Offre n°2025-09207

PhD Position F/M Filippov Solutions for Discontinuous Differential-Algebraic Equations (DAEs): Control and Simulation

Type de contrat : Fixed-term contract

Niveau de diplôme exigé : Graduate degree or equivalent

Fonction : PhD Position

A propos du centre ou de la direction fonctionnelle

The Inria Rennes - Bretagne Atlantique Centre is one of Inria's eight centres and has more than thirty research teams. The Inria Center is a major and recognized player in the field of digital sciences. It is at the heart of a rich R&D and innovation ecosystem: highly innovative PMEs, large industrial groups, competitiveness clusters, research and higher education players, laboratories of excellence, technological research institute, etc.

Contexte et atouts du poste

Collaboration & Contacts

- This PhD is conducted in collaboration with Prof. Stephan Trenn at the University of Groningen (The Netherlands). The selected candidate is expected to visit Groningen regularly.
- There is also the possibility of pursuing a double doctoral degree, which would include a 1-year extension to meet Dutch PhD requirements.
- This position will be funded by ANR JCJC Project: **GFdDAE** (ANR-25-CE48-4916)
- Contacts: yahao.chen@inria.fr, benoit.caillaud@inria.fr, s.trenn@rug.nl

Context & Background

Differential-algebraic equations (DAEs) arise naturally when modeling dynamical systems from first principles. In many cases, physical laws are expressed as combinations of differential and algebraic equations. This modeling approach is common in constrained mechanics, chemical and biological processes, power systems, and especially analog circuit design—where idealized components (e.g., resistors, capacitors, inductors) and Kirchhoff’s laws define the system dynamics.

When these systems experience abrupt changes—such as switching in electric circuits, mechanical contacts, or discontinuous control inputs—**discontinuous DAEs** emerge. However, there is currently no comprehensive theoretical foundation for studying such systems. Challenges include:

- Their **hybrid behaviors**, which differ significantly from ODE counterparts,
- The **inconsistent initialization problem** caused by switching and algebraic constraints,
- The occurrence of **Dirac impulses** due to state jumps.

Without a rigorous solution concept, tasks such as simulation, stability analysis, and control design lack solid justification.

Discontinuous DAEs are relevant across many research areas, including systems and control, hybrid systems, and computer-aided simulation. A notable example is **switched DAEs**. While time-dependent switching has been extensively studied [2-5], progress on **state-dependent switching**, a subclass of discontinuous DAEs, remains limited.

The **Hycomes** team at Inria Rennes has contributed to related research through the concept of **multi-mode DAEs,** in the context of the **Modelica** language [6-7]. Despite these advancements, challenges persist, including:

- Computing consistent initial values and jumps,
- Managing sliding and chattering behaviors,
- Addressing scalability for large-scale, high-dimensional systems.

These issues emphasize the need for refined mathematical foundations and advanced control methods compatible with Modelica-based simulation platforms.

[1] D. Liberzon. Switching in Systems and Control. Systems and Control: Found. and Appl. Boston: Birkhäuser, 2003.

[2] D. Liberzon and S. Trenn. “On stability of linear switched differential algebraic equations”. In: Proc. IEEE CDC 2009, pp. 2156–2161.

[3] D. Liberzon and S. Trenn. “Switched nonlinear differential algebraic equations: Solution theory, Lyapunov functions, and stability”. In: Automatica 48.5, pp. 954–963.

[4] Y. Chen and S. Trenn. “Impulse-free jump solution of nonlinear differential algebraic equation”. In: Nonlinear Analysis: Hybrid Systems 46 (2022), p. 101238.

[5] Y. Chen and S. Trenn. “On impulse-free solutions and stability of switched nonlinear differential–algebraic equations”. In: Automatica 156 (2023), p. 111208

[6] A. Benveniste, B. Caillaud, and M. Malandain. “The mathematical foundations of physical systems modeling languages”. In: Ann. Rev. in Control 50 (2020), pp. 72–118.

[7] A. Benveniste, B. Caillaud, M. Malandain, and J. Thibault. “Algorithms for the structural analysis of multimode modelica models”. In: Electronics 11.17 (2022),

p. 2755.

[8] A.F. Filippov. Differential Equations with Discontinuous Right-hand Sides. English (Transl. from the Russian). Mathematics and Its Applications: Soviet Series, 18. Dordrecht etc.: Kluwer Academic Publishers, 1988.

[9] Y. Shtessel, C. Edwards, L. Fridman, A. Levant, et al. Sliding Mode Control and Observation. Vol. 10. Springer, 2014

Mission confiée

For discontinuous ODEs, the **Filippov solution framework** [8] plays important roles both theoretically (e.g., in switching ODE systems [1] and sliding mode control [9]) and practically (e.g., via Filippov-type solvers in MATLAB). This PhD project aims to:

1. Extend the **Filippov solution concept** to discontinuous DAEs,
2. Integrate the proposed framework into **simulation tools**, particularly **Modelica**.

Principales activités

The PhD student will focus on the following tasks:

1. Conduct a thorough literature review of discontinues DAEs and related systems (e.g., complementarity systems, switching DAEs, hybrid systems).
2. Starting with **discontinuous linear DAEs**, propose a solution concept and prove **well-posedness**.
3. Extend the theory to **nonlinear systems** and compare it with other existing frameworks.
4. Perform **stability analysis** and develop **stabilization or control strategies** for discontinuous DAEs.
5. Implement simulation methods in **Modelica tools**, and test them on benchmark examples.

Deliverables include scientific reports, papers submitted to international conferences and journals, and prototype simulation code.

Compétences

Technical Skills

- Solid understanding of **system modeling**, **control theory**, and **differential equations**
- Familiarity with any of the following topics would be appreciated:
    - **DAEs**, **switched systems**, **complementarity systems**, **sliding mode control**;
    - **hybrid systems simulation, Modelica**;
    - power electronics, **contact mechanics, multiphysics modeling**.

Avantages

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  - Subsidized meals
  - Partial reimbursement of public transport costs
  - Possibility of teleworking (90 days per year) and flexible organization of working hours
  - Partial payment of insurance costs

Rémunération

monthly gross salary 2200 euros

Informations générales

- **Thème/Domaine :** Optimization and control of dynamic systems
  Information system (BAP E)
- **Ville :** Rennes
- **Centre Inria :** Centre Inria de l'Université de Rennes
- **Date de prise de fonction souhaitée :** 2026-01-02
- **Durée de contrat :** 3 years
- **Date limite pour postuler :** 2025-09-22

Contacts

- **Équipe Inria :** HYCOMES
- **Directeur de thèse :**
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A propos d'Inria

Inria est l’institut national de recherche dédié aux sciences et technologies du numérique. Il emploie 2600 personnes. Ses 215 équipes-projets agiles, en général communes avec des partenaires académiques, impliquent plus de 3900 scientifiques pour relever les défis du numérique, souvent à l’interface d’autres disciplines. L’institut fait appel à de nombreux talents dans plus d’une quarantaine de métiers différents. 900 personnels d’appui à la recherche et à l’innovation contribuent à faire émerger et grandir des projets scientifiques ou entrepreneuriaux qui impactent le monde. Inria travaille avec de nombreuses entreprises et a accompagné la création de plus de 200 start-up. L'institut s'e?orce ainsi de répondre aux enjeux de la transformation numérique de la science, de la société et de l'économie.

L'essentiel pour réussir

Requirements

- M.Sc. degree in **systems and control**, **applied mathematics**, **computer science**, or related fields
- Proficiency in **academic English writing** and fluency in **spoken English**
- Strong **mathematical thinking** and problem-solving skills
- Scientific curiosity, **autonomy**, and the ability to work independently

Attention: Les candidatures doivent être déposées en ligne sur le site Inria. Le traitement des candidatures adressées par d'autres canaux n'est pas garanti.

Consignes pour postuler

Please submit online : your resume, cover letter and letters of recommendation eventually

Sécurité défense :
Ce poste est susceptible d'être affecté dans une zone à régime restrictif (ZRR), telle que définie dans le décret n°2011-1425 relatif à la protection du potentiel scientifique et technique de la nation (PPST). L'autorisation d'accès à une zone est délivrée par le chef d'établissement, après avis ministériel favorable, tel que défini dans l'arrêté du 03 juillet 2012, relatif à la PPST. Un avis ministériel défavorable pour un poste affecté dans une ZRR aurait pour conséquence l'annulation du recrutement.

Politique de recrutement :
Dans le cadre de sa politique diversité, tous les postes Inria sont accessibles aux personnes en situation de handicap.