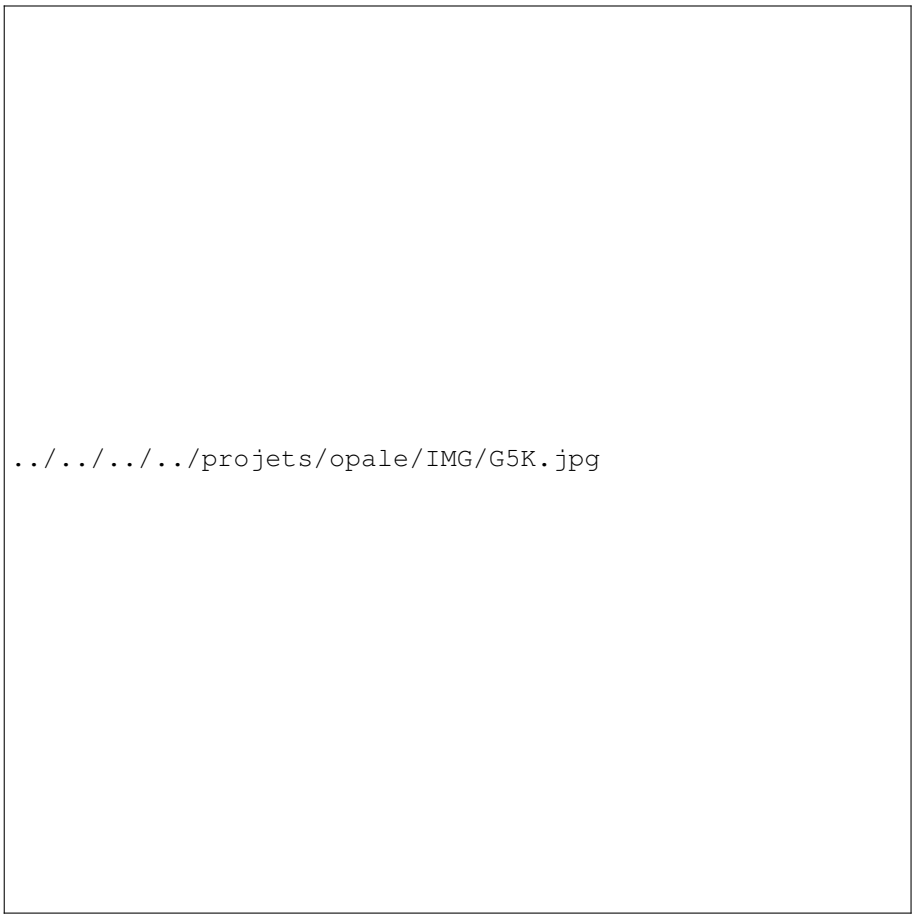


Figure 1. Testcase deployment on the Grid5000 infrastructure.

POEMS Project-Team

5. Software and Platforms

5.1. Software

5.1.1. Introduction

We are led to develop two types of softwares. The first one is prototype softwares : various softwares are developed in the framework of specific research contracts (and sometimes sold to the contractor) or during PhD theses. They may be also contributions to already existing softwares developed by other institutions such as CEA, ONERA or EDF. The second category is an advanced software which are intended to be developed, enriched and maintained over longer periods. Such software is devoted to help us for our own research and/or promote our research. We have chosen to present here our advanced software.

5.1.2. XLiFE++

Participants: Eric Lunéville, Nicolas Kielbasiewicz, Colin Chambeyron, Manh Ha Nguyen.

XLiFE++ is a new Finite Element library in C++ based on philosophy of the previous library MELINA in Fortran but with new capabilities (boundary elements and 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.

In 2012, as a reminder, all development tools were set up and all fundamental and major libraries were done. In 2013, developments have sped up. The Finite Elements, the Spectral Elements and the Boundary Elements computation cores have been implemented and are currently under testing. In addition to the implementation of direct and iterative solvers, an internal eigen solver is operational and coupled to external solver libraries (Arpack++, Umfpack, ...).

As far as inputs/outputs are concerned, XLiFE++ allows to export a solution to the visualization tool PARAVIEW and to read mesh files from GMSH, MELINA and PARAVIEW (vtk). Furthermore, mesh tools have been enriched and a C++ interface to the mesh tool GMSH is under development. XLIFE++ can now solve the Helmholtz equation with Neumann boundary conditions in any mesh. A first version of the library should be published soon.

APICS Project-Team

5. 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 $\overline{H}^{2^{m\times l}}$, 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 rather high so that the choice of an initial point for the optimization can play a crucial role. 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 and Brussels. 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 provides satisfactory results in the source recovery problem and 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 provides no guarantee to obtain a single realization that satisfies the prescribed constraints. The software Dedale-HF (see Section 5.4), which is the successor of RGC, solves with guarantees 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), a rational approximation engine developed within the team. 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 strong 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 airborn systems and a license agreement has been recently negotiated with TAS-Espagna. 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).

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 users of the filtering community. For a given 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. problem of the user, *i.e.* the one corresponding to user-specified filter characteristics. The reference files are computed off-line using Groebner basis techniques or numerical techniques based on the exploration of a monodromy group. The use of such a continuation technique combined with an efficient implementation of the integrator produces a drastic reduction, by a factor of 20, of 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 of this software has been sold end of 2011, to TAS-Espagna, in order for it to tune filters with topologies having multiple solutions. The use of Dedale-HF is here coupled with that of 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, and 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 [10].

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 [2] 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 [8] and Section 4.2 , it makes use of the software RARL2 (Section 5.1) for the rational approximation step in plane sections. The data transmission preliminary step ("cortical mapping") is solved using boundary element methods through the software OpenMEEG (its CorticalMapping features) developed by the Athena Team (see http://www-sop.inria.fr/athena/software/OpenMEEG/). A new release of FindSources3D is now available, which is being demonstrated and distributed to the medical team we maintain contact with (hosp. la Timone, Marseille). A further release is currently under development, due to the strong interest for this software by the German firm BESA GmbH (see http://www.besa.de/), involved in EEG software for research and clinical applications, and a deeper collaboration with this company has been started this year. Figure 4 shows the good results of a two sources distribution recovered by FindSources3D from potential values at electrodes on a sphere (scalp) generated by BESA's simulator, and then back to a more realistic head geometry. There, the achieved localization error is small enough, and FindSources3D provides suitable initial guess to heavier dedicated recovery tools, along with an estimation of the number of sources which may be incorporated to the software as an additional functionality (at the moment, the user is still involved in this estimation). Taking into account several time instants will be considered next.

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).

[2] CeCILL license, APP version 2.0 (2012): IDDN.FR.001.45009.001.S.A.2009.000.10000

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

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.

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. It also 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. 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, intercations, 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 a 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. Optimization

Participant: Claude Lemaréchal.

Essentially two possibilities exist to distribute our optimization software: library programs (say Modulopt codes), communicated either freely or not, depending on what they are used for, and on the other hand specific software, developed for a given application.

The following optimization codes have been developed in the framework of the former Promath project. They are generally available at http://www-rocq.inria.fr/~gilbert/modulopt/; M1QN3 is also distributed under GPL.

5.2.1. Code M1QN3

Optimization without constraints for problems with many variables ($n \geq 10^3$, has been used for $n = 10^6$). Technically, uses a limited-memory BFGS algorithm with Wolfe's line-search (see Chap. 4 of [3] for the terminology).

5.2.2. Code M2QN1

Optimization with simple bound-constraints for (small) problems: D is a parallelotope in R^n. Uses BFGS with Wolfe's line-search and active-set strategy.

5.2.3. Code N1CV2

Minimization without constraints of a convex nonsmooth function by a proximal bundle method (Chap. XV of [10], Chap. 9 of [3]).

5.2.4. Modulopt

In addition to codes such as above, the Modulopt library contains application problems, synthetic or from the real world. It is a field for experimentation, functioning both ways: to assess a new algorithm on a set of test-problems, or to select among several codes one best suited to a given problem.

5.3. Simulation of fibrous materials subject to frictional contact

5.3.1. 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 [8]). 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. 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.

5.3.2. Cloc: super-space clothoids

Participants: Romain Casati, Florence Bertails-Descoubes.

This software implements the super-space clothoid model published this year in [25]. This model consists of a new dynamic rod primitive relying upon high-order elements with a linear curvature (clothoidal arcs). The source code of this software is distributed from our webpages from December 2013, based on a dual licensing policy: a free GPLv.3 license, mainly dedicated to academics; and a commercial license, mainly dedicated to industry.

5.3.3. APPROCHE: APPROximate Curves with HElices

Participants: Alexandre Derouet-Jourdan, Florence Bertails-Descoubes.

APPROCHE is a software that implements the 3d floating tangents algorithm published. The algorithm takes as input a set of curves, either represented as splines or sequences of points, and fits each curve to a C^1-smooth piecewise helix. This software has been transferred to L'Oréal in December 2013 and some source code will be made freely available to academics under the GPLv.3 licence.

COMMANDS Project-Team

4. Software and Platforms

4.1. Bocop

Participants: Pierre Martinon [corresponding author], Daphné Giorgi, Joseph Frédéric Bonnans.

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, and then Daphné Giorgi since October 2012. The first prototype was released at the end of 2011, Bocop is currently at version 1.1.4 and has been downloaded more than 700 times. The software was first succesfully 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 ([30], [27]), swimming micro-robots ([39]), and quantum control for medical imaging ([25]). Bocop was also featured during our participation in the Imatch "Optimisation and Control" in october, which resulted in a contract with the startup Safety Line (aeronautics).

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

Figure 1. BOCOP

4.2. CollAv

Participants: Hasnaa Zidani [corresponding author], Olivier Bokanowski, Anna Désilles.

This software simulates the evolution of controlled dynamical systems (possibly under uncertainties). The numerical algorithm here is based on HJB or viability approaches, and allows the design of optimal planning strategies (according to a criterion determined by the user: time, energy, ...). It also provides conflict resolution and avoidance of collisions with fixed or moving obstacles. So far, the software is used in collaboration with DGA for avoidance collision of UaVs, and by Volkswagen in some studies related to collision avoidance of cars.

4.3. OCOPHyS

Participant: Hasnaa Zidani [corresponding author].

This is a software for optimisation-based controller design for operating in different regimes or modes of operation. The software can be used, for example, to determine the optimal management for hybrid vehicles or hybrid engines with multiple energy sources. However, the methods used in software are still quite general and can be used in many applications.

4.4. BiNoPe-HJ

Participants: Hasnaa Zidani [corresponding author], Olivier Bokanowski, Anna Désilles.

Web page: http://www.ensta-paristech.fr/ zidani/BiNoPe-HJ

This project aims at developping sequential and parallel MPI/openMP C++ solvers for the approximation of Hamilton-Jacobi-Bellman (HJB) equations in a d-dimensional space. The main goal is to provide an HJB solvers that can work in dimension d (limited by the machine's capacity). The solver outputs can be visualized with Matlab or Paraview (via VTK files).

The development of the HJB Solver has been initiated under a partnership between COMMANDS and the SME HPC-project in the period between December 2009 to November 2011. Currently, it is still maintained and improved by COMMANDS.

In 2012, two versions were released:

- HJB-SEQUENTIAL-REF: sequential version that can run on any machine
- HJB-PARALLEL-REF: parallel version that can run only on multi-core architectures.

4.5. Shoot

Participant: Pierre Martinon [corresponding author].

Shoot was designed for the resolution of optimal control problems via indirect methods (necessary conditions, Pontryagin's Maximum Principle). Such methods transform the original problem into finding a zero of a certain shooting function. The package offers several choices of integrators and solvers, and can handle control discontinuities. Features also include the use of variational equations to compute the Jacobian of the shooting function, as well as homotopy and grid shooting techniques for easier initialization. Shoot is an academic software, and was used during several research contracts with the CNES (french space agency).

CORIDA Project-Team

4. Software and Platforms

4.1. Simulation of viscous fluid-structure interactions

Participants: Takeo Takahashi [correspondant], Jean-François Scheid, Jérôme Lohéac.

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 developped by ALICE.

- Version: v0.5
- Programming language: MATLABc++

4.2. Fish locomotion in perfect fluids with potential flow

Participants: Alexandre Munnier [correspondant], Marc Fuentes, 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++

4.3. SUSHI3D : SimUlations of Structures in Hydrodynamic Interactions

Participants: Marc Fuentes, Jean-François Scheid, Jérémy Sinoir, Takéo Takahashi, Rhaleb Zayer.

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++

DISCO Project-Team

5. Software and Platforms

5.1. OreModules

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

The OREMODULES package [92], based on the commercial Maple package Ore_algebra [93], 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 [100], [102] 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) [109], [108], [91] 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/.

A Mathematica version of the OREMODULES package is in development. It is being developed by Maris Tõnso (Institute of Cybernetics, University of Tallinn), Thomas Cluzeau (ENSIL, University of Limoges) and A. Quadrat within the PHC Parrot project CASCAC. The Mathematica version of the OREMODULES package is based on the implementation of Gröbner bases over Ore algebras available in the Mathematica HolonomicFunctions package developed by Christoph Koutschan.

5.2. Stafford

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

The STAFFORD package of OREMODULES [92] contains an implementation of two constructive versions of Stafford's famous but difficult theorem [124] 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 [119] 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 [124] have recently been made constructive in [121] (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: Alban Quadrat [correspondent], Anna Fabiańska [Univ. Aachen].

The QUILLEN-SUSLIN package [96] contains an implementation of the famous Quillen-Suslin theorem [123], [125]. 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 [96] (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: Alban Quadrat [correspondent], Thomas Cluzeau [ENSIL, Univ. Limoges].

The OREMORPHISMS package [95] of OREMODULES [91] 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://www-sop.inria.fr/members/Alban.Quadrat/OreMorphisms/index.html.

A Mathematica version of the OREMORPHIMS package is in development. It is being developed by Maris Tõnso (Institute of Cybernetics, University of Tallinn), Thomas Cluzeau (ENSIL, University of Limoges) and Alban Quadrat within the PHC Parrot project CASCAC. The Mathematica version of the OREMORPHIMS package is based on the implementation of Gröbner bases over Ore algebras available in the Mathematica HolonomicFunctions package developed by Christoph Koutschan.

5.5. JanetMorphisms

Participants: Alban Quadrat [correspondent], Thomas Cluzeau [ENSIL, Univ. Limoges], Daniel Robertz [Univ. Aachen].

The JANETMORPHISMS package is dedicated to a new mathematic approach to quasilinear systems of partial differential equations (e.g., Burger's equation, shalow water equations, Euler equations of a compressible fluid) based on algebraic analysis and differential algebra techniques [90]. This package computes symmetries, first integrals of motion, conservation laws, study Riemann invariants... The JANETMORPHISMS package is based on the `Janet` package (http://wwwb.math.rwth-aachen.de/Janet/).

5.6. PurityFiltration

Participant: Alban Quadrat [correspondent].

The PURITYFILTRATION package, built upon the OREMODULES package, is an implementation of a new effective algorithm obtained in [30] which computes the purity/grade filtration [86], [87] of linear functional systems (e.g., partial differential systems, differential time-delay systems, difference systems) and equivalent block-triangular matrices. See Section 6.1 . 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. This package will soon be available.

5.7. AbelianSystems

Participants: Alban Quadrat [correspondent], Mohamed Barakat [Univ. Kaiserslautern].

The ABELIANSYSTEMS package is an implementation of an algorithm developed in [30] for the computation of the purity/grade filtration [86], [87] in the powerful `homalg` package of GAP 4 dedicated to constructive homological algebra methods, and developed by Barakat (University of Kaiserslautern) and his collaborators (http://homalg.math.rwth-aachen.de/). This package both supersedes the existing PURITYFILTRATION package which uses the non-efficient Maple Gröbner basis computation (see Section 5.6), and the original `homalg` procedure which computes purity filtration by means of time-consuming spectral sequences. Using the `homalg` package philosophy, the ABELIANSYSTEMS package can be used for the computation of the purity filtration of objects in different constructive abelian categories such as coherent sheaves over projective schemes as demonstrated in the `homag` package called `Sheaves` (see http://homalg.math.rwth-aachen.de/).

5.8. SystemTheory

Participants: Alban Quadrat [correspondent], Thomas Cluzeau [ENSIL, Univ. Limoges], Markus Lange-Hegermann [Univ. Aachen], Mohamed Barakat [Univ. Kaiserslautern].

The SYSTEMTHEORY package is a `homalg` based package dedicated to mathematical systems. This package, still in development, will include the algorithms developed in the OREMODULES and OREMORPHISMS packages. It currently contains an implementation of the OREMORPHISMS procedures which handle the decomposition problem aiming at decomposing a module/system into direct sums of submodules/subsystems, and Serre's reduction problem aiming at finding an equivalent system defined by fewer unknowns and fewer equations.

5.9. YALTA

Participants: David Avanessoff, Catherine Bonnet [correspondent], Hugo Cavalera, André R. Fioravanti [UNICAMP], Jim Pioche.

The YALTA toolbox is 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, [88] and [97]) and on classical continuation methods exploiting the particularities of the problem [98], [99]. For classical delay systems, a Pade2 approximation scheme is available as well as a finite-dimensional approximation of the system.

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

GECO Project-Team

5. 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

4. Software and Platforms

4.1. COSMAD

Participants: Michael Doehler, Laurent Mevel.

With the help of former engineers, I4S team has developed and maintained a Scilab toolbox devoted to modal analysis and vibration monitoring of structures or machines subjected to known or ambient (unknown) excitation. This software (COSMAD 3.64) has been registered at the APP under the number

IDDN.FR.001.210011.002.S.A.2003.000.20700

A list of test-cases (simulators, laboratory test-beds, real structures) for which COSMAD has been used is available on I4S website. The problem is to identify the eigenstructure (eigenvalues and observed components of the associated eigenvectors) of the state transition matrix of a linear dynamical system, using only the observation of some measured outputs summarized into a sequence of covariance matrices corresponding to successive time shifts. Other services are

- *Output-only and Input/Ouptut subspace-based identification*,
- *Automated on-line identification package*,
- *Subspace-based identification through moving sensors data fusion*,
- *Damage detection and monitoring*,
- *Damage localization*,

The modules have been tested by different partners, especially the French industrial partners, EADS, Dassault and Sopemea, within the FLITE2 project, by partners from the past CONSTRUCTIF project, and within the framework of bilateral contracts with SNECMA and SVS.

Based on intensive internal evaluation of the toolbox, on both simulated and real data sets, EADS Space Transportation and CNES have been investigating how to use the toolbox for the exploitation of the Ariane 5 flight data sets.

This Scilabtoolbox continues to play the role of a programming and development environment for all our newly designed algorithms. Moreover, offering a *maintained* Scilab platform turns out to be a crucial factor in convincing industrial partners to undertake joint investigations with us. Just recently, SNECMA funded development for the Cosmad toolbox in 2010.

4.2. PEGASE

Participants: Vincent Le Cam, Mathieu Le Pen, Laurent Mevel.

We have developed a generic wireless platform that can be considered as the a result of redundant needs in wireless monitoring especially applied to civil engineering monitoring applications. This platform includes software and hardware bricks and aims at being generic by its native implementation of sober components, the worldwide TCP/IP protocol (802.11g), a signal processor, a small GPS receiver, and a micro embedded operating system (uClinux).

Since 2009, this platform -named PEGASE - is subject of an industrial transfer that has generated some tens of indivudual sales. A set of pluggable boards (that integrate the application specific sensing operation) offers a ready-to-use panel of wireless sensing solutions for developing specific applications as well as they can be seen as prototyping boards for further electronic developments.

As PEGASE platform reached a mature level of dissemination, LCPC recent efforts are now leaded with the goal of improving its wireless capacities. Those works concern energy saving while keeping a high level of embedded processing, of sampling rate or time-synchronization.

As software layers are mainly written in standard C language under Linux OS, those pragmatic solutions could easily be re-used by even radically different systems. The focus will specifically be pointed on: an algorithm that allows PEGASE wireless boards to be synchronized up to some uS using a GPS technique while keeping the GPS receiver OFF most of the time; a description of how the use of an operating system such as uClinux allows a full and remotely update of wireless sensors; the hardware and software strategies that have been developed to make PEGASE fully autonomous using solar cells.

The main characteristics of PEGASE feature are the following:

- Use of TCP/IP/WiFi as the wireless protocol: reliable, low-cost, scalable (IP is the worldwide protocol). Turned OFF when PEGASE doesn't communicate.
- Use of the Analog Device low-power Blackfin BF537 as core processor (Digital Signal Processor): 16 bits processor able of complex operations.
- Implementation of a small and low-power GPS receiver to ensure localization and, first of all, absolute time synchronization up to few μS GMT.
- uClinux as the embedded operating system: allows high level of abstraction while PEGASE algorithms are then programmed using standard ANSI C language.

Since its first version on january 2008, PEGASE has been used in various configurations where its properties fitted specific needs. Since a third-party partner (A3IP company) has been licensed by LCPC, PEGASE has been sold in hundreds of specimens and implemented in various configurations. This dissemination proved the capacity of wireless systems to really answer a large spectrum of applications. Developments in progress have the goal to increase this panoply. Even if uClinux and WiFi integration could be considered as *heavy*, the result is a great ability for developers or customers to achieve their own applications. The genericity of C language and the worldwide IP protocol make them ubiquitous. A quite expert job has been leaded to develop specific embedded drivers under uClinux OS in order to get specific behaviors for time synchronization, quartz drift auto-training and correction. This specific and dynamic correction takes temperature effects into account and the result is an absolute time synchronisation better that 4 μS. Even if technologies evolve (components, processor, batteries...), generic principle could be extracted independently from technological choices. Those main principles are: daughter/mother boards, Linux integration, a ready to use c-object library, a boost circuit linked to a MPPT algorithm, GPS synchronization and quartz correction. Most of the improvements can be reused and applied to other wireless platforms even using drastically different electronic implementations.

m Porting of subspace modal analysis algorithms is currently under way on the PEGASE platform.

Maxplus Project-Team

5. 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 [65], [135]. 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 [65], [135]. 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 [84]. 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 [98]), 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 [84]. Several internships allowed us to implement in Scilab, C or C++, and to test such algorithms (see the work of Vishesh Dhingra [98]), 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 §6.2.1 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 [96]), 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 [63]).

TPLib est aujourd'hui utilisé dans le logiciel Polymake [116], développé à la Technische Universität Darmstadt (Allemagne). Ce dernier logiciel constitue une boite 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 §6.5.4). De même, une interface à la bibliothèque de domaines abstraits numériques APRON [128] 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 §6.2.1 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 [96]), 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 [63]).

TPLib is now used in the software Polymake [116], developed in Technische Universität Darmstadt (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 §6.5.4). An interface to the numerical abstract domain APRON [128] is also under development.

MCTAO Project-Team

5. Software and Platforms

5.1. Hampath

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

Hampath is a software developped to solve optimal control problems but also to study Hamiltonian flow. It has been developped 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. 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, F. Morbidi.

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. NeCSCar

Participants: C. Canudas de Wit [contact person], J. Dumon, V. Ciarla.

NeCSCar is an electrical vehicle (scale 1:3) used as an experimental platform to study new control architectures. The vehicle is designed to be remotely tele-operated from our active steering-wheel platform, ant it will be equipped of a 3D vision system to provide the operator with stereo vision capabilities. Bilateral teleoperation can be performed using wheel contact torque measurements, fed back for force deflexion; wireless connection allows us to test coding algorithms, resource sharing, and robustness against transmission delays.

NeCSCar has been recently used for simulation tests in the framework of the VolHand project, a multidisciplinary project with the goal to develop a new generation of electronic power assistance steering (EPAS) systems for disabled people.

5.3. 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. 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.

CLASSIC Project-Team (section vide)

DOLPHIN Project-Team

5. Software and Platforms

5.1. ParadisEO

Participants: Clive Canape, Laetitia Jourdan, Arnaud Liefooghe, Nouredine Melab, Alexandre Quemy, El-Ghazali Talbi [correspondent], Sébastien Verel.

ParadisEO (PARallel and DIStributed Evolving Objects) is a C++ white-box object-oriented framework dedicated to the flexible design of metaheuristics. See web site http://paradiseo.gforge.inria.fr. Based on EO, a template-based ANSI-C++ compliant evolutionary computation library, it is composed of five modules:

- Paradiseo-EO provides tools for the development of population-based metaheuristic (evolutionary and genetic algorithm, genetic programming, particle swarm optimization, etc.)
- Paradiseo-MO provides tools for the development of single solution-based metaheuristics (hill-climbing, tabu search, simulated annealing, iterative local search, variable neighborhood search, incremental evaluation, partial neighborhood, etc.)
- Paradiseo-MOEO provides tools for the design of multi-objective metaheuristics (MO fitness assignment, MO diversity preservation, elitism, performance indicators, easy-to-use state-of-the-art algorithms, etc)
- Paradiseo-PEO provides tools for the design of parallel and distributed metaheuristics (parallel evaluation, parallel evaluation function, island model)
- Paradiseo-SMP provides tools for the design of shared memory parallel metaheuristics (parallel evaluation, island model)

Furthermore, Paradiseo also introduces tools for the design of distributed, hybrid and cooperative models:

- High level hybrid metaheuristics: coevolutionary and relay models.
- Low level hybrid metaheuristics: coevolutionary and relay models.

The ParadisEO framework has been especially designed to best suit to the following objectives:

- Maximum design and code reuse: ParadisEO is based on a clear conceptual separation of the solution methods from the problems they are intended to solve. This separation confers to the user a maximum code and design reuse.
- Flexibility and adaptability: The fine-grained nature of the classes provided by the framework allows a higher flexibility compared to other frameworks.
- Utility: ParadisEO allows the user to cover a broad range of metaheuristics, problems, parallel distributed models, hybridization mechanisms, etc.
- Transparent and easy access to performance and robustness: As the optimization applications are often time-consuming the performance issue is crucial. Parallelism and distribution are two important ways to achieve high performance execution. ParadisEO is one of the rare frameworks that provide the most common parallel and distributed models. These models can be exploited in a transparent way, one has just to instantiate their associated provided classes.
- Portability: The implemented models are portable on distributed-memory machines as well as on shared-memory multiprocessors, as they use standard libraries such as MPI and std::threads. ParadisEO supports the most recent version of standard of the C++ programming, c++11.

This year a new module, Paradiseo-SMP, has been released. All the new features is managed via the Inria Gforge project http://paradiseo.gforge.inria.fr. The version 2.0 has been released in Septembre 2012.

5.1.1. Paradiseo-SMP: a new module for shared memory parallel

This year, we released a new module dedicated to shared memory parallel. This module improves the technical mechanisms of Paradiseo-PEO thanks a new software architecture and the new c+11 features.
Paradiseo-SMP implements parallel evaluation, dynamic heterogeneous island model, and their hybridization. The main features are:

- Dynamic Island Model: topology can be changed during the execution.
- Heterogeneous Islands: different kinds of population-based metaheuristics can communicate (evolutionary and genetic algorithm, particle swarm optimization, etc.).
- Island Model and master/slave model can be hybridized.

All these new features are developed in c++11.

5.1.2. New technical features

Regarding the technical aspects, the compatibility with dependencies taken into account is:

- c++11 features supporting.
- Checked compatibility with different operating systems.
- Reviewed and checked compatibility with new versions of the tools used (CMake, g++, clang, MinGW...).
- Unit and integration test of all additional components, and experiments on classical applications.

5.1.3. Contributions and documentations

Many investigations were made in this context in order to help users to manipulate the framework.

- New quick start guide is available.
- New tutorials:
  - Tutorials SMP.
  - Tutorials GPU.
- Updated implementation for classical problems.

Self-assessment of the team effort (software criteria: http://www.inria.fr/institut/organisation/instances/commission-d-evaluation)

(A-4-up5) Audience: 4 - Used in many universities for teaching and several companies.

(SO-4) Software Originality: 4 - ParadisEO aggregates the last results of the Dolphin team.

(SM-4) Software Maturity: 4 - Extensive documentation, strong software engineering and testing, regression testing, user feedback ...

(EM-2-up3) Evolution and Maintenance: 2 - Basic maintenance with persistent attention to users.

(SDL-4) Software Distribution and Licensing: 4 - CeCILL license, public source, Windows and Mac installer, Linux packages.

(OC) Own Contribution: (Design/Architecture) DA-4, (Coding/Debugging) CD-4, (Maintenance/Support) MS-4, (Team/Project Management) TPM-4

GEOSTAT Project-Team

5. Software and Platforms

5.1. Fluex

Participants: Denis Arrivault [correspondant], Rémi Paties, Hussein Yahia, Joel Sudre.

- Denis Arrivault has joined the team for a complete refoundation, rewriting, generalization and diffusion of the FluidExponents software, now called Fluex. FluidExponents is a software implementation of the MMF, presently written in Java, in a cooperative development mode on the Inria GForge, deposited at APP in 2010. 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. Fluex is in the process of being deposited in 2014. The Fluex project is carried on in 2014 by Rémi Paties. Contact: denis.arrivault@inria.fr, remi.paties@inria.fr
- A matlab code for the speech GCI detection algorithm has been made publicly available on the GeoStat website.

MISTIS Project-Team

5. Software and Platforms

5.1. The LOCUS software

Participants: Florence Forbes, Senan James Doyle.

Joint work with: 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, Senan James Doyle, Flor Vasseur.

Joint work with: 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 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 submitted to IEEE trans. on Medical Imaging reports the challenge results [62].

5.3. The PyHRF software

Participants: Christine Bakhous, Florence Forbes, Thomas Vincent.

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

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 under revision for Frontiers in Neuroinformatics gives more details on the current PyHRF functionalities.

MODAL Project-Team

5. Software and Platforms

5.1. Rmixmod package for mixed data

Participants: Christophe Biernacki, Serge Iovleff, Parmeet Bhatia.

MIXMOD (MIXture MODelling) is an important software for the mΘdal 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 2013, Parmeet Bhatia, under scientific supervision of Christophe Biernacki and Serge Iovleff, has developped possibility in Rmixmod to cluster simultaneously continuous and categorical data with the restrictive conditional independence assumption. It is an important first step towards the long term purpose of mΘdal to cluster heterogeneous (or mixed) data sets. It is a joint work with Florent Langrognet, Rémi Lebret, Gilles Celeux and Gérard Govaert.

5.2. RankClust package for rank 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. Available on CRAN.

5.3. 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. Available on CRAN.

5.4. Clustericat package for correlated categorical variable

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

`Clustericat` is a R package for model-based clustering of categorical data. In this package, the model CCM [41] where the main conditional dependencies between variables are taken into account is implemented. `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).

5.5. CorReg package for correlated variables in regression

Participants: Christophe Biernacki, Clément Théry.

Databases from the steel industry are often large (very long process with many parameters) and have strong correlations between variables. Some variables may be written directly in terms of other via physical models or related by definition. Moreover the process, which is specific to the type of finished product, conditions most of the process parameters and therefore induces strong correlations between variables. The main idea 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. This research is placed in a steel industry context (Arcelor-Mittal Dunkerque).

The associated CorReg package is now available on Rforge. It is a joint work with Gaétan Loridant.

5.6. AAM

Participant: Serge Iovleff.

A console based program written in C++ abd dedicated to the estimation of the Auto-Associative Models.

5.7. BlockCluster

Participants: Serge Iovleff, Parmeet Bathia.

Serge Iovleff, Parmeet Bathia
BlockCluster: An R package on top of the coclust C++ library.

5.8. HDPenReg

Participants: Quentin Grimonprez, Serge Iovleff.

R-package written in collaboration based on a C++ code dedicated to the estimation of regression model with l1-penalization.

5.9. STK++ release 0.5

Participant: Serge Iovleff.

New release including new functionalities for templated expression evaluation (similar to the Eigen library offer) and a new subproject offering tools for Clustering.

5.10. Funclustering package for R

Participants: Cristian Preda, Julien Jacques.

Funclustering package for R proposes a clustering tool for functional data. Multivariate curves can be also taken into account. Available on CRAN.

5.11. metaMA

metaMA is a specialised software for microarrays. It is a 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.

Guillemette Marot is the main contributor and the maintainer of this package.

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 makes it available to a wider community, as attested by the citations of publications related to the methods implemented in the software.

More information is available on the website http://cran.r-project.org/web/packages/metaMA/

5.12. metaRNASeq

Participant: Guillemette Marot.

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. Guillemette Marot and Andrea Rau are the main contributors of this package and Guillemette Marot is the maintainer of this package.

5.13. MPAGenomics

Participants: Quentin Grimonprez, Guillemette Marot, Alain Celisse.

MPAGenomics is a R package for multi-patients analysis of genomics markers. Its main contributor is Quentin Grimonprez. 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. It is available on the Inria forge and should be released on the R-forge in January.

5.14. SMVar

Participant: Guillemette Marot.

SMVar is a specialised software for microarrays. This R package implements the structural model for variances in order to detect differentially expressed genes from gene expression data. It performs gene expression differential analysis, based on a particular variance modelling. Its main competitor is the Bioconductor R package limma but limma assumes a common variance between the two groups to be compared while SMVar relaxes this assumption.

Guillemette Marot is the main contributor and the maintainer of this package.

More information is available on the website http://cran.r-project.org/web/packages/SMVar/index.html

REALOPT Project-Team

5. Software and Platforms

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

Participants: Romain Leguay [Software Engineer], Pierre Pesneau, Ruslan Sadykov, François Vanderbeck [correspondant].

BaPCod is a prototype code that solves Mixed Integer Programs (MIP) by application of a Dantzig-Wolfe reformulation technique. The reformulated problem is solved using a branch-and-price (column 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) the automation of the Dantzig-Wolfe reformulation process (the user defines a mixed integer programming problem in a pseudo modeling language, defining variables and constraints, identifying subproblems. He 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.
(ii) a default column generation procedure with standard initialization and stabilization [1], [59] [89] [88] [27] and
(iii) a default branching scheme that is generic to all applications [7],
(iv) default primal heuristics specially developed for use in a decomposition framework [64], [79], [90].
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 assocaited 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. 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 this 2010, MIXMOD has a proper graphical user interface (Version 1) which has been presented at the MIXMOD day in Lyon in December 2010. 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.

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, categorial and continuous datas with the variational Bayes algorithm or Gibbs sampler. Criteria ICL and BIC are used for selecting a relevant block clustering.

SequeL Project-Team

5. 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 Denseisen, 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/

SIERRA Project-Team

5. Software and Platforms

5.1. SPAMS (SPArse Modeling Software)

Participants: Jean-Paul Chieze [correspondent], Guillaume Obozinski [correspondent].

SPAMS (SPArse Modeling Software) is an optimization toolbox for solving various sparse estimation problems: dictionary learning and matrix factorization, solving sparse decomposition prob- lems, solving structured sparse decomposition problems. It is developped by Julien Mairal (former Willow PhD student, co-advised by F. Bach and J. Ponce), with the collaboration of Francis Bach (Inria), Jean Ponce (Ecole Normale Supérieure), Guillermo Sapiro (University of Minnesota), Rodolphe Jenatton (Inria) and Guillaume Obozinski (Inria). It is coded in C++ with a Matlab interface. This year, interfaces for R and Python have been developed by Jean-Paul Chieze (engineer Inria). Currently 650 downloads and between 1500 and 2000 page visits per month. See http://spams-devel.gforge.inria.fr/.

5.2. BCFWstruct

Participants: Simon Lacoste-Julien [correspondent], Mark Schmidt.

BCFWstruct is a Matlab implementation of the Block-Coordinate Frank-Wolfe solver for Structural SVMs. See the ICML 2013 paper with the same name.

Participants outside of Sierra: Martin Jaggi (Centre de Mathématiques Appliquées, Ecole Polytechnique); Patrick Pletscher (Machine Learning Laboratory, ETH Zurich)

5.3. 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.

5.4. 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. Software and Platforms

5.1. METIS

Participants: Olivier Teytaud [correspondent], Adrien Couëtoux, Jérémie Decock, Jean-Joseph Christophe.

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.

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) and outpeforming professional players in 7x7. However, the work in the UCT-SIG has now shifted to energy management.

5.3. CMA-ES: Covariance Matrix Adaptation Evolution Strategy

Participant: Nikolaus Hansen [correspondent].

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

The Covariance Matrix Adaptation Evolution Strategy (CMA-ES) [72] is considered to be state-of-the-art in continuous domain evolutionary computation [69], 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, Java, Matlab, Octave, Python, and Scilab including the latest variants of the algorithm.

Link: 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 developement and has been used for the GECCO 2009, 2010, 2012, and 2013 workshops on "Black Box Optimization Benchmarking" (BBOB) (see Section 6.1). 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

Participants: Balázs Kégl [correspondent], Djalel Benbouzid.

Keywords: Multi-class, Multi-label Classification.

The MultiBoost package [68] 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. Its implementation is developed within the FUI project TIMCO. The GO has been supported by an Inria ADT (Action de Développement Technologique) up to September 2013, and by University Paris Sud through the MRM (Moyens de Recherche Mutualisés) program. Stabilization through the VirtualData initiative is currently explored.

Link: http://grid-observatory.org

ALEA Project-Team

5. Software and Platforms

5.1. BiiPS software

BiiPS is a general software, developped by Adrien Todeschini, for Bayesian inference with interacting particle systems, a.k.a. sequential Monte Carlo (SMC) methods. It aims at popularizing the use of these methods to non-statistician researchers and students, thanks to its automated “black box" inference engine.

It borrows from the BUGS/JAGS software, widely used in Bayesian statistics, the statistical modeling with graphical models and the language associated with their descriptions.

Unlike MCMC methods used by BUGS/JAGS, SMC methods are more adapted to dynamic problems (tracking, signal filtering, etc).

A beta version of the software can be downloaded from the website of the BiiPS project. This software has been presented at the international workshop BayesComp in Kyoto, the international conference ISBA in Tokyo, the conference on Premières Rencontres R in Bordeaux, and the international workshop on efficient simulation in finance in Paris.

Adrien Todeschini participated to a session focused on Recent Developments in Software for MCMC (and SMC) (MCMSki IV, Fifth IMS-ISBA joint meeting MCMSki IV, Chamonix Mont-Blanc, France).

This invited panel features four leading researchers working on software development for Bayesian computation. Each panelist will highlight their particular software, including its history, development, and relative strengths and weaknesses. Looking forward, panelists will discuss and debate the future of Bayesian computation and software development, including challenges, opportunities and bottlenecks. Emphasis throughout will be on simplifying and automating the implementation of Monte Carlo methods, with an eye towards scalability to larger and more complex models and data.

ASPI Project-Team (section vide)

CQFD Project-Team

5. Software and Platforms

5.1. Package edrGraphicalTools

This R package gives graphical tools for selecting the number of slices and the dimension of the model in SIR and SAVE approaches. It also provides the estimation of the reduction dimension subspace and the non parametric estimation of the link function using smoothing techniques. The package is available via the link http://cran.r-project.org/web/packages/edrGraphicalTools/index.html.

5.2. Package ClustOfVar

This R package is dedicated to cluster analysis of a set of variables. Variables can be quantitative, qualitative or a mixture of both. A new version 0.8 of the package is available since december 2013 via the link http://cran.r-project.org/web/packages/ClustOfVar/index.html. This version provides now a function to predict values of new observations on the synthetic variables of the clusters. This new function was used for supervised classification and variable selection in gene expressions data [42].

5.3. Package PCAmixdata

This package is dedicated to factorial analysis and rotation of quantitative data, qualitative data, or mixed data. The PCAMIX method, proposed in this package includes the ordinary principal component analysis (PCA) and multiple correspondence analysis (MCA) as special cases. Orthogonal varimax rotation of the principal components of PCAMIX is also implemented in this package.This year, a new method has been developped for Multiple Factorial Analysis in case of mixtures of quantitative and qualitative variables within groups. It was implemented in the package and presented to the 2èmes Rencontres R in Lyon [44], and to the 45èmes Journées de Statistique in Toulouse [41].

MATHRISK Project-Team

5. Software and Platforms

5.1. PREMIA

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

Premia is a software designed for option pricing, hedging and financial model calibration. It is provided with it's 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/Middelware: 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.
- 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, 103 Mbyte of PDF files of documentation.
- interfaces : Nsp for Windows/Linux/Mac, Excel, binding Python, and a Web interface.
- Publications: [1], [68], [75], [83], [86], [55]

5.1.1. 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: CDS, 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**

   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.

5.1.2. Premia design

Premia has managed to grow up over a period of more than a dozen 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 will be made to continue and stabilize the development of PNL.

1. Development of the PNL. Here are the major 2013 contributions (by Jérôme Lelong):
   1. PNL relies on CMake for compiling.
   2. Add the sampling of new distributions: log-normal, inverse Gaussian, asymmetric double exponential distributions.
   3. Add the computation of eigenvalues and eigenvectors for complex matrices. Based on this new function, add the computation of the matrix logarithm for complex matrices.
   4. Add Newton's algorithm with Armijo line search.
   5. The top level PnlOjbect is modified to keep track of the number of references on an object to improve memory management in lists. This delicate change in the core of the library enabled us to speed codes based on lists by a great deal.
   6. Several other functions have also been added.
2. Premia

1. The compilation of Premia is now based on CMake which is a cross-platform building tool. It allows us to maintain a single building chain and to automatically generate Makefiles or a Visual project. This technology change significantly improves our ability to generate Windows versions.
2. Add support for PnlMatrix both in Premia VAR and in the Nsp toolbox.
3. A model size change in the Nsp GUI automatically propagates to all parameters thanks to the addition a *Return* callback in the GUI.
4. Some fixes in the core of Premia: several setters were broken.
5. Refactor the credit toolbox to simplify the number of products.
6. Scripts to generate new model templates have been significantly improved and reimplemented in Python.
7. Improve the generic functions `Get`, `FGet`, `Show`, `PrintVar` and `FScanVar` to enable all the models to use them. This led us to remove a lot of code.

5.1.3. Algorithms implemented in Premia in 2013

Premia 15 was delivered to the consortium members in March 2013. It contains the following new algorithms:

- **Interest Rate, Inflation, FX**
  - Inflation products with stochastic volatility and stochastic interest rates. S. Singor, L. Grzelak C.W.Oosterlee D.D.B. van Bragt.
  - On cross-currency models with stochastic volatility and correlated interest rates. L. Grzelak C.W.Oosterlee. *Applied Math. Finance, to appear.*
  - Repricing the Cross Smile: An Analytic Joint Density. P.Austing. *preprint 2011*
- **Energy and Commodities**
  - Efficient Pricing of Commodity Options with Early-Exercise under the Ornstein–Uhlenbeck process. C.W.Oosterlee. B.Zhang. *preprint 2011*
  - A finite dimensional approximation for pricing moving average options. M. Bernhart P.Tankov X. Warin, *to appear in SIAM Journal on Financial Mathematics.*
  - Pricing and hedging spread options. R. Carmona V.Durrleman. *SIAM Rev. 45 (2003), no. 4, 627—685.*
  - Closed form spread option valuation. P.Bjerksund G. Stensland *Quantitative Finance, 2011.*
  - A Fourier transform method for spread option pricing. T. R. Hurd and Z. Zhou. *SIAM Journal on Financial Mathematics. 1, 142-–157, 2010.*
  - Multi-asset spread option pricing and hedging *Quantitative Finance, Vol.10, No3, 305-324, 2010.*
  - Unspanned Stochastic Volatility and the Pricing of Commodity Derivatives. A.B.Trolle E.Schwartz. *Rev. Financ. Stud. (2009) 22(11): 4423-4461*
  - Pricing Commodity Swaptions in Multifactor Models. K.Larsson. *The Journal of Derivatives Winter 2011, Vol. 19, No. 2,32-44.*
- **Equity Derivatives**
  - Importance sampling and Statistical Romberg Method. M.B. Alaya A.Kebaier K.Hajji
  - New approximations in local volatility models. E. Gobet, A.Suleiman
  - Componentwise splitting methods for pricing American options under stochastic volatility. Ikonen, S.; Toivanen,J. *Int. J. Theor. Appl. Finance 10 (2007), no. 2, 331–361.*
  - ADI finite difference schemes for option pricing in the Heston model with correlation. K.J. in 't Hout and S. Foulon. *Int. J. Numer. Anal. Mod. 7, 303–320 (2010).*

- ADI schemes with Ikonen-Toivanen splitting for pricing American put options in the Heston model. T. Haentjens, K. in 't Hout and K. Volders. In: Numerical Analysis and Applied Mathematics, eds. T. E. Simos et. al., AIP Conf. Proc. 1281, 231-234 (2010).
- Pricing of Timer Options. C. Bernard Z. Cui. *Journal of Computational Finance, to appear*
- Efficient Simulation of the Double Heston Model. P.Gauthier D.Possamai.
- Greedy methods method for basket options. T.Lelievre J.I.Acevedo
- Pricing higher-dimensional American options using the stochastic grid method. C.W.Oosterlee S. Jain
- Calibration in the Heston model. L. Abbas Turki

The software Premia 15 has been registered at the APP (Agence pour la Protection des Programmes) with the reference IDDN.FR.001.190010.012.S.C.2001.000.31000.

REGULARITY Project-Team

5. Software and Platforms

5.1. FracLab

Participants: Paul Balança, 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 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.

Last year, we produced a major release of FracLab (version 2.1). This year, we corrected a number of bugs.

TOSCA Project-Team

5. Software and Platforms

5.1. SDM

Participant: Mireille Bossy [correspondant].

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 project-team MOISE.

- Version: 2.0

5.2. CarbonQuant

Participants: Mireille Bossy [correspondant], Selim Karia.

CarbonQuant is a simulator project of CO2 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.

Starting in September 2011, CarbonQuant is an ADT [1] Inria.

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

- Version: 2.0

[1] Technology Development Action