Offer #2025-08919

Post-Doctoral Research Visit F/M Single-cell modeling of biochemical processes with fluorescence microscopy data collected from microfluidic chips with ring-shape channels

Contract type : Fixed-term contract

Renewable contract : Yes

Level of qualifications required : PhD or equivalent

Fonction : Post-Doctoral Research Visit

About the research centre or Inria department

The Inria Saclay-Île-de-France Research Centre was established in 2008. It has developed as part of the Saclay site in partnership with ***Paris-Saclay University*** *and with the* ***Institut Polytechnique de Paris*** *.*

The centre has ***40 project teams*** *, 32 of which operate jointly with Paris-Saclay University and the Institut Polytechnique de Paris; Its activities occupy over 600 people, scientists and research and innovation support staff, including 44 different nationalities.*

Context

The project is part of the ERC Starting Grant of Jakob Ruess (Lifeware team at Inria Saclay). Inria is the French national institute for research in computer science, control, and applied mathematics promoting scientific excellence and technology

transfer. Within this project, we primarily work on the development of mathematical modeling approaches and statistical inference/estimation methods but we also collaborate with biologists to apply our methods to real data. Our main long-term goal is to develop a comprehensive methodological framework supporting the development of a quantitative understanding of biochemical processes inside single cells that are coupled to the dynamics of growing cell populations. Our research topics are at the intersection of mathematical biology, statistics, control engineering, and statistical physics applied to problems in biology.

This job announcement is for a 2-year postdoc position on the project but we are generally looking for young scientists at all career stages (internship, PhD, postdoc) to join the team at any time in 2025.

Assignment

In collaboration with Dr. Remy Chait (University of Exeter, UK), we have recently developed new microfluidics chips for single-cell fluorescence microscopy experiments with bacteria or yeast cells. The chips are based on the design of the so-called “mother machine” but replace the dead-end channels of the mother machine by rings. These chip designs allow us to track single cells (and cell lineages) in the ring, which enables us to perform much longer microscopy experiments with cells that are more representative of typical cells in a growing population compared to the single aging “mother” cell that is tracked in standard mother machine devices. Microscopy data (cell size dynamics and expression levels of fluorescent proteins) collected with these new chip designs is available for this project and AI models for image analysis and cell tracking have already been trained but the new structure and quantity of the data raise the need for the development of new approaches for mathematical modeling to extract knowledge about single-cell processes from the data.

The primary goal of this project is to develop a modeling framework that abstracts mechanistic descriptions of stochastic single-cell processes (such as stochastic reaction networks) into models that track state changes of cells from birth to division coupled to splitting kernels that distribute the cellular content between daughter cells at division. These models will then be parameterized with the available microscopy data. Another aim of the project is to study how cell-to-cell variability in single-cell growth rates impacts residence times of cells on the microfluidic chip, to incorporate growth rate variability in the developed single-cell models, and to use these results to study the role of selection of fast-growing cells for these new types of experiments.

Main activities

Overview of the ERC Project:

Synthetic biology aims at engineering biochemical processes to supplement cells with artificial functionality. To this end, we design synthetic gene circuits that operate as dynamical systems inside cells and deploy methods from control engineering to regulate circuit functionality. A key problem in this is that biochemical processes inside single cells are inherently stochastic and create heterogeneity within cell populations that eventually leads to complex couplings between single-cell processes and population dynamics. It is thus difficult to quantitatively predict how exactly a constructed circuit will function in the context of a growing population and to design single-cell circuits such that desired dynamics emerge at the population scale.
At the single-cell scale, stochastic biochemical processes are typically represented as continuous-time Markov chains governed by a chemical master equation (Kolmogorov forward equations). We have recently started to develop a multi-scale modeling framework that augments models of single-cell processes with population scale processes such as growth and selection (Ruess et al., The Journal of Chemical Physics, 2023).
Our multi-scale modeling framework gives us unprecedented opportunities to forward-simulate coupled dynamics of stochastic single-cell and population processes, which paves the way to model, design, and dynamically control synthetic gene circuits so as to create desired functionality within growing populations.
Within this project, we thus aim to focus on the development of methods for reverse engineering and controlling multi-scale models and on applying this methodology in real applications for a collection of gene circuits constructed by our collaborators.

Links to publications:
https://doi.org/10.1063/5.0160529
https://doi.org/10.1371/journal.pcbi.1009214
https://doi.org/10.1073/pnas.2114438119
https://doi.org/10.1007/s00285-023-01876-x

Skills

Candidates for the postdoc position should have a PhD in a theoretical field, such as mathematics, physics, computer science, control engineering or similar, and be capable of using methods from these fields to study dynamical systems and stochastic processes in applications. Specific experience with either continuous-time Markov chains, stochastic differential equations, stochastic chemical kinetics is a plus. Expertise in biology is not required but candidates are expected to build up an understanding of our concrete applications throughout the course of the project. Candidates who expect to finish their PhD-studies in the near future are also encouraged to apply.

Benefits package

- 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
- Access to vocational training
- Social security coverage

Remuneration

2788€ gross/month

General Information

- **Theme/Domain :** Modeling and Control for Life Sciences
  Biologie et santé, Sciences de la vie et de la terre (BAP A)
- **Town/city :** Palaiseau
- **Inria Center :** Centre Inria de Saclay
- **Starting date :** 2025-09-01
- **Duration of contract :** 2 years
- **Deadline to apply :** 2025-08-31

Contacts

- **Inria Team :** LIFEWARE
- **Recruiter :**
  Ruess Jakob / jakob.ruess@inria.fr

About Inria

Inria is the French national research institute dedicated to digital science and technology. It employs 2,600 people. Its 200 agile project teams, generally run jointly with academic partners, include more than 3,500 scientists and engineers working to meet the challenges of digital technology, often at the interface with other disciplines. The Institute also employs numerous talents in over forty different professions. 900 research support staff contribute to the preparation and development of scientific and entrepreneurial projects that have a worldwide impact.

The keys to success

Applications should include a CV, list of publications, and contact details of scientists willing to recommend the candidate.

Warning : you must enter your e-mail address in order to save your application to Inria. Applications must be submitted online on the Inria website. Processing of applications sent from other channels is not guaranteed.

Instruction to apply

Defence Security :
This position is likely to be situated in a restricted area (ZRR), as defined in Decree No. 2011-1425 relating to the protection of national scientific and technical potential (PPST).Authorisation to enter an area is granted by the director of the unit, following a favourable Ministerial decision, as defined in the decree of 3 July 2012 relating to the PPST. An unfavourable Ministerial decision in respect of a position situated in a ZRR would result in the cancellation of the appointment.

Recruitment Policy :
As part of its diversity policy, all Inria positions are accessible to people with disabilities.