PhD Position: Monte Carlo methods and uncertainty quantification applied to nerve cell models

Advisors: Pierre Nyquist, Olivia Eriksson, Andrei Kramer.

Doctoral program: Applied and Computational Mathematics; also part of SeRC and SciLifeLab.

Job description

This PhD project is a collaboration between researchers in the Department of Mathematics and the Division of Computational Science and Technology at KTH, within SeRC's Brain-IT program. The project concerns stochastic numerical methods and uncertainty quantification in the context of brain modelling. More specifically, the project is aimed at statistical inference in high-dimensional dynamical systems corresponding to models of nerve cell..

A detailed understanding of the brain over multiple scales, from molecules to behaviour, is believed necessary for a new generation of diagnostic tools and treatments of brain disease. This requires data integration and model construction at different levels of brain resolution.

The goal of this project is to develop, implement and analyse robust and scalable methods for uncertainty quantification and sensitivity analysis of models related to the brain, with a focus on intracellular nerve cell models. The computational methods that have been used within the Brain-IT MCP so far are approximate Bayesian computation (ABC) methods and versions of the Metropolis-adjusted Langevin algorithm (MALA). For both, there are several open questions related to the project, including new distance measures for ABC, modifications of the ABC methodology to aim for variance reduction and optimal choice of proposal density, approximation of Fisher information in MALA, and diagnostic tools related to convergence. Combining ABC methods with deep learning techniques and sequential Monte Carlo methods is also a topic of interest.

A number of other Markov chain Monte Carlo methods are of interest for the project as well, e.g. simplified manifold MALA and other stochastic numerical methods for processes on Riemannian manifolds, Hamiltonian Monte Carlo, and infinite swapping. A potential direction is also to develop new Markov chain dynamics based on ideas from optimal transport, differential geometry and spectral analysis. For all methods we aim for a theoretical analysis, including convergence and concentration properties, optimal parameter selection and scaling limits. An important aspect is the implementation of the relevant methods in a reusable fashion, including a structured handling of models and data.

The current models for intracellular pathways are based on systems of ODEs. A natural extension is to investigate the use of *stochastic* models for the underlying dynamics. That is, to consider populations of individual particles and their random interactions and diffusion, or look at random perturbations of existing models, leading to a system of SDEs and the question of how to modify the statistical methodology for accurate inference.

Students interested in one or more fields related to the following are encouraged to apply: probability theory, statistics, Monte Carlo methods, uncertainty quantification, computational mathematics, stochastic analysis, machine learning, differential geometry, neuroinformatics or systems biology. Some programming experience is also necessary.

The position is a time-limited, full-time, five year position starting August 2020 or at an agreed upon date. The position is fully funded for four years and will be extended to five years by assigning teaching duties. The position is financed by the Department of Mathematics and the Brain-IT MCP within SeRC;

the successful candidate will also be part of the SciLifeLab (`https://www.scilifelab.se`). Supervisors will be Pierre Nyquist (mathematics), Olivia Eriksson and Andrei Kramer (computational sciences, SeRC). Alexandra Jauhiainen (Astra Zeneca and collaborator in the UQSA subproject of Brain-IT) will also be involved.

Within the Department of Mathematics at KTH, the successful candidate will be part of vibrant and diverse groups in Probability and Mathematical Statistics. There will also be strong interactions with the "Brummer & Partners MathDataLab", a research lab in mathematics and applied mathematics, hosted at the Department of Mathematics, that aims at creating a hub for mathematical research in the analysis of complex data. In addition, the candidate will be part of the interdisciplinary and highly active environments at SeRC and SciLifeLab (see below).

KTH Royal Institute of Technology

KTH Royal Institute of Technology in Stockholm has grown to become one of Europe's leading technical and engineering universities, as well as a key center of intellectual talent and innovation. We are Sweden's largest technical research and learning institution and home to students, researchers and faculty from around the world. Our research and education covers a wide area including natural sciences and all branches of engineering, as well as in architecture, industrial management, urban planning, history and philosophy.

The School of Engineering Sciences carries out a wide range of research at the international frontline, from fundamental disciplines such as Physics and Mathematics, to Engineering Mechanics with applications such as Aeronautics and Vehicle Engineering. We also offer university degree programs in Engineering Physics, Vehicle Engineering, and 'Open entrance', as well as a number of international masters programs.

Swedish e-science Research Center (SeRC) and SciLifeLab

The Swedish e-science Research Center (SeRC, `https://e-science.se`) is an environment within the strategic research area (SRA) of e-Science, funded by the Swedish government Strategic Research Area Initiative and based on a collaboration between four universities: Kungliga Tekniska högskolan (KTH), Stockholms universitet (SU), Karolinska institutet (KI) and Linköpings universitet (LiU). It was founded in 2010 resulting from the Swedish Government Bill on Research Policy. In this bill, a total of 24 different strategic research areas were defined, of which e-Science is one. The mission statement of SeRC is to develop state-of-the-art e-Science tools and provide an e-infrastructure support to existing and emerging e-Science communities to achieve scientific breakthroughs in Sweden.

The SciLifeLab, Science for Life Laboratory, started in 2010 as a joint effort between four universities: Karolinska Institutet, KTH Royal Institute of Technology, Stockholm University and Uppsala University. It is an institution for the advancement of molecular biosciences in Sweden, funded as a national research infrastructure by the Swedish government. The organisation leverages the unique strengths of individual researchers across Sweden into a focused resource for the life science community. It provides access for thousands of researchers to the cutting-edge instrumentation and deep scientific expertise necessary to be internationally competitive in bioscience research. This infrastructure is supported and developed by the research community, including internationally recognised experts in life science and technology. SciLifeLab's facilities and expertise create a unique environment for carrying out health and environmental research at the highest level.

Application

The official ad will be available May 14 2020 via KTH's recruitment system. Interested students are encouraged to contact Pierre or Olivia at any time for an informal chat about the position.

Once the job is online, log into KTH's recruitment system in order to apply to the position. You are the main person responsible for ensuring that your application is complete according to this advertisement. Your complete application must be received by KTH no later than the stated application deadline **(May 31)**, midnight CET/CEST (Central European Time/Central European Summer Time). We expect a decision to be made by mid-June. Note that interviews may start while the application period is still ongoing, however all submissions before the deadline will be given full consideration.

The application must include the following documents:

- CV including any relevant professional experience and knowledge.

- Cover letter (detailing your academic interests, your previous studies and scientific work experience and your interest in this position); maximum 2 pages long.

- Copy of the degree certificate(s) and transcripts of records from your previously attended university-level institutions. Translations into English or Swedish if the original documents are not issued in one of these languages.

- Desirable but not mandatory: Contact information (email, address, and phone number) for two references.

General information

Type of employment: Temporary position longer than 6 months.

Contract type: full-time.

First day of employment: 15 August 2020 or an agreed upon date.
Contact: Pierre Nyquist (pierren@kth.se) and Olivia Eriksson (olivia@kth.se)

Application Submission Deadline: 31 May, 2020.