



# PhD Position on Simultaneous Model Learning and Control via Embedded Optimization for Autonomous Driving

at the Systems Control and Optimization Laboratory,  
University Freiburg, Germany

The PhD position is part of the European Training Network “ELO-X – Embedded Learning and Optimization for the neXt generation of smart industrial control systems”. ELO-X will recruit altogether 15 PhD fellows at 6 research universities and 5 international companies from 5 European countries, who will meet regularly during exchange visits, training events, workshops, and summer schools organized by the network. The positions at the University of Freiburg have a strong methodological focus in the field of computational control and mathematical optimization. They are based in the Systems Control and Optimization Laboratory (Syscop) at University Freiburg headed by Prof. Moritz Diehl. Their aim is the development of advanced optimal control methods and open-source software and their application to industrially relevant optimization and estimation problems. While these methods are generic and applicable in several branches of engineering, they shall be tested and used in close cooperation with the other ELO-X PhD fellows, in particular with those who are based in Siemens Industry Software NV, ODYS and ShanghaiTech during mutual exchange visits of several months duration.

## BACKGROUND

Digital technologies are transforming all sectors of our economy and will increasingly do so in the years to come. Thanks to the increasing capabilities of digital technologies, the next generation of smart industrial control systems (SICS) are expected to learn from streams of data and to take optimal decisions in real-time on the process at hand, leading to increased performance, safety, energy efficiency, and ultimately value creation. Numerical optimization is at the very core of both learning and decision-making, since both the extraction of information from data and the choice of the most suitable action are naturally cast as optimization problems and solved numerically. However, to realize this potential embedded learning and optimization methods needs to be developed, able to operate in industrial devices and to guarantee high safety standards. ELO-X addresses the timely and pressing need for highly qualified and competent researchers, able to develop embedded learning- and optimization-based control methodologies for SICS, thus enabling new technologies and the next generation of digital industrial products and processes.



The Systems Control and Optimization (Syscop) Laboratory at the University of Freiburg focuses on methods and software for optimal control and estimation, in particular on embedded systems. Its members developed, among other, the open-source tools ACADO, CasADi, qpOASES, BLASFEO, HPIPM and acados. The applied research of syscop is focused on control and optimization for a variety of dynamical systems, recent fields of application are: wind turbines, combustion engines, electric machines, airborne wind energy, electric inverters among others.

The ELO-X PhD positions will be supervised by world leading experts in mathematical modelling and optimization-based control and estimation and shall prepare the fellows for a high-level career in advanced control engineering in industry or in academia.

## PHD PROJECT DESCRIPTION

### **PhD Project: Simultaneous model learning and control via embedded optimization and application to autonomous driving.**

Autonomous driving on roads with unknown friction coefficients (dry/wet/icy road) poses both practical and theoretical challenges due to the conflicting objectives of (a) exploitation, i.e., good lane keeping and fast driving (b) exploration, i.e., good knowledge of the road conditions which might necessitate some steering and braking experiments. Dual control theory tries to find an optimal compromise between these conflicting objectives, but did not yet find its way into industrial practice due to its prohibitive computational complexity for even small-scale models. The idea of this PhD project is to develop a practically useful framework for dual control that is based on embedded optimization, by combining moving horizon estimation (MHE) with robust model predictive control (MPC), where the MPC objective includes an approximation of the cost of uncertainty. The methods shall be generally applicable to nonlinear models with a moderate number of unknown parameters and should be based on linearization along trajectories, covariance matrix propagation via Lyapunov equations, linear state feedback approximations to reduce the conservatism, and robust constraint satisfaction.



**Timeline and remuneration:** The ideal starting time is in early summer 2021. The PhD projects last for the duration of three years, and are carried out at the Systems Control and Optimization Laboratory headed by Prof. Dr. Moritz Diehl at the University of Freiburg, Germany. The PhD years include at least one longer visit – a so called "secondment" – between one and six months to another group in the ELO-X network, depending on the project needs and the scientific interests of the PhD fellows. The first year is mainly dedicated to studying and getting acquainted with the relevant state of the art in NMPC formulations for autonomous driving, the connections between learning and control and dedicated problem formulations. The second year focuses on method development, software implementation and benchmarking. In the third year benchmarking on the simulated application to autonomous driving applications and an evaluation of the complete embedded control system in an industrial driving simulator is planned. A fourth PhD year can be added and funds are reserved for this at the University of Freiburg. The remuneration is generous and will be in line with the EC rules for Marie Curie grant holders. It consists of a salary augmented by a mobility allowance, resulting in a net monthly salary of about 1900-2300 Euro depending on family status.

## SUPERVISORS AND MAIN CONTACTS

**Supervising team at the University of Freiburg:** Prof. Dr. Moritz Diehl (head of systems control and optimization laboratory), Dr. Gianluca Frison (Postdoc at Syscop working on high-performance linear algebra and QP solvers for embedded optimization), Katrin Baumgärtner (PhD student focusing on efficient algorithms for MHE and Iterative Learning Control), Florian Messerer (PhD student working on robust optimal control and sequential convex programming), Jonathan Frey (PhD student working on efficient software for MPC and MHE, acados) among others.

**Main Contacts at the ELO-X Partner Groups which could host secondments:** Dr. Herman Van der Auweraer and Dr. Son Tong (Siemens Industry Software NV); Dr. Daniele Bernardini and Prof. Dr. Alberto Bemporad (ODYS); Prof. Dr. Boris Houska (ShanghaiTech).

## CANDIDATE PROFILES

Ideal candidates have a master degree in one of the following disciplines or a related field: control engineering, numerical mathematics, computational physics or computer science. They should have a good background or interest in mathematical optimization, dynamic system modelling and simulation, and programming (C/C++, Python, Matlab), as well as a desire to contribute to the development of open-source software and the success of real-world experiments. Proficiency in English is a requirement. The positions adhere to the European policy of balanced ethnicity, age and gender. Both men and women are encouraged to apply.

## APPLICATION

To apply, send an email to [elo-x@imtek.uni-freiburg.de](mailto:elo-x@imtek.uni-freiburg.de) in form of **one single PDF attachment containing all contents or links** (any other information within the email will not be processed). Subject of your email should be: "ELO-X PhD Application – ESR 1".

Please include, in your single PDF document, the following items in this order:

1. A cover letter incl. statement of research interests and career goals (max. 2 pages);
2. An academic CV;
3. Contact details of at least two referees incl. phone numbers and emails;
4. Your diplomas and transcript of course work and grades;
5. Sample of technical writing (publication or thesis);
6. Proof of English language proficiency test results.

**Please send your application before January 17, 2021.**

**Note that your PDF will be forwarded to several people in the ELO-X institutions and that in particular all Supervisory Board members of ELO-X will have access to your application material. If you want to apply to more than one ELO-X position, please create and send separate PDFs.**

### MARIE CURIE ELIGIBILITY CRITERIA IN SHORT

To be eligible, you need to be an "early stage researcher" i.e. simultaneously fulfill the following criteria **at the time of recruitment**:

- a) Nationality: you may be of any nationality.
- b) Mobility: you must not have resided or carried out your main activity (work, studies, etc...) in Germany for more than 12 months in the 3 years immediately prior to your recruitment under the ELO-X project.
- c) Qualifications and research experience: you must be in the first 4 years of your research career after the master degree was awarded.

For more information, please visit the following webpages:

<https://www.elo-x.eu>  
<https://www.syscop.de>