INRIA

INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

Team BIPOP

Modeling, Simulating, Controlling Non-Regular Dynamical Systems

Rhône-Alpes

THEME NUM

Activity Report

2004

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1. Team

This newly created project team gathers researchers from the former teams Bip and Numopt.

Head of project-team
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Administrative assistant
Elodie Toihein [jointly with Popart, Mistis]

Staff members Inria
Vincent Acary [junior research scientist]
Claude Lemaréchal [senior research scientist]
Pierre-Brice Wieber [junior research scientist]

Ph. D. students
Jean-Mathieu Bourgeot [Ministry fellowship, till November 2004]
Sophie Chareyron [Siconos fellowship]
Mathieu Guilbert [Cifre fellowship]
Rodolphe Heliot [CEA fellowship]
Jérôme Malick [ENS fellowship]
Doh-Elvis Taha [as of November 2004; Inria - Scheider Electric fellowship]

Post-Doc students
Matthieu Renouf [Bipop-Siames, as of October 2004; Ministry fellowship]

Training students
Alexandre Ravoux [January-June 2004; Siconos fellowship]
Jean-Michel Barbier [January-September 2004; Siconos fellowship]
Jérémie Blanc-Tranchant [January-June 2004; Siconos fellowship]

Expert engineers
Jean-Baptiste Charlety [as of October 2004; Siconos fellowship]

2. Overall Objectives

Generally speaking, this project deals with non-regular systems, with emphasis on

- dynamic systems, mostly mechanical systems with unilateral constraints and Coulomb friction, but also electrical circuits with ideal diodes, etc;
- biped robots and their connection with human walking, a rich and instructive instance of such systems;
- numerical methods for nonsmooth optimization, and more generally the connection between continuous and combinatorial optimization.

3. Scientific Foundations

3.1. Dynamic non-regular systems

Keywords: *analysis*, *complementarity*, *control*, *convex analysis*, *impacts*, *mechanical systems*, *modeling*, *simulation*, *unilateral constraints*.

Dynamical systems (we limit ourselves to finite-dimensional ones) are said to be *non-regular* whenever some nonsmoothness of the state arises. This nonsmoothness may have various roots: for example some outer impulse, entailing so-called *differential equations with measure*. An important class of such systems can be described by the complementarity system

$$\begin{cases} \dot{x} = f(x,u,\lambda)\,, \\ 0 \le y \perp \lambda \ge 0\,, \\ g(y,\lambda,x,u,t) = 0\,, \\ \text{re-initialization law of the state } x(\cdot)\,, \end{cases} \tag{1}$$

where $\perp$ denotes orthogonality; u is a control input. Now (1) can be viewed from different angles.

- Hybrid systems: it is in fact natural to consider that (1) corresponds to different models, depending whether $y_i = 0$ or $y_i > 0$ (y_i being a component of the vector y). In some cases, passing from one mode to the other implies a jump in the state x; then the continuous dynamics in (1) may contain distibutions.
- Differential inclusions: $0 \le y \perp \lambda \ge 0$ is equivalent to $-\lambda \in \mathrm{N}_K(y)$, where K is the nonnegative orthant and $\mathrm{N}_K(y)$ denotes the normal cone to K at y. Then it is not difficult to reformulate (1) as a differential inclusion.
- Dynamic variational inequalities: such a formalism reads as $\langle \dot{x}(t) + F(x(t),t), v - x(t)\rangle \ge 0$ for all $v \in K$ and $x(t) \in K$, where K is a nonempty closed convex set. When K is a polyhedron, then this can also be written as a complementarity system as in (1).

Thus, the 2nd and 3rd lines in (1) define the modes of the hybrid systems, as well as the conditions under which transitions occur from one mode to another. The 4th line defines how transitions are performed by the state x. There are several other formalisms which are quite related to complementarity. Two tutorial-survey papers have been published [2][5], whose aim is to introduce the dynamics of complementarity systems and the main available results in the fields of mathematical analysis, analysis for control (controllability, observability, stability), and feedback control.

3.2. Biped robots

Keywords: *control*, *mechanics*, *mobile robotics*, *modeling*, *robotics*, *sensor-based control*, *simulation of mechanical systems*, *solid mechanics*.

3.2.1. Modeling

A biped robot can be modeled [52][53] as a tree-like articulated chain of rigid bodies in R^3. Walking is characterized by different phases, mainly (for a given leg): swing (35% of the cycle), support (65%); there is a double-support phase (12%), which does not exist when running. A finer decomposition takes into account the movement of the mass center, and above all of the foot. These different phases are characterized by different contacts between the system and the ground.

As a result, the mechanical model of such a system has three aspects:

- the dynamics of a rigid articulated system, free in the space, representable by Lagrangian equation;
- a set of equality and inequality constraints, depending on the phase, which expresses the existence of contacts without penetration nor sliding; each one of these sets defines an operating mode;
- the selection of impact laws modeling the transitions (assumed instantaneous) between these modes.

This makes up a sophisticated hybrid system, whose study is still little explored, see [8] for a survey on modeling, stability and control of biped robots.

3.2.2. Controlling

The pace naturally adopted by a human walker is regular and symmetric, consuming little energy for a reasonable speed. Some hybrid systems, such as leaping robots or transmissions with slack, present likewise limit cycles corresponding to dynamic equilibria, possibly stable in a certain domain. For the simplest walking robot – a compass on a slope – these cycles correspond to passive periodic trajectories (without external action), in which the transition between kinematic and potential energies is entirely balanced by the energy absorbtion during the impact [43].

As a result of these considerations, our approach of control aims at constructing cyclic trajectories, minimizing energy – whatever this means. Also, it is important to guarantee a global progression while preserving a particular mechanical stability, which is dynamic. Classical approaches – for example following accurately nominal articulated trajectories – are therefore inadequate, except if one is just interested in controlling the attitude. The field is far from being settled, so we have to explore diverse control techniques: nonsmooth optimization, predictive control, adaptive learning, task function control [51]... including sensor-based control, allowing to use local measures of distance, proximity, reaction to the ground etc.

3.3. Nonsmooth optimization

Keywords: *Lagrangian relaxation, combinatorial optimization, convexity, numerical algorithm, optimization*.

Here we are dealing with the minimization of a function f (say over the whole space R^n), whose derivatives are discontinuous. A typical situation is when f comes from dualization, if the primal problem is not strictly convex – for example a large-scale linear program – or even nonconvex – for example a combinatorial optimization problem. Also important is the case of spectral functions, where $f(x) = F(\lambda(A(x)))$, A being a symmetric matrix and λ its spectrum.

For these types of problems, we are mainly interested in developing efficient resolution algorithms. Our basic tool is bundling [7] and we act along two directions:

- To explore application areas where nonsmooth optimization algorithms can be applied, possibly after some tayloring. A rich field of such application is combinatorial optimization, with all forms of relaxation [10][9].
- To explore the possibility of designing more sophisticated algorithms. This implies an appropriate generalization of second derivatives when the first derivative does not exist and uses advanced tools of nonsmooth analysis, for example [11].

4. Application Domains

Many systems (either actual or abstract) can be represented by (1). Some typical examples are:

- Mechanical systems with unilateral constraints and dry friction (the biped robot is a typical example), including kinematic chains with slack, phenomena of liquid slosh, etc.
- Electrical circuits with ideal diodes and/or transistors MOS.
- Optimal control with constraints on the state, closed loop of a system controlled by an MPC algorithm, etc.

This class of models is not too large (to allow thorough studies), yet rich enough to include many applications. This goes in contrast to a study of general hybrid systems. Note for example that (1) is a “continuous” hybrid system, in that the continuous variables x and u prevail in the evolution (there is no discrete control to commute from a mode to the other: only the input u can be used).

Walking robots – for example hexapods – possess definite advantages over the rolling ones whenever the ground is not plane or free: clearing obstacles is easier, holding on the ground is lighter, adaptivity is improved. However, if the working environment of the system is adapted to man, the biped technology must be preferred, to preserve good displacement abilities without modifying the environment. This explains the interest displayed by the international community in robotics toward humanoid systems, whose aim is to back man in some of his activities, professional or others. For example, a certain form of help at home to disabled persons could be done by biped robots, as they are able to move without any special adaptation of the environment.

In virtual reality and real-time applications, a major issue is the representation of real phenomena and the fine control of the model behind it. In particular, the interaction between objects and therefore the treatment of contact, friction and impacts is crucial. This treatment is usually decomposed into two tasks:

- Geometric detection of the interaction; this is now carried out in a very efficient way for simple geometric primitives.
- Numerical treatment, which constitutes the core of the collaboration between the Siames (Irisa/Rennes) and Bipop projects. Our main aim is to bridge the gap between the know-how of Bipop on the nonsmooth mechanics and the know-how of Siames on virtual reality applications.

ptimization exists in virtually all economic sectors. Simulation tools can be used to optimize the system they simulate. Another domain is parameter *identification* (Idopt or Estime teams), where the deviation between measurements and theoretical predictions must be minimized. Accordingly, giving an exhaustive list of applications is impossible. Some domains where Inria has been implied in the past, possibly through the former Promath and Numopt teams are: production management, geophysics, finance, molecular modeling, robotics, networks, astrophysics, crystallography, ...

5. Software

Two sorts of software are developed within Bipop.

5.1.1. Nonsmooth dynamics

In the framework of the European project Siconos, Bipop is 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 requirements 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) is order to ensure numerical efficiency and the use of standard libraries (Blas, Lapack, ...)

2. *Siconos/Kernel(Engine + Front-End)* The Engine is an object-oriented structure (C++) for modeling and simulation of abstract dynamical systems. The Front-End is the driver interface of the Engine thanks to two types of API's. The first one is an API in C++, interfaced in Python for scripting uses. The second API, in C, will be interfaced with Scilab for a more user-friendly platform.
3. *Siconos/Analysis* This part is devoted to the stability and bifurcation analysis of nonsmooth dynamical systems.
4. *Siconos/Control* This part is devoted to the implementation= of control strategies of non smooth dynamical systems.
5. *Siconos/*IMSE The final product is an Integrated modeling and Simulation Environment dedicated to applied nonsmooth problems.

Further informations may be found at http://siconos.inrialpes.fr/software

5.1.2. Optimization

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.

5.1.2.1. Code M1QN3

Participants: Jean-Charles Gilbert [Estime team – partner], Claude Lemaréchal [partner].

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 [1] for the terminology).

5.1.2.2. Code M2QN1

Participant: Claude Lemaréchal.

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

5.1.2.3. Code N1CV2

Participants: Claude Lemaréchal [partner], Claudia Sagastizábal.

Minimization without constraints of a convex nonsmooth function by a proximal bundle method ([7], [1]).

5.1.2.4. Modulopt

Participants: Jean-Charles Gilbert [Estime team – partner], Claude Lemaréchal [partner].

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.

6. New Results

6.1. Stability and Feedback Control

6.1.1. Stability of evolution variational inequalities

Participant: Bernard Brogliato.

We continued our work with D. Goeleven, from the University of la Réunion on systems of the type $\langle \dot{x}(t) + Ax(t), v - x(t) \rangle \geq 0$ for all $v \in K$, $x(t) \in K$ (K being a nonempty closed convex set). Necessary conditions for the asymptotic stability have been obtained in [34], where the notion of Brouwer degree of a function is used. The difficulty here is that the function is nonsmooth. The results are applied to the asymptotic stabilization of a controlled variational inequality. They show that in general the controllability of the unconstrained system, is neither sufficient nor necessary to assure the existence of a constant feedback which guarantee asymptotic stability.

The LaSalle invariance principle has also been studied for the case of evolution variational inequalities, see Sect. 6.1.4.

6.1.2. Absolute stability with maximal monotone mappings

Participant: Bernard Brogliato.

We recall that the absolute stability problem consists of studying the stability of a system made of the negative feedback interconnection of a dissipative system with a nonlinear characteristic. Last year in [15] we extended absolute stability to a feedback branch containing a maximal monotone operator. These results have been used subsequently in [35][36] to design stable observers (open-loop [36]), and feedback controllers using observed states (closed-loop [35]). There is an additional difficulty in the sense that we now consider inclusions which are non-autonomous. All of these works use well-posedness results for monotone diferential inclusions *à la* Brézis.

6.1.3. Tracking control of complementarity Lagrangian systems

Participants: Jean-Matthieu Bourgeot, Bernard Brogliato.

As a sequel to our previous works [3][4], we clarified in [14] the design and the role of the transition phases (stabilisation on the constraint surface or detachment from this surface) in the closed-loop stability, extending the so-called passivity-based control design to unilaterally constrained systems. In [22], the robustness of these family of controllers has been tested with numerical simulations.

6.1.4. Lyapunov stability theory and LaSalle's invariant theorem for nonsmooth dynamical systems

Participants: Sophie Chareyron, Pierre-Brice Wieber.

The mathematical analysis of nonsmooth Lagrangian dynamical systems requires mathematical tools which are unusual in control theory: velocities with locally bounded variations, measure accelerations, measure differential inclusions, to name a few. The control theory for such dynamical systems is just beginning to appear, and even the basic Lyapunov stability theory still needs to be stated. In [25], we propose a Lyapunov stability theorem for dynamical systems with state discontinuities. Based on this theorem, we are then able to propose a Lagrange-Dirichlet theorem for nonsmooth Lagrangian dynamical systems that can be applied through Potential Shaping to the regulation of the position and force of a robotic manipulator [17]. Note that though we have been able to derive a Lyapunov stability analysis for nonsmooth dynamical systems very similar to what appear in the smooth case, the derivation of a theorem equivalent to the LaSalle's invariance theorem is far from being straighforward. A key condition for the statement of Lasalle's invariance theorem is the continuity of the trajectories of the systems with respect to initial conditions. Nonsmooth Lagrangian dynamical systems generally do not present such a continuity, but they do in many specific cases. So we propose in [33] a version of LaSalle's invariance theorem for time-invariant flows that are countinuous with respect to initial conditions.

6.1.5. The BIP robot, an experimental setup for humanoid walking

Participant: Pierre-Brice Wieber.

First experiments of standing with different task function control laws have been undertaken, but the results in tracking reference trajectories revealed deficiencies in the velocity observer and the friction compensation. Then a breakage of the mechanical structure (left hip) stopped experimentations for 4 months; as a result, our work on improvement of the trajectory tracking resumed by the end of the year.

6.1.6. Simulation of walking: humanoid robots and electro-stimulated paraplegic people

Participant: Pierre-Brice Wieber.

The modeling and simulation software for humanoid robots and electro-stimulated paraplegic people, developed the team in C/C++/Scilab/Maple, is used at Inria Rhône-Alpes, LMS in Poitiers and LIRM in Montpellier. It is soon to reach its first official release, with more realistic models of the sensors of the Bip robot, and a complete dynamical model of the electro-stimulated muscles of paraplegic people.

6.1.7. Trajectory generation for industrial robot

Participants: Pierre-Brice Wieber, Matthieu Guilbert.

Work done with Stäubli SCA, Faverges (Luc Joly).

Trajectory generation in industry is usually based on simple laws like bang-bang profile. Such a profile is not adapted to industrial problems because it makes it difficult to search the best trajectory for a given task. Accordingly, we formulate the problem of trajectory generation as a constrained optimization problem. We model the robot (geometry, kinematics and dynamics) and the physical constraints (on actuators, temperature, etc.) in a traditional way. For a numerical resolution, the profile is discretized by cubic splines and the constrained optimization problem is solved by a Sequential Quadratic Programming solver. Our algorithm is robust to the initial conditions, and it can be implemented as an off-line optimization tool; see [27].

6.2. Controllability

Our controllability studies concern two classes of complementarity systems: juggling systems and planar evolution variational inequalities. In the first case, it is shown that studying controllability amounts to solving a nonlinear system subject to inequality constraints [40]. The second study [16] shows that controllability depends on the form of the convex set K in which the system is constrained to evolve. Interestingly enough, the complementarity conditions that are activated on the boundary of K may improve controllability in some cases.

6.3. Modeling

6.3.1. Unified models in nonsmooth mechanics

Participants: Vincent Acary, Bernard Brogliato, Claude Lemaréchal.

Work done with A. Daniilidis (Autonomous Univ. of Barcelona), a former post-doctoral fellow at Inria Rhône-Alpes.

A complementarity model such as (1) is actually an instance of more general differential *inclusions*, where the speed $\dot{x}$ is constrained to lie in some set T. Equivalence of a few such models was known before under fairly *ad hoc* assumptions [44]. Using exclusively tools from standard convex and nonsmooth analysis, we establish in [24] the same equivalence with several other models, under much simpler assumptions; this work in particular reveals the importance of the concept of *slow* solution [41].

6.3.2. Multiple impacts

Participants: Vincent Acary, Bernard Brogliato, Doh-Elvis Taha.

An impact is said to be multiple when several impacts occur at the same time on the system. The multiple impact mappings which have already been proposed in the literature are not satisfactory, because they often entail post-impact velocities that obviously disagree with experiments, and/or are not tractable from the numerical point of view. Based on previous works in Bipop [37], [21], the goal of the PhD thesis D.E. Taha in collaboration with Schneider Electric is to extend the multiple impact law to finite-dimensional systems such as circuit breakers and to exhibit the limit of validity of the approach (assumption of quasi-rigid solids).

6.4. Nonsmooth optimization

Generally speaking, our activity this year has mainly consisted of *synthetic works*, revisiting various technical subjects from a higher convex-analysis perspective.

6.4.1. Classification of nonsmooth functions

Participant: Jerôme Malick.

Work done with A. Daniilidis (Autonomous Univ. of Barcelona), a former post-doctoral fellow at Inria Rhône-Alpes.

Important nonsmooth functions are lower-C^1 and lower-C^2 functions (a lower-C^k function is the supremum of C^k functions). We have defined and studied in [18] a class of intermediate functions, called lower-$C^{1,\alpha}$; they play a role analogous to Hölder functions in standard analysis.

6.4.2. Separation in combinatorial optimization

Participant: Claude Lemaréchal.

Work done in collaboration with Gérard Cornuéjols (Carnegie Mellon) and funded by the Inria new investigation grant ODW, extending over 2003-04.

One of the crucial techniques in combinatorial optimization is *separation*: given a closed convex set P and a point $\overline{x} \notin P$, find a hyperplane separating $\overline{x}$ from P "best". Traditional studies of this problem are limited to a polyhedral P and rely heavily on LP theory. In [26] (submitted to Mathematical Programming), we consider this question from the higher point of view of convex analysis, confirming the importance of the *reverse polar* [38] of a set Q:

$$Q^\circ_- := \{d : d^\top x \leq -1 \text{ for all } x \in Q\} .$$

It is the set of directions separating Q from 0 *strictly*, and is at the same time a *closed* set, which considerably eases theory and computations. We show how this new perspective can be applied to disjunctive cuts [39]. This synthetic point of view helps understanding better the issue, suggests an appropriate definition of "best" separations, and opens the way to generalizations (say to SDP relaxations).

6.4.3. Unified perspective on partly smooth functions

Participant: Jerôme Malick.

Work done with S. Miller (Univ. of Cal. at San Diego), a former post-doctoral fellow at Inria Rhône-Alpes.

The concept of smooth restriction of a nonsmooth function f to a smooth manifold was exhibited in [11]; it is fundamental to design fast algorithms minimizing f. Making use of its formalization [47], we analyze in [29] (submitted to Mathematical Programming) fruitful links with Riemannian geometry [42], SQP theory [1], proximal mapping [50]. Our study reveals the importance of the existence of the so-called U-gradient (essentially: the gradient of the smooth part of f), without which developing the smooth part of f to second order is hardly conceivable.

6.4.4. The spherical constraint in combinatorial optimization

Participant: Jerôme Malick.

Recall (see [10] for example) that SDP relaxations of a combinatorial problem replace the variable $x \in \{-1, +1\}^n$ by a symmetric $n \times n$ matrix X (standing for $xx^\top$) of rank 1 and whose diagonal entries are all 1 (then they relax the rank-one constraint to $X \succeq 0$).

In [28] we note that the set of such matrices can also be described by the constraits $X \succeq 0$ and $\sum_{ij} X_{ij} = n^2$. Then we propose to dualize this latter *single* quadratic constraint, say with a multiplier α. For $\alpha = 0$, the optimal value of the Lagrangian is the SDP bound, while the duality gap is closed when $\alpha \to -\infty$. On the other hand, the Lagrangian problem for $\alpha > 0$ is a so-called SDLS problem, which is substantially easier than a standard linear SDP: [20]. This opens the way to potentially more efficient relaxations than SDP. Besides, an interesting class of nonconvex problems with no duality gap is thus revealed.

6.4.5. Convex optimization and column generation

Participant: Claude Lemaréchal.

Work done in collaboration with F. Vanderbeck (Univ. Bordeaux 1) and K.C. Kiwiel (Systems Research Institute, Warsaw) and funded by the Inria new investigation grant ODW, extending over 2003-04; see Numopt Activity Report 2003, §6.2).

For technical reasons the team from Geneva had to withdraw from this project. Our continued collaboration with the team from Bordeaux confirmed last year's results: compared with the traditional Dantzig-Wolfe algorithm, the bundle approach is always competitive and sometimes drastically faster. This, however, holds in terms of numbers of calls to the oracle. On the other hand, we observed strange behaviours: an NP oracle may take considerably more CPU time when called by bundle. It is therefore crucial for bundle to accept inaccurate oracles, thereby reducing computing times (see Numopt Activity Report 2003, §6.3). Accordingly, we implemented with K.C. Kiwiel his version of bundle with noise [46].

This work was also the occasion to revisit *stabilization* of Dantzig-Wolfe (see [48][45][49] among others), relating it with the Moreau-Yosida regularization in the dual space. These results are published in [23], submitted to Mathematical Programming.

6.5. Software development

Participants: Vincent Acary, Jean-Baptiste Charlety, Jérémie Blanc-Tranchant, Jean-Michel Barbier, Alexandre Ravoux.

The deliverable D2.2 has been successfully delivered in March 2004. It reports on the work carried out at Inria (CO1) and LMGC (AC2) on the architectural design of the Siconos Platform. The contents of this deliverable follow the work performed between September 2003 and March 2004:

1. The Quality Plan (QP v1.0). Following the recommendations of the first review meeting, a project management plan has been defined with the definition of a work breakdown structure and a set of milestones for the development process.
2. The Software Requirements Document (SRD v1.0) summarizes the work done with the end-users on the elicitation of functional requirements. It contains also the requirements concerning the performance, interface, resources, portability and quality. All of the specifications are classified in order to facilitate the definition of Milestones.
3. The External Specification Document (ESD v1.0) specifies the using context and the user interfaces.
4. The Architectural Design Document (ADD) describes the major features of the general architecture of the platform. This work is based on the SA/SD method and the UML tools.
5. The contents of the Theory Manual (TM). This document contains a first attempt at collecting some theoretical material in order to use the platform. It will be finished with the first version of the Software User Manual (SUM).
6. A first Template on the numerical simulation of Lagrangian systems associated with "Guidelines for authors" for a template.

The four first documents are based on the ESA (European Space Agency) standards for software engineering. Most of these documents are still in progress. A stable version in June 2004 has been tagged as version 1.0, available on the private area of the Siconos WP2 website.

The major achievement performed by the Bipop Project between April 2004 and September 2004 is the detailed design and the first implementation of the Siconos/Engine, the kernel of the Siconos platform. The general implementation in C++ of the complete skeleton of the architecture has been carried out as it has been defined in the ADD document. The development provides the first version of the API C++ as an expert interface to the platform. The detailed implementation of the data input and output in XML format has been completed. This module is based on the API DOM and SAX, norms of the W3C, implemented in the Libxml2 library. Specific XML formats have been defined with the help of the XML scheme. This data file serves as expert users data files and as internal data base for the platform. The platform is now able to read an XML data file, check its validity with respect to the scheme, and save it. Dynamic instantiation of new object in the platform through the user interface is also taken into account. Finally, the detailed implementation of the formalization of various nonsmooth dynamical system has been performed together with validations and benchmarks.

7. Other Grants and Activities

7.1. European Actions

The Bipop project coordinates the European project Siconos (modeling, SImulation and COntrol of NOnsmooth dynamical Systems, IST 2001-37172), which is an FP5 project starting September 2002 and ending September 2006. See http://siconos.inrialpes.fr.

7.2. Invitations of specialists

– G. Cornuéjols (Carnegie Mellon) 2 weeks;
– K. Goeleven (Univ. la Réunion) 1 week;
– K.C. Kiwiel (Systems Research Institute, Warsaw) 2 weeks;
– F. Potra (Univ. Maryland, Baltimore) 1 week.

7.3. Teaching

– Univ. Joseph Fourier, Grenoble (V. Acary: tutoring "Mathematical models for physics" 48h; S. Chareyron: tutoring discrete time control, 21h; J. Malick: various, 70h);
– Polytech'Grenoble (J.-M. Bourgeot: tutoring automatic control, 21h; S. Chareyron: tutoring identification and control, 21h);
– Ensimag, Grenoble (C. Lemaréchal, J. Malick: Numerical Optimization, 21h);
– École de Physique, Chimie, Électronique de Lyon (C. Lemaréchal: Numerical Optimization, 16h);
– Artelys Lectures, Paris (C. Lemaréchal: Nonlinear Programming, Combinatorics 2, 10h);
– RTE, Versailles (C. Lemaréchal: Nonlinear Programming and Lagrangian relaxation, 10h);

7.4. Participation to conferences, seminars, invitations

– 8th Workshop on Combinatorial Optimization; Aussois, Jan. 2003;
– Journées du Groupe Mode; le Havre, March 2004 (1 presentation);
– Siconos General Meetings; Grenoble, March 2004; Univ. of Bristol, Sept. 2004 (3-5 participants, 2-3 presentations each time).
– Meetings for the Robea Project "Commande pour la marche et la course d'un robot bipède"; Paris, March 2004; Metz, Oct. 2004 (1 participant, 2 presentations each time);
– Meeting for the Robea Project "Contrôle du mouvement du member inférieur humain paralysé sous stimulation électrique" Montpellier, June and Nov. 2004 (1 participant, 1 presentation each time);
– Journées SFDS (French Assoc. Statistics); Montpellier, May 2004 (1 presentation);
– School on Constrained Control and Estimation; Grenoble, Sept. 2004 (2 participants);
– Piecewise Smooth Dynamical Systems: Analysis, Numerics and Applications, Sept. 2004 (participants, 2 presentations);
– HLR'04 workshop on humanoid and legged robots; Metz, Oct. 2004 (2 presentations).

8. Dissemination

8.1. Dissemination of software

N1cv2 is used at Univ. Polit. Catalunya (E.C. Sancho, bilevel programming)

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