2018-00575 - PhD position : Structural analysis of nonsmooth DAE systems

**Context**
This PhD will be co-supervised by Vincent Acary (Tripop team at Inria Grenoble) and Benoît Caillaud (HYCOMES team at Inria Rennes), in the realm of the IPL ModeliScale initiative on cyber-physical systems modeling, simulation and verification: [https://team.inria.fr/modeliscale/](https://team.inria.fr/modeliscale/)

The PhD student will be located either at Inria Grenoble or at Inria Rennes.

**Assignment**
Not applicable

**Main activities**
Modeling languages such as Modelica and SimScape are based on systems of algebraic differential equations (DAE). Although modeling is made scalable with the use of DAE, simulating large CPS is a challenge because of their exponential number of modes. Although the structural analysis of pure DAE systems is now well established and benefits from fast algorithms (based on graph theory or linear programming), the state-of-the-art structural analysis methods for multi-mode DAE systems either relies on overly restrictive assumptions on the structure of the model, or faces the combinatorial explosion of mode enumeration.

Modeling CPS with hybrid state machines is not always the best option at hand: there are alternative modeling paradigms, avoiding the inherent drawbacks of hybrid state machines. A fine example are NonSmooth Dynamical Systems (NSDS), a formalism best suited to capture the dynamics of multibody mechanical systems (with contacts and friction), switched electronic circuits, or gene regulatory networks in cell biology. NSDSs can be formulated in several ways, using Filippov differential inclusions (with piece-wise continuous functions appearing on the right-hand side of the differential inclusions), or using complementarity conditions.

The correct formulation of a NSDS has to follow a very strict structure, and modeling a CPS in this way often proves to be a challenging task. CPS models expressed in an equation-based language such as Modelica should not be expected to follow a predetermined structure. On the contrary, the model should rather be structured according to the physical structure of the system, in a component-based fashion. The mathematical structure of the model has to be discovered by the compiler, and this is the purpose of the structural analysis, implemented in most Modelica tools. Extending Modelica to NSDS requires new structural analysis algorithms, adapted to the new language constructs (piece-wise continuous operators or complementarity conditions). This research topic encompasses both theoretical developments on the structural analysis of nonsmooth DAE systems (combining algebraic differential equations, complementarity conditions and/or piece-wise continuous operators), the design and implementation of efficient graph-theoretic structural analysis algorithms for these systems, and the generation of simulation code for NSDS numerical solvers (for instance, the Siconos library).

**Skills**
Scientists with a Master degree in Computer Science, Applied Mathematics or Automatic Control are invited to apply. Knowledge of the Modelica language will be a plus, but is not necessary.

**Benefits package**
- Subsidised catering service
- Partially-reimbursed public transport
- Social security
- Paid leave
- Sports facilities

**Remuneration**
1982 euros (gross salary)