Delft Center for Systems and Control

TU Delft
Delft University of Technology

PhD Position Trustworthy and Tractable Methods for Data-Driven Modeling and Control of Complex Systems

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Job description

The complexity of cyber-physical systems is rising in line with the everyday advancements in technology and industry. Smart power grids, autonomous cars, distributed sensor networks, advanced robotic systems, district heating networks, and traffic platoons are only a few examples of such systems. Their primary features are high complexity, operation in complex time-varying environments, and safety-critical issues.

Utilizing measurement data, one may develop model-based or model-free techniques for controlling them. One may employ purely physics-based models built from available information in the model-based strategy. To produce a model representing reality precisely, we need a comprehensive grasp of the system's nature and a method for generating detailed models from the first principles. Due to the information limitations, this is not feasible in many applications. Also, this framework results in estimating an immense amount of parameters via non-convex large-scale optimizations formulated based on limited, heterogeneous, and noisy data, which further decreases their performance. One may utilize a reasonably simple physics-based model with few parameters to address these concerns. Though the built model may show meaningful behaviors, it may not fairly represent reality due to its excessive simplicity and inadequate inclusion of the first principles. Thus, the resulting decision-making is vulnerable to substantial bias and error.

Recent machine and reinforcement learning advances have delivered promising directions for developing black-box models, particularly when complexity prevents direct physics-based description. When a massive amount of informative data is provided, advanced ML methods may identify features and structures, so that the model is interpretable. Modern ML algorithms can capture complicated spatio-temporal patterns; however, they require extensive data, which is seldom accessible in most real-world settings. Moreover, ML models may not be capable of extending to out-of-sample contexts as they only identify links in the training data. Since naïve application of ML techniques to the data results in a blind interpretation of reality, the critical underlying traits are disregarded. Thus, inconsistent results may be obtained. Hence, if there is significant uncertainty or the model structures are relatively complicated, the generated models will not correctly represent reality. Therefore, we have high inaccuracies in the

models, and decision-making is vulnerable to risks. Though the inclusion of model uncertainty may address safety issues, it results in over-conservativism according to model mismatches leaked into the ambiguity envelopes. Thus, the decision-making policy will be sub-optimal. Analogous arguments exist for model-free approaches when certain aspects of reality are ignored.

The ML methods can be modified to become applicable for autonomous and large-scale complex systems by including readily available side-information on the underlying reality. This allows the rejection of inconsistent models and decisions. Subsequently, we obtain more interpretable models and decisions. Additionally, imposing specific attributes can promote more effective control mechanisms. Motivated by the above discussion, we need to derive trustworthy and tractable data-driven and learning-based control schemes incorporating side-information systematically and correctly. As the side-information can originate from various sources and no standardized procedure exists for its inclusion, the emphasis will be more on standard structures. To achieve this objective, we need to leverage advanced mathematical frameworks like the theory of reproducing kernel Hilbert spaces, Gaussian processes, and Koopman operator theory. The results should be delivered as a user-friendly numerical toolbox validated in real-world settings like energy systems, district heating networks, buildings, and greenhouses.

Requirements

- You have obtained an MSc degree, or will receive it before the starting date of the position, in one of the following science and engineering fields: Electrical Engineering, Systems & Control, Mathematics, Mechanical Engineering, or similar disciplines;
- You should have a solid mathematical background and are willing to learn further and get skilled in advanced mathematical topics such as functional analysis, PDE, optimization, and probability theory;
- You have a good command of the English language.

Doing a PhD at TU Delft requires English proficiency at a certain level to ensure that the candidate is able to communicate and interact well, participate in English-taught Doctoral Education courses, and write scientific articles and a final thesis. For more details please check the Graduate Schools Admission Requirements.

Conditions of employment

Doctoral candidates will be offered a 4-year period of employment in principle, but in the form of 2 employment contracts. An initial 1,5 year contract with an official go/no go progress assessment within 15 months. Followed by an additional contract for the remaining 2,5 years assuming everything goes well and performance requirements are met.

Salary and benefits are in accordance with the Collective Labour Agreement for Dutch Universities, increasing from € 2541 per month in the first year to € 3247 in the fourth year. As a PhD candidate you will be enrolled in the TU Delft Graduate School. The TU Delft Graduate School provides an inspiring research environment with an excellent

team of supervisors, academic staff and a mentor. The Doctoral Education Programme is aimed at developing your transferable, discipline-related and research skills.

The TU Delft offers a customisable compensation package, discounts on health insurance and sport memberships, and a monthly work costs contribution. Flexible work schedules can be arranged. For international applicants we offer the Coming to Delft Service and Partner Career Advice to assist you with your relocation.

TU Delft (Delft University of Technology)

Delft University of Technology is built on strong foundations. As creators of the world-famous Dutch waterworks and pioneers in biotech, TU Delft is a top international university combining science, engineering and design. It delivers world class results in education, research and innovation to address challenges in the areas of energy, climate, mobility, health and digital society. For generations, our engineers have proven to be entrepreneurial problem-solvers, both in business and in a social context.

At TU Delft we embrace diversity as one of our core values and we actively engage to be a university where you feel at home and can flourish. We value different perspectives and qualities. We believe this makes our work more innovative, the TU Delft community more vibrant and the world more just. Together, we imagine, invent and create solutions using technology to have a positive impact on a global scale. That is why we invite you to apply. Your application will receive fair consideration.

Challenge. Change. Impact!

Faculty Mechanical, Maritime and Materials Engineering

The Faculty of 3mE carries out pioneering research, leading to new fundamental insights and challenging applications in the field of mechanical engineering. From large-scale energy storage, medical instruments, control technology and robotics to smart materials, nanoscale structures and autonomous ships. The foundations and results of this research are reflected in outstanding, contemporary education, inspiring students and PhD candidates to become socially engaged and responsible engineers and scientists. The faculty of 3mE is a dynamic and innovative faculty with an international scope and high-tech lab facilities. Research and education focus on the design, manufacture, application and modification of products, materials, processes and mechanical devices, contributing to the development and growth of a sustainable society, as well as prosperity and welfare.

Click here to go to the website of the Faculty of Mechanical, Maritime and Materials Engineering. Do you want to experience working at our faculty? These videos will introduce you to some of our researchers and their work.

Additional information

For more information about this vacancy, please contact Dr Mohammad Khosravi, mohammad.khosravi@tudelft.nl.

For information about the application procedure, please contact Irina Bruckner, recruitment-3me@tudelft.nl.

Application procedure

Are you interested in this vacancy? Please apply via the application button before **December 15, 2022** and upload:

- a cover letter stating your motivation,
- detailed curriculum vitae (including a list of publications, if any),
- names of up to three professional referees,
- a summary of your MSc thesis,
- list of courses and grades at Master and Bachelor level (in English).

Please note:

- A pre-employment screening can be part of the selection procedure.
- You can apply online. We will not process applications sent by email and/or post.
- Contact by recruiting agencies is not appreciated.

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