INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

Team BIPOP

Modeling, Simulating, Controlling Non-Regular Dynamical Systems

Grenoble - Rhône-Alpes

THEME NUM

Activity Report

2007

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1. Team

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2. Overall Objectives

2.1. Introduction

Generally speaking, this project deals with nonregular systems, control, modelling and simulation, with emphasis on

- dynamic systems, mostly mechanical systems with unilateral constraints and Coulomb friction, but also electrical circuits with ideal diodes and transistors Mos, etc;
- numerical methods for nonsmooth optimization, and more generally the connection between continuous and combinatorial optimization.

2.2. Highlights of the year

Our efforts to link nonlinear and combinatorial optimizations have concretized by a two-week Summer school at the Univ. of Pisa: “Convex Analysis for Bounding and Cutting”.

A large part of our work this year has been devoted to finalizing a monograph on the numerical simulation of complementarity dynamical systems, with emphasis on mechanical systems and electronics; it will appear in March 2008 as [11].

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

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

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 distributions.
- 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. A tutorial-survey paper has been published [2], 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. 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 (Chap. XV of [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 [9], [8].
- 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 we use advanced tools of nonsmooth analysis, for example [10].

4. Application Domains

4.1. Introduction

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). Let us cite some specific applications.

4.2. Computational neuroscience

Modeling in neuroscience makes extensive use of nonlinear dynamical systems with a huge number of interconnected elements. Our current theoretical understanding of the properties of neural systems is mainly based on numerical simulations, from single cell models to neural networks. To handle correctly the discontinuous nature of integrate-and-fire networks, specific numerical schemes have to be developed. Our current works focus on event-driven, time-stepping and voltage-stepping strategies, to simulate accurately and efficiently neuronal networks. Our activity also includes a mathematical analysis of the dynamical properties of neural systems. One of our aims is to understand neural computation and to develop it as a new type of information science.

4.3. Electronic circuits

Whether they are integrated on a single substrate or as a set of components on a board, electronic circuits are very often a complex assembly of many basic components with non linear characteristics. The IC technologies now allow the integration of hundreds of millions of transistors switching at GHz frequencies on a die of 1cm^2. It is out of question to simulate a whole such IC with standard tools such as the SPICE simulator. We currently work on a dedicated plug-in able to simulate a whole circuit comprising various components, some modelled in a nonsmooth way.

4.4. Walking robots

As compared to rolling robots, the walking ones – for example hexapods – possess definite advantages 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.

4.5. Optimization

Optimization 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, ...Our current applicative activity includes: the management of electrical production, deterministic or stochastic, the design and operation of telecommunication networks.

4.6. Computer graphics Animation

A new application in BIPOP is the simulation of complex scenes involving many interacting objects. Whereas the problem of collision detection has become a mature field those recent years, simulating the collision response (in particular frictious contacts) in a realistic, robust and efficient way, still remains an important challenge. Another related issue we began to study is the simulation of heterogeneous objects such as granular or fibrous materials, which requires the design of new high-scales models for dynamics and contacts; indeed, for such large systems, simulating each interacting particle/fiber individually would be too much time-consuming for typical graphics applications. Finally, our current activity includes the shape control of simulated objects, which is of great importance in the field of artistic design, for the making of movies and video games for example. Such problems typically involve constrained optimization.

5. Software

5.1. Nonsmooth dynamics: Siconos

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(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.gforge.inria.fr/

5.2. Humanoid motion analysis and simulation

The HuMAnS toolbox offers tools for the modelling, control and analysis of humanoid motion, be it of a robot or a human. It is a C/C++/Scilab/Maple-based set of integrated tools for the generation of dynamical models of articulated bodies with unilateral contact and friction, their simulation with an event-driven integration scheme, their 3D visualization, the computation of stability measures, optimal positions and trajectories, the generation of control laws and observers, the reconstruction of movements from different sensing systems.

5.3. 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.

5.3.1. 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 [1] for the terminology).

5.3.2. 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.

5.3.3. Code N1CV2

Minimization without constraints of a convex nonsmooth function by a proximal bundle method (Chap. XV of [7], Chap. 9 of [1]).

5.3.4. 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.

6. New Results

6.1. Modeling

6.1.1. Simulation of spiking neuronal networks

Participant: Arnaud Tonnelier.

The numerical simulation of neural networks requires special attention to reproduce accurately the short-time scale fluctuations of spiking neurons, while allowing efficient simulation of large networks. In [33] we propose a new technique: *voltage-stepping schemes*, which is based on a discretization of the voltage state-space. The new simulation strategy defines a local event-driven method inducing an implicit activity-dependent time stepping scheme. Long time-steps are used when a neuron is slowly varying, whereas small time-steps are used in periods of intense activity. Our method is illustrated on nonlinear integrate-and-fire models.

6.1.2. Modeling and well-posedness of electrical circuits

Participant: Bernard Brogliato.

We recall [14], where we showed that electrical circuits, viewed as dynamical systems, could benefit a lot from the tools of convex and nonsmooth analysis introduced by J.J. Moreau and P.G. Panagiotopoulos. We introduced a general formalism, extending the work initiated in [36]. In [32] the well-posedness of static nonsmooth circuits was studied, relying on the use of recession tools that defined a new class of problems that we call semi-complementarity problems. This enabled the study of existence and uniqueness for a large class of variational inequalities arising in electronics. In [21], a suitable state transformation is used to rewrite nonsmooth electrical circuits as perturbed sweeping processes. Well-posedness results are obtained, when solutions are absolutely continuous or of bounded variation.

6.1.3. Simulation of electrical circuits as nonsmooth dynamical systems

Participants: Vincent Acary, Olivier Bonnefon, Bernard Brogliato, Pascal Denoyelle.

DC-DC converters are usually difficult to simulate with classical tools like SPICE because of the highly nonlinear behaviour of some components and the frequent occurrence of intrinsically generated switching events.

The simulation of such circuits modelled as nonsmooth systems has been successfully achieved with a clear advantage over several SPICE simulators and a simulator belonging to the hybrid modelling approach.

6.1.4. Numerical Algorithms for 3D frictional contact problem

Participants: Vincent Acary, Houari Khenous.

The aim of this work is to compare numerical methods devoted to the simulation of dynamical systems with unilateral contact and tridimensional friction, with a view to real-time applications in robotics, virtual reality, haptic systems. First, an exhaustive review of existing methods and results has been performed. formulation and the mathematical results of convergence are compared and criticized with respect to the assumptions. Keeping in mind our applications, we have compared them in terms not only of the usual mathematical criteria (convergence, stability), with respect to CPU time, robustness, quality of the solution found. In order to achieve this numerical comparison, our work was based on the pre-existing routines in the open-source platform SICONOS http://siconos.gforge.inria.fr. New algorithms have also been implemented and tested.

6.2. Optimization

6.2.1. Variational analysis of spectral functions

Participant: Jerôme Malick.

With A. Daniilidis (Univ. Barcelona), we have resumed a work started with A. Lewis (Cornell U.). Our aim was to show that spectral functions [39] inherit the *prox-regularity* [40] of the symmetric function underlying them. We managed to prove this result, as well as a few other, by way of characterizing their subdifferential.

6.2.2. Alternate projections onto nonconvex sets

Participant: Jerôme Malick.

With A. Lewis and R. Luke from Cornell U., we have completed a study of the problem $\mathrm{p}_{A\cap B}a$, solved by the algorithm $y+ = \mathrm{p}_A x$, $x_+ = \mathrm{p}_B y_+$ (initialized at $x = a$). The important result is that this algorithm converges with quasi no assumption on A and B set, providing that they intersect transversally (in words: their intersection forms a nonzero angle). This explains *a posteriori* its success for some recent applications in control and image processing, where no convexity is present. Besides, an explicit link has been established between the problem's conditioning (the angle between A and B) and the algorithm's speed of convergence.

6.2.3. Regularized algorithms for SDP optimization

Participant: Jerôme Malick.

With F. Rendl and his team (Univ. Klagenfurt), we are now finalizing our work described in Bipop's Activity Report of 2005. Our approach turns out to be very efficient, as it outperforms all known methods for some combinatorial problems such as MaxCut or Lovász' ϑ number. The results appear in [34] and will be submitted shortly in a regular journal.

6.2.4. Telecommunication networks

Participants: Claude Lemaréchal, Georges Petrou.

Following our work [27] on robust network design, we have considered the case of an uncertain demand defined by polyhedral constraints. We have developed two approaches: one computes upper bounds, using [27] which assumed the extreme points of the polyhedron to be known explicitely. The other computes lower bounds and is based on reverse convex programming. Together with [26], this will complete Petrou's thesis.

6.2.5. Unit-commitment

Participant: Claude Lemaréchal.

The unit-commitment problem is to optimize the electrical production. Its solution is usually based on Lagrangian relaxation, see for example [37]. In [38] is given a technique allowing inexact minimization of the Lagrangian. In 2003 we tested this technique on EDF's experimental software. This year, we had a contract to make the final grafting, so as to insert this facility in the next release of their operating software.

6.2.6. Mixing constraint programming and relaxations

Participant: Florent Cadoux.

This was a three-month work at Artelys SA, a firm specialized in consulting and software development for optimization. The idea was to graft LP relaxations into *Artelys Kalys*, a commercial software for constraint programming. Automatic derivation of such relaxations by suitable algorithms has been implemented, together wih an interface with *Xpress MP Optimizer* to solve them. Their optimal value provides better bounds, their optimal solution orients the tree search and their dual solution filters the feasible domain (a technique known as "propagating reduced costs").

Numerical experiments, conducted on a large number of random problems and on the unit-commitment problem, have confirmed robustness and efficiency of the approach.

6.3. Locomotion analysis

6.3.1. Reconstruction of 3D movements with inertial or optical sensors

Participants: Fabien Jammes, Pierre-Brice Wieber.

This is a collaborative work with Mickaël Begon, Univ. Loughborough. The problem of reconstructing 3D movements of a person, based on inertial or optical measurements, is considered here as an inverse problem; the direct model includes both the biomechanics of the person and the measurement process. This reconstruction can then be seen as a nonlinear least-squares problem with box constraints.

In the case of optical sensors, this problem has been solved successfully with a classical Gauss-Newton scheme, validated in a biomechanical study in gymnastics, allowing more robust and precise results than the classical methods of this field, not based on articulated models of the motion. In the case of inertial sensors, Kalman filters have been investigated successfully, but the choice of the process model best describing human motions is still under investigation.

A patent has been filed on this research theme in 2007, and a second one is being written, in connection with a CEA spin-off developing the corresponding technologies.

6.3.2. Model Predictive Control of Walking

Participants: Holger Diedam, Dimitar Dimitrov, Pierre-Brice Wieber.

This is a collaborative work with the University of Louvain Joachim Ferreau, Moritz Diehl. The problem of safe locomotion of legged robots, when trying to avoid falling or hitting obstacles, has been analyzed from the viewpoint of viability (controlled invariance) and not of Lyapunov stability. Model Predictive Control has then been shown to be a very promising approach for solving this viability problem through its set invariance properties.

We have focused so far on a linearized model of the walking system with a quadratic cost function, which results in a classical quadratic program. In order to allow experimentations on real robots such as the HRP-2 robot, fast computation of this specific QP has been investigated. A precise analysis of the active constraints of the QP has been undertaken, in order to efficiently warm-start the active set method, together with an analysis of the discretization scheme of the MPC in order to reduce as much as possible the size of the QP. The use of parametric active set methods (homotopy) is also under investigation.

We have started investigating onlinear evolutions of this method, introducing first of all step length and timing in the control variables of the MPC scheme.

6.3.3. Rehabilitation of posture and walking: coordination of valid and deficient limbs

Participants: Bernard Espiau, Rodolphe Héliot.

This is a collaborative work with LIRMM (Christine Azevedo) and Leti (Dominique David). When controlling postural movements through artificial prosthetic limbs or Functional Electrical Stimulation, an important issue is the enhancement of the interaction of the patient with the artificial system through his valid limb motions. We address the problem of the coexistence of voluntary controlled with artificially controlled movements. We propose to observe the valid limbs through movement sensors, in order to optimize the interaction at two levels: a strategic level, where we aim at identifying as soon as possible the postural task the patient intends to execute, and a tactic level, where we aim at monitoring the ongoing task, in order to estimate some movement parameters. Specifically, to ensure legs coordination during walking, the CPG (Central Pattern Generator) concept is introduced, and we propose a robust phase estimation method based on the observer of a non-linear oscillator. This framework mixes discrete and continuous behaviors, a duality which raises some integration issues and implies to set up a hybrid command architecture. Two additional constraints are the required number of sensors, as well as the complexity of the algorithms: both have to be kept as low as possible. The proposed solutions are based on movement models, and have been validated through real time experiments.

6.4. Software development

6.4.1. HuMAnS toolbox

Participants: Laurence Boissieux, Fabien Jammes, Remy Mozul, Roger Pissard-Gibollet, Pierre-Brice Wieber.

The complete rewriting in C++ of the HuMAnS toolbox has been initiated: 20% of the Scilab code has been translated so far. A prototype of hot generation (Just-In-Time compilation) of optimized models of articulated bodies has been realized in C++ (using the GiNaC library for symbolic computations), for replacing in the future the current Maple implementation. The connection with the Siconos platform has progressed also, with a complete simulation of the Bip robot running in Siconos, but so far with frictionless 3D unilateral contact.

The GForge repository of the toolbox has been split, for considering separately the 3D motion reconstruction part. The latter is no longer distributed under the GPL license, in contrast with the rest of HuMAnS; it is going to be licensed separately to CEA and one of its spin-offs.

6.4.2. Platform development: Siconos

Participants: Vincent Acary, Franck Pérignon.

The main achievements for the Siconos platform are

- *Siconos/Numerics*
  - Improvements and optimization of various numerical algorithms: frictional contact problem in two-dimensional and tree-dimensional configurations, non smoo th solvers for block-structured problems, convergence tests based on Fischer-Bur smeister functions.
- *Siconos/Kernel*. Improvements and enhancements of
  - Modeling part: new Lagrangian relations, new first order dynamical systems;
  - Simulation part: time-stepping and event-driven schemes monitoring by an event pile and an event manager;
  - Control part: Adding of control classes: Actuators, Sensors;
  - optimization of the Siconos algebra class based on the Boost Library http://www.boost.org/;
  - example Library.
- Improvements and extensions of the documentation: Getting Started Guide, Installation guide, User manual, Example manual and Theory Manual.

7. Contracts and Grants with Industry

7.1. Industrial contracts

– EDF R&D, contract 2641: introduction of inexact Lagrangians in the software PROXMYQN;
– FT R&D, contract 444: robust design of telecommunication networks.

7.2. Other grants

– A common project named "VAL-AMS", dedicated to the high confidence validation of analog and mixed signal circuits was submitted by the Verimag laboratory, jointly with Inria-Bipop and LJK (laboratoire Jean Kuntzmann, Grenoble) as an answer to the ANR (Agence Nationale de la Recherche) call for projects on safety of computer systems. This project was selected by ANR last year.

Using this funding, a specialist engineer has started in September to work on the automatic equation-formulation of circuits as non smooth dynamical systems.
– Coordination of the European project Siconos (modeling, SImulation and COntrol of NOnsmooth dynamical Systems, IST 2001-37172), which was an FP5 project from September 2002 to September 2006. See http://siconos.inrialpes.fr.
– ANR Slalom (Système de capteurs et logiciel d'animationn permettant l'observation du mouvement d'un skieur freestyle), RNTL.
– ANR Guidage (Nouvelles stratégies pour le guidage et la commande de systèmes), BLAN NT05-1_43040.

8. Dissemination

8.1. Software

– N1CV2 at Yahoo Research (SVM), Shanghai Jiao Tong U. (academic testing of new algorithms for convex optimization), Univ. Paris 13 (column generation with knapsack oracle);
– M2FC1 at Institut des Mers du Nord (gas transmission networks).

8.2. Animation of the scientific community

B. Brogliato is:
– Associate Editor for Automatica (June 1999 to June 2005: Intelligent and Adaptive Systems; since June 2005: Nonlinear Systems and Control)
– Reviewer for Mathematical Reviews since 2001
– Reviewer for ASME Applied Mechanics Reviews since 2001

B. Espiau is a member of
– the Steering Committees of Laas and Lirm,
– the Scientific Committee of JRL-France (Joint Robotics Laboratory),

8.3. Teaching

– UFR IMA, UJF Grenoble, (V. Acary, lectures on " Mathematical models for physics", 48h in Master 2)
– ENSIMAG, (V. Acary, lectures on " Modeling and simulation in Mechanics" 12h in third year, track Modeling and Scientific Computing; J. Malick, F. Cadoux: "Numerical Optimization", 54h lecturing and tutoring);
– CPE, Lyon (C. Lemaréchal: Numerical Optimization, 10h lecturing and tutoring).
– Univ. Pisa (C. Lemaréchal: School of Graduate Studies G. Galilei "Convex Analysis for Bounding and Cutting", 20h lecturing);

8.4. Invitation of specialists

– A. Daniilidis (Univ. Barcelona) 2 weeks;
– K.C. Kiwiel (Systems Research Institute, Warsaw) 2 months;

8.5. Participation to conferences, seminars

– 11th Workshop on Combinatorial Optimization; Aussois, January (3 participants, 1 presentation);
– First annual forum New Technologies for Energies; Grenoble, February (scientific committee, 1 presentation) http://www.minatec.com/nte2007/;
– Francoro V – Roadef 2007; Grenoble, February (3 participants, 1 presentation);
– Journées Nationales de Recherche sur les Humanoïdes; Montpellier, March (1 presentation);
– Optimisation convexe et applications en commande, probabilités et statistiques; Luminy, April (co-organization);
– Journées du Groupe Mode; Paris, April (2 participants);
– FT R&D Optimization seminar; Sophia Antipolis, May (1 presentation);
– 3rd IEEE conference on neural engineering; Kohala Coast, Hawaii, May (1 presentation);
– Dynamic Walking III; Mariehamn, Åland, June (2 presentations);
– ISPGR'07 (International Symposium on Posture and Gait Research); Burlington, Vermont, July (1 presentation);
– Optimization Methods and Software; Prague, July (1 communication);
– Euro XXII; Prague, July (1 communication);
– 13th Czech-French-German Conference on Optimization; Heidelberg, September (4 presentations);
– Journées Nationales de la Recherche en Robotique; Obernai, October (1 presentation);
– Seminars in Florence, Grenoble, Marseille, Zürich.

9. Bibliography

Major publications by the team in recent years

[1] J. Bonnans, J. Gilbert, C. Lemaréchal, C. Sagastizábal. *Numerical Optimization*, Springer Verlag, 2003.

[2] B. BROGLIATO. *Some perspectives on the analysis and control of complementarity systems*, in "IEEE Trans. Automatic Control", vol. 48, n° 6, 2003, p. 918-935.

[3] B. BROGLIATO. *Nonsmooth Mechanics*, 2nd edition, Springer Verlag, 1999.

[4] B. BROGLIATO, R. LOZANO, B. MASCHKE, O. EGELAND. *Dissipative Systems Analysis and Control*, 2nd edition, Springer Verlag, London, 2007.

[5] B. BROGLIATO, S. NICULESCU, P. ORHANT. *On the control of finite-dimensional mechanical systems with unilateral constraints*, in "IEEE Trans. Automatic Control", vol. 42, n° 2, 1997, p. 200-215.

[6] J.-B. HIRIART-URRUTY, C. LEMARÉCHAL. *Fundamentals of Convex Analysis*, Springer Verlag, Heidelberg, 2001.

[7] J.-B. HIRIART-URRUTY, C. LEMARÉCHAL. *Convex Analysis and Minimization Algorithms*, Two volumes, Springer Verlag, Heidelberg, 1993.

[8] C. LEMARÉCHAL. *Lagrangian relaxation*, in "Computational Combinatorial Optimization", M. JÜNGER, D. NADDEF (editors), Springer Verlag, 2001, p. 115-160.

[9] C. LEMARÉCHAL, F. OUSTRY. *Semi-definite relaxations and Lagrangian duality with application to combinatorial optimization*, Rapport de Recherche, n° 3710, Inria, 1999, http://hal.inria.fr/inria-00072958.

[10] C. LEMARÉCHAL, F. OUSTRY, C. SAGASTIZÁBAL. *The $\mathcal{U}$-Lagrangian of a convex function*, in "Trans. AMS", vol. 352, n° 2, 2000, p. 711-729.

Year Publications

Books and Monographs

[11] V. ACARY, B. BROGLIATO. *Numerical Methods for Nonsmooth Dynamical Systems: Applications in Mechanics and Electronics*, L.N. Applied and Computational Mechanics, To appear, vol. 35, Springer Verlag, 2008.

Doctoral dissertations and Habilitation theses

[12] R. HÉLIOT. *Rehabilitation of posture and walking: coordination of valid and deficient limbs*, Ph. D. Thesis, INPG, 2007.

Articles in refereed journals and book chapters

[13] V. ACARY, B. BROGLIATO, D. GOELEVEN. *Higher order Moreau's sweeping process: Mathematical formulation and numerical simulation*, in "Mathematical Programming", to appear, 2007, https://hal.inria.fr/inria-00070762.

[14] S. ADLY, K. ADDI, B. BROGLIATO, D. GOELEVEN. *A method using the approach of Moreau and Panagiotopoulos for the mathematical formulation of non-regular circuits in electronics*, in "Nonlinear Analysis: Hybrid Systems", n° 1, 2007, p. 30-43.

[15] M. BEGON, P.-B. WIEBER, M.-R. YEADON. *Kinematics estimation of straddled movements on high bar from limited number of skin markers using a chain model*, in "Journal of Biomechanics", to appear, 2007.

[16] F. BERTAILS, B. AUDOLY, M.-P. CANI. *S'arracher les cheveux au vent*, in "La Recherche", to appear, 2007.

[17] F. BERTAILS, B. AUDOLY, M.-P. CANI, B. QUERLEUX, F. LEROY, J.-L. LÉVÊQUE. *Modélisation de coiffures naturelles à partir des propriétés physiques du cheveu*, in "Technique et Science Informatiques (TSI)", vol. 26, n^{o} 8, 2007.

[18] S. BONNET, R. HÉLIOT. *A magnetometer-based approach for studying human movements*, in "IEEE Trans. Biomedical Engineering", vol. 54, 2007, p. 1353-1355.

[19] O. BRIANT, C. LEMARÉCHAL, P. MEURDESOIF, S. MICHEL, N. PERROT, F. VANDERBECK. *Comparison of bundle and classical column generation*, in "Mathematical Programming", to appear, 2007.

[20] B. BROGLIATO. *Comments on 'Control of a planar underactuated biped on a complete walking cycle'*, in "IEEE Transactions on Automatic Control", vol. 52, n^{o} 5, 2007, p. 961-964.

[21] B. BROGLIATO, L. THIBAULT. *Well-posedness results for non-autonomous dissipative complementarity systems*, submitted to Mathematics of Control, Signal and Systems, 2007, https://hal.inria.fr/inria-00079220.

[22] M. GUILBERT, PIERRE-BRICE. WIEBER, L. JOLY. *Optimization of complex robot applications under real physical limitations*, in "International Journal of Robotics Research", to appear, 2007.

[23] R. HÉLIOT, B. ESPIAU. *Online Generation of Cyclic Leg Trajectories Synchronized with Sensor measurement*, in "Robotics and Autonomous Systems", to appear, 2007.

[24] R. HÉLIOT, C. AZEVEDO, B. ESPIAU. *Functional rehabilitation: Coordination of artificial and natural controllers*, in "Rehabilitation Robotics", S. S. KOMMU (editor), chap. 10, I-Tech Education and Publishing, 2007, p. 163-186.

[25] K. KIWIEL, C. LEMARÉCHAL. *An inexact conic bundle variant suited to column generation*, in "Mathematical Programming", to appear, 2007.

[26] C. LEMARÉCHAL, A. OUOROU, G. PETROU. *A bundle-type algorithm for routing in telecommunication data networks*, in "Computational Optimization and Applications", to appear, 2007.

[27] C. LEMARÉCHAL, A. OUOROU, G. PETROU. *An approach to robust network design in telecommunications*, in "RAIRO-RO", vol. 41, n^{o} 4, 2007, p. 411-426.

[28] J. MALICK. *Spherical constraint in Boolean quadratic programming*, in "Journal of Global Optimization", to appear, 2007.

[29] A. TONNELIER, H. BELMABROUK, D. MARTINEZ. *Event-driven simulations of nonlinear integrate-and-fire neurons*, in "Neural Computation", vol. 19, 2007, p. 1-13.

Publications in Conferences and Workshops

[30] R. HÉLIOT, S. DOSEN, C. AZEVEDO, B. ESPIAU, D. POPOVIC. *Online adaptation of optimal control of externally controlled walking of a hemiplegic individual*, in "3rd International IEEE EMBS Conference on Neural Engineeering, Kohala Coast, Hawaii, May 2007", 2007.

[31] R. HÉLIOT, B. ESPIAU, C. AZEVEDO, D. DAVID, D. POPOVIC. *FES-based training and gait evaluation of stroke patients using a microsensor on their valid leg*, in "International Society for Posture and Gait Research (ISPGR), Burlington, Vermont, July 2007", 2007.

Internal Reports

[32] K. ADDI, B. BROGLIATO, D. GOELEVEN. *A qualitative mathematical analysis of a class of variational inequalities via semi-complementarity problems. Applications in electronics*, submitted to Mathematical Protramming, Technical report, n° RR5990, INRIA, 2007, https://hal.inria.fr/inria-00103328.

[33] G. ZHENG, A. TONNELIER, D. MARTINEZ. *Voltage-stepping schemes for the simulation of spiking neural networks*, submitted to Journal of Computational Neuroscience, Technical report, Inria, 2007, http://hal.inria.fr/inria-00189386/fr/.

Miscellaneous

[34] J. MALICK, J. POVH, F. RENDL, A. WIEGELE. *Regularization methods for semidefinite programming*, Optimization on line, submitted to SIAM J. on Opt., 2007, http://www.optimization-online.org/DB_HTML/2007/10/1800.html.

[35] A. TONNELIER. *McKean Model*, Scholarpedia, 2007, http://scholarpedia.org/.

References in notes

[36] B. BROGLIATO. *Absolute stability and the Lagrange-Dirichlet theorem with monotone multivalued mappings*, in "Systems and Control Letters", vol. 51, 2004, p. 543-553.

[37] L. DUBOST, R. GONZALEZ, C. LEMARÉCHAL. *A primal-proximal heuristic applied to the French unit-commitment problem*, in "Mathematical Programming", vol. 104, n° 1, 2005, p. 129-152.

[38] K. KIWIEL. *A proximal bundle method with approximate subgradient linearizations*, in "SIAM J. on Optimization", vol. 16, n° 4, 2006, p. 1007-1023.

[39] A. LEWIS. *Nonsmooth analysis of eigenvalues*, in "Mathematical Programming", vol. 84, n° 1, 1999, p. 1-24.

[40] R. ROCKAFELLAR, R.-B. WETS. *Variational Analysis*, Springer Verlag, Heidelberg, 1998.