2018-00651 - Post-doctoral position: Structural analysis of nonsmooth DAE systems. FUI Modeliscale

Contract type: Public service fixed-term contract
Level of qualifications required: PhD or equivalent
Function: Post-Doctoral Research Visit
Level of experience: Recently graduated

About the research centre or Inria department
Grenoble Rhône-Alpes Research Center groups together a few less than 800 people in 35 research teams and 9 research support departments.

Staff is localized on 5 campuses in Grenoble and Lyon, in close collaboration with labs, research and higher education institutions in Grenoble and Lyon, but also with the economic players in these areas.

Present in the fields of software, high-performance computing, Internet of things, image and data, but also simulation in oceanography and biology, it participates at the best level of international scientific achievements and collaborations in both Europe and the rest of the world.

Context
TRIPOP is a joint research team of Inria Grenoble Rhône-Alpes and of the Laboratoire Jean Kuntzmann and started in January 2018 as a follow up of the BIPOP team. The team is mainly concerned by the modeling, the simulation and the control of nonsmooth dynamical systems. Nonsmooth dynamics concerns the study of the time evolution of systems that are not smooth in the mathematical sense, i.e., systems that are characterized by a lack of differentiability, either on the mappings in theirs formulations, or of theirs solutions with respect to time. In mechanics, the main instances of nonsmooth dynamical systems are multibody systems with Signorini’s unilateral contact, set-valued (Coulomb-like) friction and impacts. In Electronics, the main instances are switched electrical circuits with ideal components (diodes, switches, transistors, ...)

Within the framework of a partnership
This position is available in the context of a FUI project, Modeliscale https://team.inria.fr/modeliscale/ coordinated by Dassault Systems and in collaboration with two others INRIA teams, HYCOMES, INRIA Rennes and PARKAS, INRIA Paris.

Assignment
Modeling languages such as Modelica https://www.modelica.org and SimScape https://fr.mathworks.com products/simscape.html 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 neither 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 multidbody 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).

**Main activities**

The main activities of the post-doctoral fellows will be:

- Enrich the Modelica language capabilities including new components based in the nonsmooth dynamical systems paradigm (complementarity, relay, multi-valued law)
- Perform the structural analysis of the hybrid systems mixing DAE and nonsmooth dynamics
- Implement a prototype that allows to generate simulation code for siconos from a Modelica description

**Skills**

Applied Mathematics, Dynamical Systems, Hybrid Systems, Programming Languages

**Benefits package**

- Subsidised catering service
- Partially-reimbursed public transport
- Social security
- Paid leave
- Flexible working hours
- Sports facilities

**Remuneration**

Gross income: 2653€