PhD Position in *Embedded nonlinear MPC using learning techniques*

at the University Politehnica Bucharest, Romania

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". The position at University Politehnica Bucharest has a strong methodological focus in the field of computational control and mathematical optimization. It is based in the Optimization, Learning and Control Lab headed by Prof. Ion Necoara. The aim is the development of advanced optimization and learning-based control methods and open-source software and their application to industrially relevant problems. While these methods are generic and applicable in several branches of engineering, they shall be tested and used in close cooperation with the the other ELO-X PhD fellows, in particularly with those who are based in ODYS, KUL and EPFL- 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 Optimization, Learning and Control (OLC) Laboratory at the University Politehnica Bucharest focuses on methods and software for optimal control and learning, in particular on embedded systems, and its members developed, among other, the open-source tools DuQuad. The most important research lines of OLC are learning, optimization and control of complex systems, such as automative systems, hypespectral imaging systems and power systems. The OLC PhD position will be supervised by world leading experts in mathematical programing and optimization-based control and learning and shall prepare the fellows for a high-level career in advanced control engineering in industry or in academia.

PHD PROJECT DESCRIPTIONS

PhD Project: Embedded nonlinear MPC using learning and optimization techniques: The aim of this PhD position is to develop and use advanced learning and optimization methods that are able to address the control design of nonlinear systems. For the control of linear systems in a receding horizon fashion (so-called model predictive control - MPC) the corresponding optimization problem is typically convex, for which very efficient optimization algorithms exist. However, when the system is nonlinear the corresponding optimization-based MPC control problem is highly nonconvex. The structure of such MPC problem is very similar to the one encountered in training of deep learning networks. An optimization algorithm depends on several parameters (e.g., stepsize, penalty parameters, etc). The goal is to find the best parameters choice. Similarly, searching the parameter space of deep architectures is a cumbersome task, but learning algorithms, such as those for deep belief networks, have recently been proposed to tackle this problem with notable success. We plan to

search the parameters of nonconvex optimization algorithms for MPC using deep learning. Moreover, though the optimization-based control problem has a similar representation as in training learning networks, it has specific structure. For example, we may know the reference signal we need to track with our embedded controller, which can help a learning algorithm. Moreover, in the optimization-based control problem we usually have a convex objective function but with nonconvex constraints, with or without sparsity, some variables are random, etc. In this PhD thesis we want to combine the best of these worlds, control, optimization and learning, to develop fast nonconvex optimization algorithms tailored for embedded MPC of SICS. We will analyse the structure of the nonlinear control problem and identify the characteristics that can help a learning algorithm (convexity, sparsity, stochasticity) to find the best parameters of the optimization algorithm. The optimization algorithms produced by the learning framework will also take into account limited computational resources, making them adequate for embedded frameworks including GPUs.

Timeline and remuneration: The start time is **September 2021**. The PhD projects last for the duration of three years, and are carried out at the University Politehnica Bucharest. 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 optimization, model predicitive control and deep learning, the second year focuses on method development, and the third year on application problems and writing the thesis. 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 1500-2000 Euro depending on family status.

SUPERVISORS AND MAIN CONTACTS

Supervising team at the University Politehnica Bucharest: Prof. Dr. Ion Necoara (head of Optimization, Learning and Conrtrol Laboratory), Daniela Lupu (senior PhD student working on Big Data Optimization).

Main Contacts at the OLC Partner Groups which could host secondments: ODYS: Prof. Alberto Bemporad; *EPFL:* Prof. Colin Jones; *KU Leuven University:* Prof. Panos Patrinos.

CANDIDATE PROFILES

Ideal candidate has a master degree in one of the following disciplines or a related field: control, numerical mathematics or computer science. He/she should have a good background or interest in mathematical optimization, machine learning, control of dynamical systems, and programming (Matlab, python), 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 ion.necoara@upb.ro. Subject of your email should be: "ELOX ESR9 Application". Please include:

a) an academic CV and a PDF of your diplomas and transcript of course work and grades
b) statement of research interests and career goals
c) sample of technical writing, e.g. a paper with you as main author, or your master thesis
d) list of at least two referees: names, phone numbers, and email addresses
e) some proof of proficiency in English (e.g. language test results from TOEFL, IELTS, CAE, or CPE)

Please send your application before May 7, 2021.

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 Romania 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://acse.pub.ro/person/ion-necoara/

and

http://www.elo-x.eu