PhD Position in Simulation-based development and model-based control of temperature-control and water-cooling devices

at Tool-Temp AG, Switzerland

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 position at Tool-Temp has a strong methodological focus in the field of computational control and mathematical optimization. They are based in the R&D-department headed by Dr. sc. Jonas Asprion. The 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 particularly with those who are based in ETH Zurich (Switzerland) and University of Freiburg (Germany), 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.

Tool-Temp AG is a private SME manufacturing temperature-control and water-cooling devices. Founded in 1973, it nowadays has 120 employees at the headquarters in Sulgen, Switzerland. Production is exclusively at the headquarters, global sales are managed by 14 subsidiaries. The USP of Tool-Temp devices is their high quality and unparalleled longevity with minimal maintenance. An entirely new generation of devices is currently under development. The goal is to keep up the exceptional robustness, while extending mechanical features, improving energy efficiency, as well as adding intelligence and IioT-capabilities to the control unit.

The R&D department is tightly integrated with the production facilities. Any device or its components can be analysed and tested during every stage of production, and special prototypes can be quickly built at any time. Modular automation and data-acquisition hardware ensures complete flexibility to realise any test setups. Special equipment can be acquired quickly and with almost no administrative overhead. For involved numerical calculations or large parameter studies, two small server clusters are available.

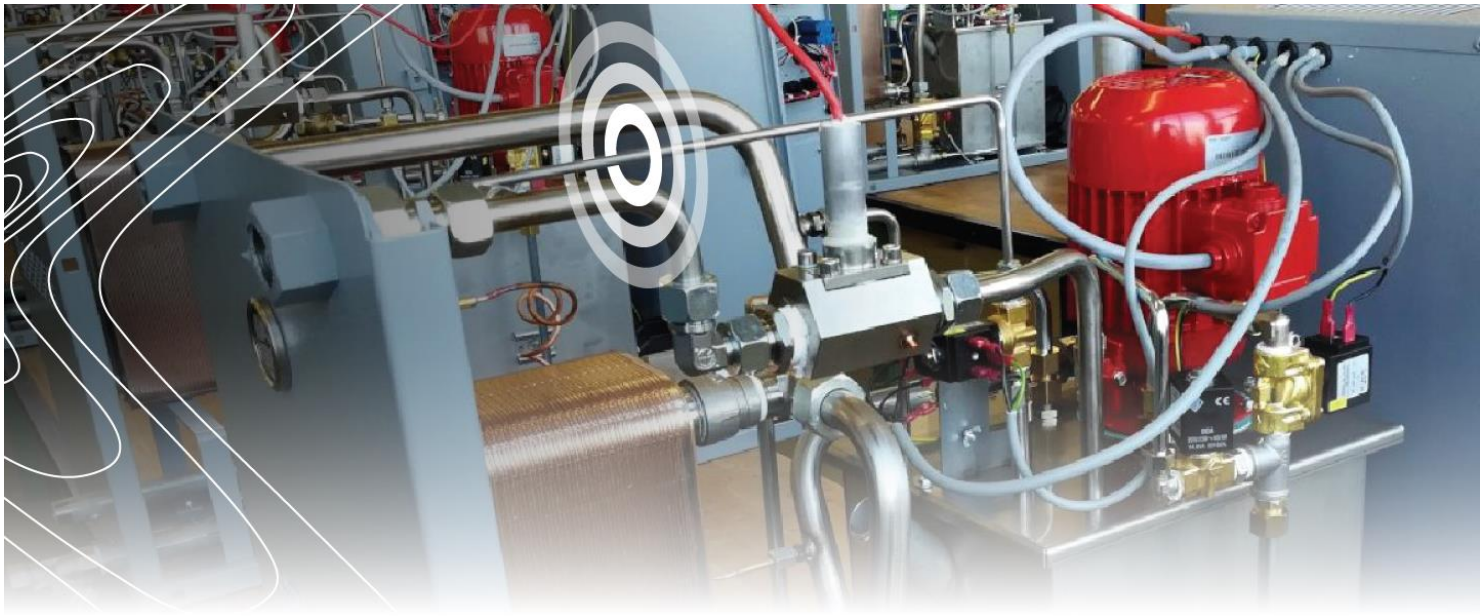
PHD PROJECT DESCRIPTION

In many industrial processes, the temperature of some fluid (e.g. chemical reactor, food-processing industry) or body (e.g. die casting, injection moulding, milling) needs to be controlled. To that end, temperature-control and cooling devices (TCCDs), such as the ones produced by TOOL-TEMP AG, are used. These devices temper the external process by supplying a thermal fluid at a suitable temperature and volumetric flow. Due to their universal applicability, TCCDs are often used for different tasks on an hourly to daily basis.

At every start up, the device does not know what external process it is connected to. Today, self-tuning PID control is used, whereby first-order system dynamics are learned during the initial heat-up phase only. The process dynamics can change over time (e.g. sudden exothermal reaction, initiation of injection process, activation of other heat sources), there is unknown and variable transport delay between the TCCD and the external process, and often there is a cyclic behaviour. The controller thus needs to autonomously and continuously learn the system dynamics, including potential cyclic behaviour.

Since the overall system is nonlinear, has multiple cross-coupled inputs and outputs, and imposes constraints, the application of MPC is key to achieve precise and robust control. Both aspects, i.e. learning and control, become more complicated when a cluster of multiple TCCDs, along other heat sources, is used to collaboratively control the spatial and temporal temperature distribution in a complex external process. At the same time, the resulting optimisation problems become orders of magnitude larger, requiring efficient, sparsity-exploiting embeddable solvers. Finally, if any degrees of freedom are left, minimal energy consumption is to be aspired, leading to economic objectives instead of pure feed-back control. Since manufacturers of TCCDs are frequently confronted with new applications of their devices, a simple to use and reliable toolchain for developing, testing and deploying the controller code is required. The series-quality code running on the microcontroller should be automatically generated from within the high-level simulation and prototyping framework.

Depending on the evolution of trends in the industry, the interests and skills of the student, and the progress speed and findings during the project itself, the application focus may be adjusted. Control of a single TCCD, a cluster of such devices, or a cluster including other sources of heat, could be considered. The algorithms can be developed and validated using an existing simulation framework as well as experimentally on real-world test-benches. Numerical methods for estimation and optimal control are considered tools rather than research topics in this project. Existing frameworks from partner universitites, as well as the onging developments in other PhD projects of ELO-X, may be exploited.



Timeline and remuneration: The start time is anywhere between spring and October 2021. The PhD project lasts for the duration of three years, and are carried out at Tool-Temp. The first year is mainly dedicated to studying, getting acquainted with the relevant state of the art, and fully understanding the industrial applications. The second year focuses on method development, and the third year on application to the industrial problems, experimental validation, and publications. The PhD years include two longer visits – so called ”secondments”. The first secondment is at the University of Freiburg (6 months in the second year) to become proficient with numerical embedded optimization methods. The second secondment will take placing during the last year of the PhD, at ETH Zurich (3 months), to deepen the knowledge on the use of learning in model identification.

The remuneration is extended over the EC rules for Marie Curie grant holders to the highest rate of PhD students at Swiss Technical Universities. It consists of a salary augmented by a mobility allowance, resulting in a gross yearly salary of about CHF 70k/75k/80k (in the first, second and third year, respectively), which is around EUR 65k/69k/74k.

SUPERVISORS AND MAIN CONTACTS

Supervisor at Tool-Temp AG: Dr. sc. Jonas Asprion (Head of Research & Development)
Co-supervisor at University of Freiburg: Prof. Dr. Moritz Diehl (Head of Systems Control and Optimization Laboratory)

Supervising team at the University of Freiburg *(first secondment):* Prof. Dr. Moritz Diehl, Mario Zanon (senior PhD student working on economic Nonlinear Model Predictive Control formulations), Robin Verscheuren (PhD student focusing on "Code Generation for Embedded Nonlinear Model Predictive Control and Moving Horizon Estimation").

Supervisor at ETH Zurich *(second secondment):* Prof. Melanie Zeilinger (Assistant Professor in the field of intelligent and networked control systems)

CANDIDATE PROFILE

Ideal candidates have a master degree in one of the following disciplines or a related field: control or mechanical engineering, computational physics. They should have a good background or an interest in control systems, thermodynamics, mathematical optimization, dynamic system modelling and simulation, and programming (languages mainly used in the R&D department are C/C++ and Julia). Proficiency in English is a requirement, German is helpful. 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 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 15".
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 Switzerland 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: http://tool-temp.ch/, http://www.elo-x.eu