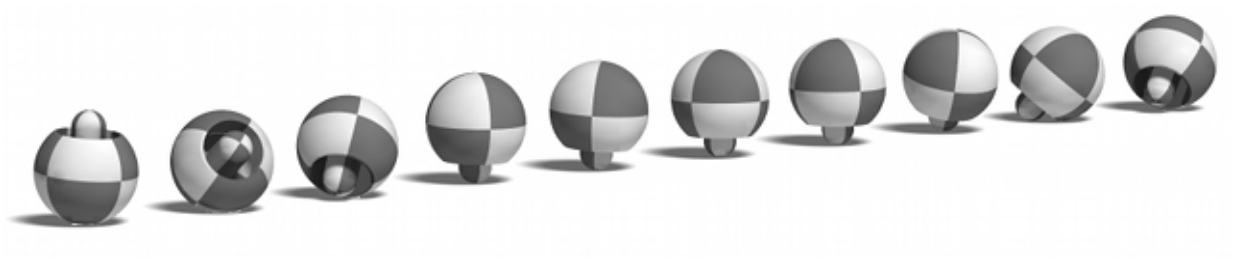


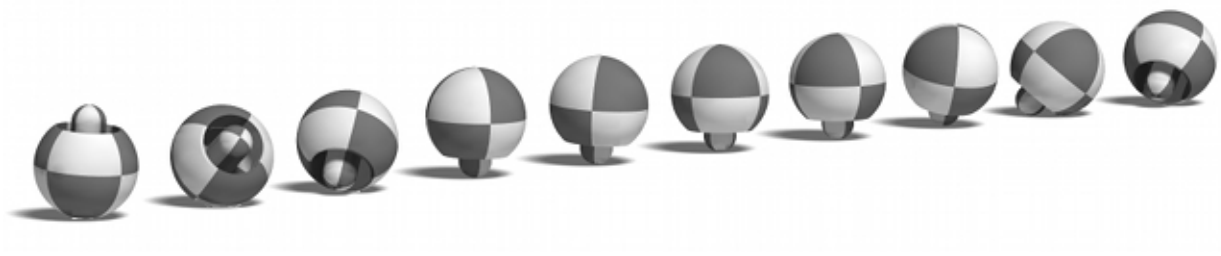
Eighth Symposium of the European Network for Nonsmooth Dynamics.

Organized by Vincent Acary, Olivier Brüls, and Remco Leine

17-18th September 2019.

Inria Grenoble - Rhône-Alpes.
Inovallée
655 avenue de l'Europe
38330 Montbonnot – France

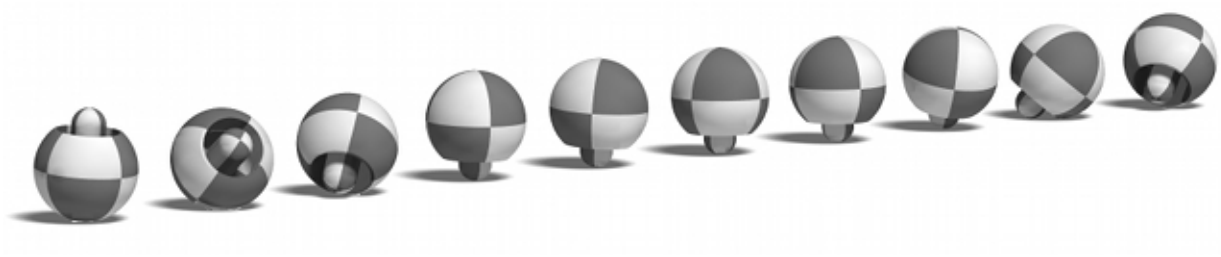
Meeting room **F108**



Timetable

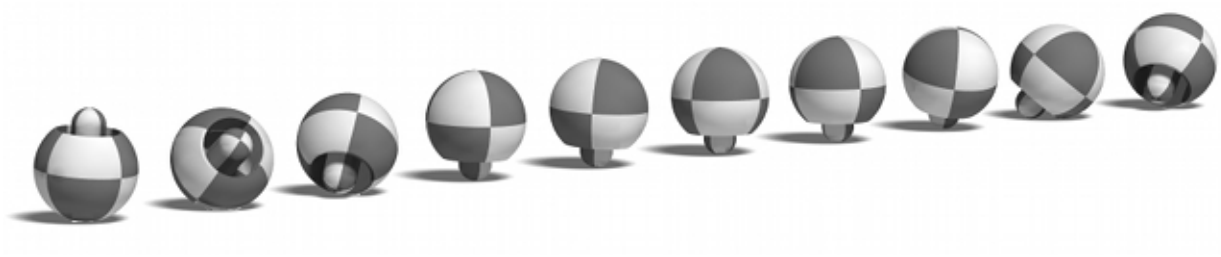
Tuesday, September 17th

8:30–8:50	**Welcome, coffee**
8:50–9:00	**Opening**
Session 1	
9:00–10:00	**Patrick Ballard** CNRS, France. Analysis of the coupling between linear elasticity and dry friction.
10:00–11:00	**Corrado Maurini** Sorbonne Université, France Nucleation and propagation of cracks in the variational approach to fracture
11:00–11:30	**Coffee break**
11:30–12:30	**Laetitia Paoli** Université de Saint-Etienne Vibrations of a beam between stops: weak and strong solutions
12:30	**Group Photo**
12:35–14:00	**Lunch**
Session 2	
14:00–15:00	**Manuela Paschkowski** Martin-Luther-Universität Halle-Wittenberg, Germany Numerical analysis of timestepping schemes for non-smooth mechanical systems with periodic solutions
15:00–15:30	**Coffee break**
15:30–16:30	**Benoit Caillaud** INRIA Bretagne Rennes Atlantique, France An Implicit Structural Analysis Method for Multi-Mode DAE Systems
19:30–	**Dinner at the restaurant**
	Les jardins de Saint Cécile 18, rue de l'Alma 38000 Grenoble France



Wednesday, September 18th

8:30–9:00	**Welcome, coffee**
Session 3	
9:00–10:00	**Paolo Frasca** INRIA, France. Non-smooth systems in opinion dynamics
10:00–11:00	**Aneel Tanwani** LAAS, CNRS, France Lyapunov Functions for Some Nonsmooth Systems
11:00–11:30	**Coffee break**
11:30–12:30	**Alessandro Saccon** Tu Eindhoven, The Netherlands Sensitivity analysis for nonsmooth mechanical systems about a trajectory with simultaneous inelastic impacts
12:30–14:00	**Lunch**
Session 4	
14:00–15:00	**Yoshihiro Kanno** University of Tokyo, Japan. Accelerated proximal gradient methods for incremental problems in plasticity
15:00–15:30	**Coffee break**
15:30–16:30	**Jozsef Kovecses** McGill University, Canada. Co-simulation of Nonsmooth Mechanical Systems
16:30–16:40	**Closing**



Useful Information

Location

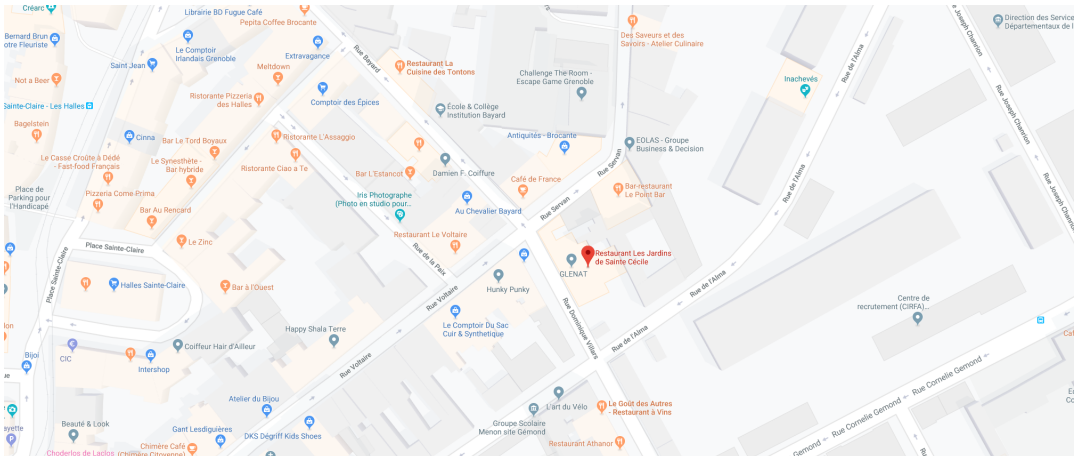
Montbonnot at Inovallée site Inria Grenoble - Rhône-Alpes Inovallée 655 avenue de l'Europe 38330 Montbonnot Meeting room F108

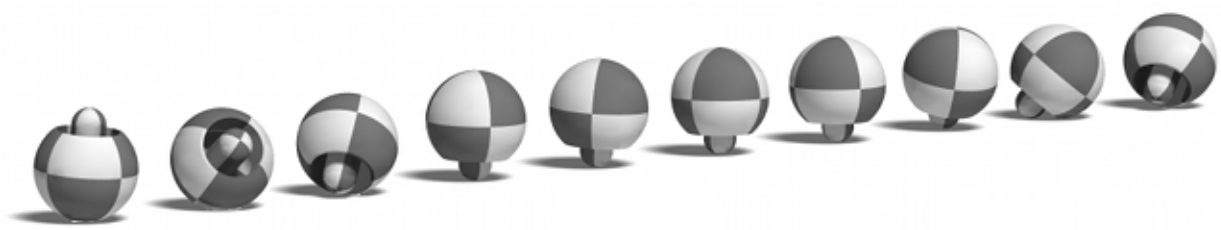
How to reach us :

https://www.inria.fr/en/centre/grenoble/overview/five-establishments-in-rhone-alpes

Dinner at the restaurant

Les jardins de Saint Cécile
18, rue de l'Alma
38000 Grenoble France
Located in the Grenoble City center. 400m meter far from "Place Notre Dame" or "Halles Sainte Claire" tramway stations.





List of Abstracts – Talks

Tuesday 17th

Analysis of the coupling between linear elasticity and dry friction.
Patrick Ballard, CNRS, France

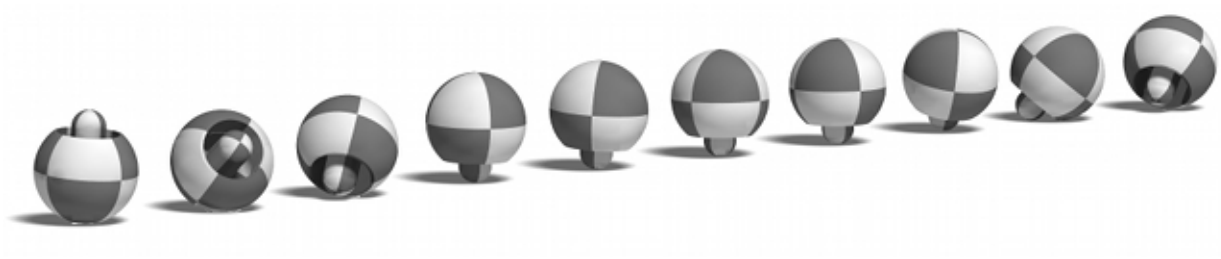
Elastic solids in frictional contact are well known to display a rich phenomenology: stick-slip, squeal, judder, etc... This phenomenology is still badly understood nowadays. One line of research consists in looking for the origin of these phenomena in complex friction laws (such as state and rate dependent friction laws). Another line of research consists in sticking to the most idealized friction law (the so-called Coulomb law of dry friction) and exploring the mathematical properties of its coupling with linear elasticity. This is this second approach which will be developed during the seminar. In particular, it will be shown that this coupling contains bifurcations which may account for the qualitative variety of response of the system. This line of research leads to the study of the effects of heterogeneous friction coefficients. The analysis yields non-intuitive new mechanical effects.

Nucleation and propagation of cracks in the variational approach to fracture
Corrado Maurini, Sorbonne Université, France

Damage and fracture in brittle materials are associated to a loss of stiffness and an energy dissipation.

These phenomena can be modelled as a minimisation problem on the sum of the elastic and the dissipated energies. This view led a fecund variational theory of fracture and to efficient numerical approximation methods based on variational regularisations. The regularised models share many similarities with phase-field models used in phase-transformation theories. Being characterised by a smeared representation of the crack set, they can be viewed as damage models introducing a gradient term on the damage variable and an internal length.

In this talk, I will review the basis of the variational approach to fracture and show how variational gradient damage models can predict nucleation and propagation of crack in



brittle solids with a minimal set of material parameters: the fracture toughness and the material strength.

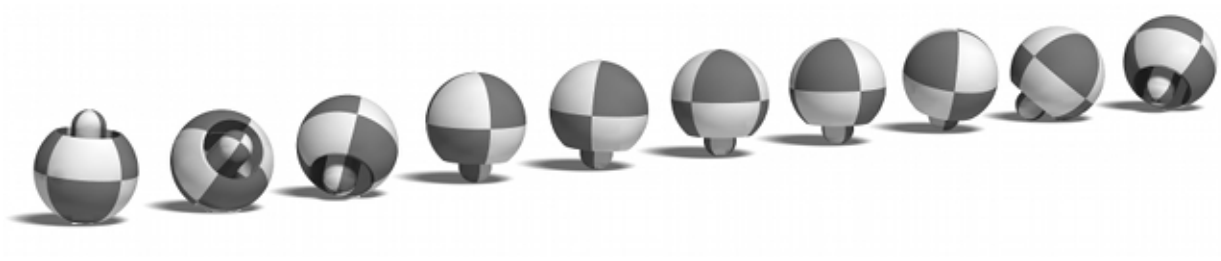
Vibrations of a beam between stops: weak and strong solutions
Laetitia Paoli, Université de Saint-Etienne

We consider the dynamics of an elastic beam between two rigid stops. The non- penetration condition leads to a weak formulation of the problem as a hyperbolic variational inequality. Existence results for weak solutions can be obtained either by using a normal compliance approximation or by using a space discretization combined with a time-stepping scheme developped for unilateral contact problems for discrete mechanical systems. In order to get better insights in the contact process we propose an alternative strong formu- lation of the problem in the framework of vector-valued measures, where the reaction shear stress appears explicitely and we prove the existence of strong solutions.

Numerical analysis of timestepping schemes for non-smooth mechanical systems with periodic solutions
Manuela Paschkowski Martin-Luther-Universität Halle-Wittenberg, Germany

Introduced by Moreau, the non-smooth and set-valued framework of measure differential inclusions allows us to describe mechanical systems with friction and impacts, including accumulation points of discontinuities. Even for simple applications like the bouncing ball or the impact oscillator this complex non-smooth effect may arise. Based on the mentioned modelling approach, the first part of the talk will cover the analytical study of one dimensional non-smooth systems with periodic solutions. We will present existence theorems for impact oscillator type problems using arguments of convex analysis and degree theory for both cases, the resonance and the non-resonance one. It can be interpreted as a measure valued generalisation of the theory for Filippov systems which are the starting point of most approaches dealing with non-smooth dynamical systems with periodic character and are no longer sufficient in presence of impacts.

Timestepping schemes are well-known possibilities to integrate such dynamical systems. Their advantage is the avoided event detection such that a large number of discontinuity points especially accumulation points of velocity jumps can be handled with higher computational efficiency. These schemes are always of integration order one with respect to discrete L^p-norms. This is a consequence of the identification of impact points only with order one independently of the approximation order in the smooth phases. In the second part of talk, the idea of orbital convergence of timestepping schemes is presented to compare the approximation accuracy of different timestepping methods. Using the framework of measure differential inclusions, the orbital convergence order of these schemes is studied for time-independent systems with periodic limit cycles. An experimental convergence analysis with different applications (impact oscillator, slider-crank mechanism) will underline the benefits of this approach.



An Implicit Structural Analysis Method for Multi-Mode DAE Systems
Benoit Caillaud, INRIA Rennes, France

The Modelica mathematical modeling language, based on Differential Algebraic Equations (DAE), brings several specific issues that do not exist with modeling languages based on Ordinary Differential Equations. The main problem is the determination of the differentiation index and of the latent equations. Prior to generating simulation code and calling solvers, the compilation of a Modelica model requires a structural analysis step, which reduces the differentiation index to a level acceptable by numerical solvers.

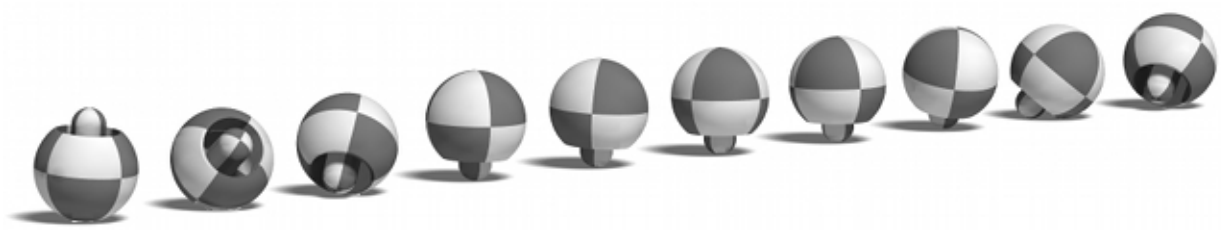
The Modelica language allows hybrid models with multiple modes, mode-dependent dynamics and state-dependent mode switching. These Multimode DAE (mDAE) systems are much harder to deal with. The main difficulties are (i) the combinatorial explosion of the number of modes and (ii) the correct handling of mode switchings.

In this talk, we focus on the first issue, namely: How can we perform a structural analysis of a mDAE in all possible modes, without enumerating these modes? We present a structural analysis algorithm for mDAE systems, based on an implicit representations of the varying structure of a mDAE. It generalizes J. Pryce's Sigma-method to the multimode case and uses Binary Decision Diagrams (BDD) to represent the mode-dependent structure of a mDAE. The algorithm determines, as a function of the mode, the set a latent equations, the leading variables and the state vector. This is then used to compute a mode-dependent block-triangular decomposition of the system, that can be used to generate simulation code with a mode-dependent scheduling of the blocks of equations.

Wednesday 18th

Non-smooth systems in opinion dynamics
Paolo Frasca, INRIA, France

The basic assumption in opinion dynamics is that one's opinion is attracted by other's opinions. Provided enough interactions occurs between the individuals, this assumption implies that consensus is asymptotically achieved. However, experience suggests that consensus is not always achieved, but disagreement persists. One explanation for such persistence postulates that individuals do not influence each other if their opinions are too far apart. The simplest way to model this idea –referred to as "bounded confidence"– is based on a fixed threshold: individuals interact if their opinions are closer than the threshold. Another explanation for persistent disagreement is that individuals do not share opinions directly, but communicate by (possibly imprecise) verbalisations or by taking certain actions. These effects can be modelled as quantisation effects. Including either bounded confidence or quantisation makes the system discontinuous and brings the need



for studying the limit behaviour of its generalised solutions. In the case of bounded confidence, we provide results of existence, completeness and convergence to clusters of agents sharing a common opinion. In the case of quantisation, we show that in general consensus can not be expected and we give an asymptotic estimate of the distance from consensus. However, we show that consensus is actually achieved on complete and on complete bipartite graphs. This is joint work with Francesca Ceragioli (Politecnico di Torino, Italy)

Lyapunov Functions for Some Nonsmooth Systems
Aneel Tanwani, LAAS – CNRS, Toulouse, France

In this talk, I will talk about constructions of Lyapunov functions for a certain class of nonsmooth system. I will provide conditions on system dynamics under which the systems under consideration admit a Lyapunov function. Numerical methods for computing such functions will also be discussed.

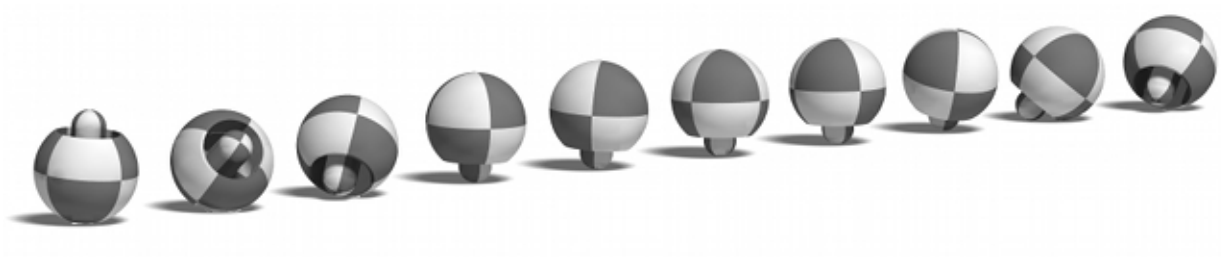
Sensitivity analysis for nonsmooth mechanical systems about a trajectory with simultaneous inelastic impacts
Alessandro Saccon, Tu Eindhoven, The Netherlands

Sensitivity analysis for dynamical systems with state-triggered state jumps has experienced renewed attention for the control of robots with intermittent contacts. The basic assumption that enables this type of analysis is that jumps are triggered when the state reaches, transversally, a sufficiently smooth switching surface. In many scenarios of practical relevance, however, this switching surface is just piecewise smooth and, moreover, a perturbation of the initial conditions or the input leads to a different number of jumps than the nominal trajectory's. This work extends the sensitivity analysis in this context, under suitable assumptions. Numerical simulations complement and validate the theoretical findings.

Accelerated proximal gradient methods for incremental problems in plasticity
Yoshihiro Kanno, University of Tokyo, Japan

Recently, acceleration of gradient methods has received considerable attention, particularly for solving large-scale convex optimization problems arising in machine learning, image processing, statistical inference, etc. Such a method has fast local convergence rate, as well as cheap computational cost for each iteration.

In this talk, application of accelerated proximal gradient methods for quasistatic elastoplastic problems is discussed. As the simplest case, we begin with elastoplastic trusses, the incremental problem of which is known to be formulated as a quadratic programming (QP) problem. We show that this QP is equivalently reformulated as a nonsmooth unconstrained optimization problem, with in the objective function a quadratic function and the sum of absolute values. This formulation is suited for an accelerated proximal



gradient method. Numerical experiments demonstrate that the proposed method is faster than standard QP solvers.

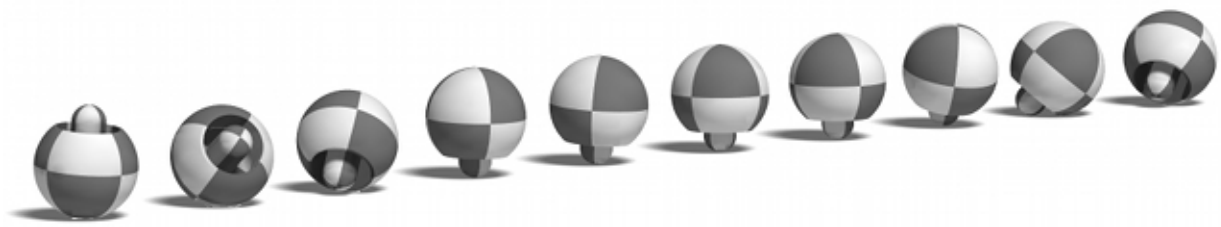
The presented method can be naturally extended to elastoplastic continua with the von Mises or Tresca yield criterion. Also, we discuss acceleration of ADMM (alternating direction method of multipliers) for frictional contact problems.

This talk is partially based on joint works with Wataru Shimizu, Vincent Acary, and Nicolas Molina.

Co-simulation of Nonsmooth Mechanical Systems

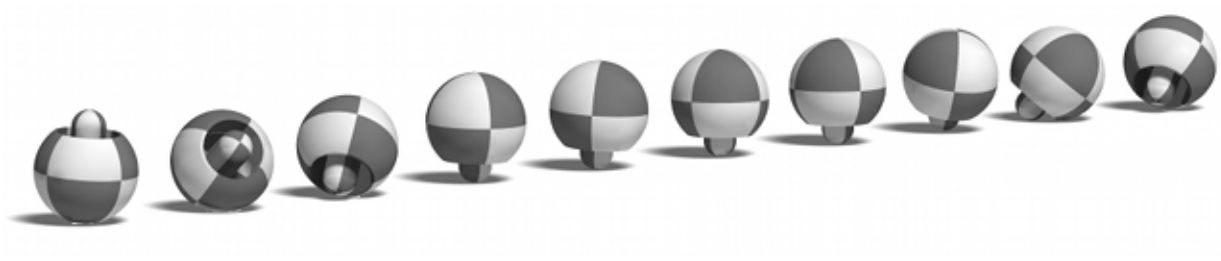
Jozsef Kovecses, McGill University, Canada.

In real-time simulation based virtual environments or virtual prototyping subsystem models often have to be coupled through non-iterative co-simulation. The stability of the simulation represents a key problem for these cases. Such problems can be traced back to how information is exchanged between subsystems at the communication time points. In this talk we will particularly discuss cases where the main subsystem is a nonsmooth multibody mechanical system model and it interfaces subsystems from other domains such as hydraulic system models. We will discuss a novel approach to the solution of the stability and information exchange problems. This relies on a reduced model of the mechanical subsystem inside the macro time step. We will use some examples of machine system models for illustration.



List of Participants

Vincent Acary	INRIA Grenoble France	vincent.acary@inria.fr
Martin Arnold	Martin-Luther-Universität Halle-Wittenberg Germany	martin.arnold@mathematik.uni-halle.de
Patrick Ballard	CNRS, France	patrick.ballard@dalembert.upmc.fr
Urs Becker	Altair, Germany	urs.becker@altair.de urs.becker@altair.de
Charlélie Bertrand	ENTPE Lyon France	charlelie.bertrand@entpe.fr
Franck Bourrier	ISRTEA & INRIA Grenoble France	franck.bourrier@irstea.fr
Bernard Brogliato	INRIA Grenoble France	bernard.brogliato@inria.fr
Olivier Bruls	U. Liège, Belgium	o.bruls@ulg.ac.be
Benoit Caillaud	INRIA Rennes, France	benoit.caillaud@inria.fr
Federico Cavalieri	Universidad Nacional del Litoral, CONICET, CIMEC (Santa Fe, Argentina)	fcavalieri@cimec.unl.edu.ar
Alejandro Cosimo	U. Liège, Belgium	alecosimo@gmail.com
Frederic Dubois	LMGC, Montpellier, France	frederic.dubois@umontpellier.fr
Paolo Frasca	INRIA, France	paolo.frasca@inria.fr
Khalil Ghorbal	INRIA Rennes, France	Khalil.ghorbal@inria.fr
Christoph Glocker	ETH Zurich, Switzerland	christoph.glocker@imes.mavt.ethz.ch
Guillaume James	INRIA Grenoble France	guillaume.james@univ-grenoble-alpes.fr
Yoshihiro Kanno	University of Tokyo, Japan	kanno@mist.i.u-tokyo.ac.jp
Jozsef Kovecses	U. McGill, Canada	jozsef.kovecses@mcgill.ca
Christelle Kozaily	INRIA Rennes, France	christelle.kozaily@inria.fr
Remco Leine	U. Stuttgart, Germany	remco-ingmar.leine@inm.uni-stuttgart.de
Corrado Maurini	Sorbonne Université, France	corrado.maurini@upmc.fr
Laetitia Paoli	U. Saint Etienne. France	Laetitia.Paoli@univ-st-etienne.fr
Manuela Paschkowski	Martin-Luther-Universität Halle-Wittenberg, Germany	manuela.paschkowski@mathematik.uni-halle.de
Alexandre Rocca	INRIA Grenoble France	alexandre.rocca@inria.fr



Alessandro Saccon	Tu Eindhoven, The Netherlands	a.saccon@tue.nl
Aneel Tanwani	LAAS – CNRS, Toulouse, France	aneel.tanwani@laas.fr
Alireza Ture Savadkoohi	ENTPE Lyon France	alireza.turesavadkoohi@entpe.fr