Offre n°2025-09046

PhD Position F/M Large-time behavior and large-population limits of non-exchangeable particle systems

Type de contrat : Fixed-term contract

Niveau de diplôme exigé : Graduate degree or equivalent

Fonction : PhD Position

Contexte et atouts du poste

The PhD project will be carried out in the project-team MUSCLEES at the Centre Inria de Paris under the joint supervision of Nastassia Pouradier Duteil (CR Inria) and Benoît Bonnet-Weil (CR CNRS) within the framework of the ANR project FISH (selF-organization of Interacting particle Systems with Heterogeneity).

Mission confiée

Many living systems exhibit fascinating dynamics of collective behavior during locomo-tion, from bacterial colonies to human crowds. The celebrated Cucker-Smale model describes the dynamics of a group of N interacting particles whose positions and velocities satisfy a system of differential equations representing the equations of motion.

The particles are said to be *exchangeable* (or identical) if they can be relabeled without impacting the global dynamics. In the exchangeable case, the Cucker-Smale system is known to exhibit a flocking behaviour,that is the asymptotic alignment of all the individual agent velocities, under a “fat-tail” condition onthe interaction kernel, see for instance the surveys [4, 5, 6]. These results were extended to the non-exchangeable case in several works including e.g. [1], under some additional conditions on thecommunication weights.

When the number of interacting agents tends to infinity, the microscopic system can be shown to converge to a continuum limit, which can be written as an integro-differential equation, in which the variables act as labels keeping track of the identities of the individual particles. In this infinite-dimensional framework, the communication weights are replaced by graphons, which can be heuristically understood as generalised adjacency matriceswhose evaluation corresponds to the propensity that one agent has to follow another agent.

Using another set of techniques (known as the non-exchangeable mean-field limit), the same microscopic system can be shown to converge to the solution to a non-local transport-type partial differential equation.

[1] B. Bonnet and É. Flayac. Consensus and Flocking under Communication Failures for a Class of Cucker-SmaleSystems. System and Control Letters, 152:104930, 10, 2021.

[2] B. Bonnet, N. Pouradier Duteil, and M. Sigalotti. Consensus Formation in First-Order Graphon Models with Time-Varying Topologies.Mathematical Methods and Models in Applied Sciences, 32(11):2121–2188, 2022.

[3] L. Boudin, F. Salvarani, and E. Trélat. Exponential Convergence Towards Consensus for Non-Symmetric LinearFirst-Order Systems in Finite and Infinite Dimensions. SIAM Journal on Mathematical Analysis, 54(3):2727–2752,2022.

[4] Y.-P. Choi, S.-Y. Ha, and Z. Li. Emergent Dynamics of the Cucker-Smale Flocking Model and its Variants. ActiveParticles, Volume 1: Advances in Theory, Models, and Applications, pages 299–331, 2017.

[5] S.-Y. Ha, K. Lee, and D. Levy. Emergence of Time-Asymptotic Flocking in a Stochastic Cucker-Smale System.Comm. Math. Sci., 7(2):453–469, 2009.

[6] S. Motsch and E. Tadmor. Heterophilious Dynamics Enhances Consensus. SIAM Review, 56(4):577–621, 2014.

Principales activités

The first goal of this PhD is to extend the existing results of convergence toflocking for the microscopic system to its continuum limit. Following the insights garnered in [2], a first natural lead to explore will be that of time-independent coefficients with positive scrambling,which correspond to topologies in which every pair of agents follows a common third party individual. Another relevant setting to investigate is that of interaction topologies with positive Fiedler number,following [1], wherein the sufficient well-connectedness of the system is understood in terms of con-nectivity properties of the underlying graph, see also [3] for a graphon counterpart of this object.

Further objectives will include (depending on the student’s appetence):

- Studing convergence to flocking in the framework of the mean-field limit equation;
- Studying other types of collective behavior introduced by the systel’s non-exchangeability
- Studying the control of the particle system in order to drive the group to a predetermined collective configuration;
- Deriving rigorously the mean-field limit of more general non-exchangeable particle systems.

Compétences

The applicant should have a solid background in the analysis of Ordinary Differential Equations (ODEs) and Partial Differential Equations (PDEs). Depending on the evolution of the PhD, a more general interest for Measure Theory and Functional Analysis, the study of infinite dimensional systems through the lens of Control Theory, or a keen interest in the practical modelling of Collective Dynamics would be very welcomed traits.

Avantages

- Subsidized meals
- Partial reimbursement of public transport costs
- Leave: 7 weeks of annual leave + 10 extra days off due to RTT (statutory reduction in working hours) + possibility of exceptional leave (sick children, moving home, etc.)
- Possibility of teleworking and flexible organization of working hours
- Professional equipment available (videoconferencing, loan of computer equipment, etc.)
- Social, cultural and sports events and activities

Informations générales

- **Thème/Domaine :** Modeling and Control for Life Sciences
  Biologie et santé, Sciences de la vie et de la terre (BAP A)
- **Ville :** Paris
- **Centre Inria :** Centre Inria de Paris
- **Date de prise de fonction souhaitée :** 2025-09-01
- **Durée de contrat :** 3 years
- **Date limite pour postuler :** 2025-07-22

Contacts

- **Équipe Inria :** MUSCLEES
- **Directeur de thèse :**
  Pouradier Duteil Nastassia / nastassia.pouradierduteil@inria.fr

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.

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

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.