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Deliverable Detail for Grant Agreement No. 953348

No.	Name
D5.6	**4th ELO-X seasonal school**

Deliverable Preparation Process

	Name and Organisation	Date
Author	Lorenzo Fagiano Riccardo Scattolini	2024-05-06
Review	Panagiotis Patrinos	Click or tap to enter a date.
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Introduction

The Fourth ELO-X seasonal School was held on February 5th - 9th, 2024 at Politecnico di Milano, Italy. This event comprised four consecutive parts: two courses, a poster session, and an advisory board meeting. In addition, two seminars and a social program have been organized during the same week, also in the framework of ELO-X. Participants were the ELO-X ESRs and associated fellows, and supervisors and advisory board members.

School program: overview

Date	**Program**
5/2/2024 Start at **10.00**	**Mini Transformer Course** @ Sala Conferenze Emilio Gatti, building 20 10:00-13:00 Morning session, with coffee break at 11:30 13:00-14:30 Lunch @ "Ad Arte" restaurant 14:30-16:30 Afternoon session 17:30-19:30 Welcome apero @Sala Seminari Nicola Schiavoni, building 20
6/2/2024 Start at **10.00**	**Mini Transformer Course** @ Sala Conferenze Emilio Gatti, building 20 10:00-13:00 Morning session, with coffee break at 11:30 13:00-14:30 Lunch @ "Ad Arte" restaurant 14:30-16:30 Afternoon session
7/2/2024 Start at **10.00**	**Innovation and Entrepreneurship Course** @ Sala Conferenze Emilio Gatti, building 20 10:00-13:00 Morning session, with coffee break at 11:30 13:00-14:30 Lunch @ "Ad Arte" restaurant 14:30-17:30 Afternoon session, with coffee break at 16:15
8/2/2024 Start at **09.00**	**Innovation and Entrepreneurship Course** @ Sala Conferenze Emilio Gatti, building 20 09:00-13:00 Morning session, with coffee break at 11:00 13:15-14:30 Lunch @ "Ad Arte" restaurant 14:30-15:45 Seminar Prof. Antonella Ferrara @ Sala Conferenze Emilio Gatti, building 20 **Social program**: 18:00-19:15 Last Supper's guided tours 20:15-22:00 Social dinner @ Osteria del Treno
9/2/2024 Start at **09.00**	All events @ Sala Conferenze Emilio Gatti, building 20 unless otherwise noted 09:00-10:00 Seminar Prof. A. Bemporad 10:15 Coffee break 10:30-10:45 Spotlight poster presentations 1 10:45-12:45 Poster session 1 13:00-14:15 Lunch @Sala Seminari Nicola Schiavoni, building 20 14:15-14:30 Spotlight poster presentations 1 14:30-16:30 Poster session 2 16:00 Coffee break

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	16:30 Concluding remarks 17:30 Farewell apero @Sala Seminari Nicola Schiavoni, building 20

Program of PhD courses

Mini Transformer Course
Prof. Matteo Matteucci and Prof. Giacomo Boracchi, Politecnico di Milano

After the seminal work “Attention Is All You Need” Transformers have become the state of the art in NLP tasks, and more recently they are quickly gaining relevance in modeling images too. The course starts from the Transformers' origin and the math behind these models, then it presents the use of Transformers in image classification and other typical computer vision tasks.

Day 1 - 05/02/2024 – Prof. Matteo Matteucci (transformers basics):

- Intro to the course and logistics
- Overview of RNN and their limits
- Seq2Seq models and Attention (neural translation)
- Attention and visualization
- The transformer idea from “attention is all you need”
- The transformer math explained step by step
- Notebook: Transformer in a nutshell

Day 2 - 06/02/2024 – Prof. Giacomo Boracchi (visual transformers)

- Basics on Images, Visual Recognition Problems, CNNs and Latent Representations
- Basics of Vision Transformer (ViT)
- CLIP + applications (e.g., zero shot learning)
- Notebook: Vision Transformer (ViT)

Innovaton & entrepreneurship
Prof. Angelo Cavallo and Prof. Cristina Lamastra, Politecnico di Milano

Day 1 – 07/02/2024 – Innovation and industry structure in IT industries

Lesson 1 – Innovation and competition in IT industries, prof. Cristina Rossi Lamastra (3 h)

The aim of this lesson is to illustrate the economic concepts that drive the dynamics of innovaton and competiton in IT-based industries, with special attention being devoted to emergent industry segments (artificial intelligence, advanced robotics, unmanned vehicles, advances air mobility).

Lesson 2 – “Business Models Archetypes in IT Industries: an Introduction with Practical Cases”, Prof. Angelo Cavallo (+ Guest: Interview with an entrepreneur) (3h)

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Main constructs and framework of business models in IT industries are introduced in this class. Students learn about appropriate terminology, meanings, and practical tools that support business model design. Concrete examples and business model archetypes are presented.

Day 2 – 08/02/2024 – From science to high-tech entrepreneurship

Lesson 3 - The Journey from Business Model Design to Business Model Validation, prof. Angelo Cavallo (+ Guest on "What IT companies look for when hiring IT PhD graduates", with an HR Director) (4h)

In this class, students learn how to move from an initial design to the validation and testing of business models based on a high-tech business idea. Emerging practice-oriented approaches, such as the lean startup, guide the students in logical reasoning and methods that specifically apply to tech businesses. The class includes 2 hours of guided group work activity on how to move from design to the elaboration and testing of the main related business assumptions. Moreover, concrete examples of business experiments for testing and validating a business model are presented.

Seminars

Title: Advanced Sliding Mode Control
Date: February 8 2024, 2:30-3:30 pm
Place: Politecnico di Milano - Department of Electronics, Information and Bioengineering, "Emilio Gatti" Conference Room (Building 20)
Speaker: Prof. Antonella Ferrara, University of Pavia, Italy

Abstract

Sliding Mode Control is a valuable control methodology capable of dealing with relevant classes of uncertain nonlinear systems. Yet, in its classical formulation, Sliding Mode Control had some limitations: the possibility of designing sliding mode controllers only in case of systems with relative-degree-one input-output map, the notorious chattering phenomenon, and the impossibility of explicitly considering the presence of state and input constraints in the design of the controller. In this talk, after a brief review of the basic concepts of Sliding Mode Control theory, advanced Sliding Mode Control approaches will be presented. They include Higher Order Sliding Mode Control strategies for nonlinear uncertain systems with arbitrary relative degree subject to input and state constraints.

Short Bio

Antonella Ferrara received the M.Sc. degree (Cum Laude and printing honours) in electronic engineering and the Ph.D. degree in computer science and electronics from the University of Genoa, Italy, in 1987 and 1992, respectively. Since 2005, she has been Full Professor of automatic control at the University of Pavia, Italy. Her research activities lie in the area of nonlinear control, with a special emphasis on sliding mode control and application to road traffic, automotive systems, robotics and power systems. She is author and co-author of more than 450 publications including more than 160 journal papers, 2 monographs and one edited book. She was Associate Editor and Senior Editor of many scientific journals. Since 2018 she

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has been Associated Editor of Automatica, and, since January 2022, Senior Editor of IEEE Open Journal of Intelligent Transportation Systems. Antonella Ferrara is the EUCA Conference Editorial Board Chair, Director of Operations of the IEEE Control Systems Society, Vice-Chair for industry of IFAC TC 2.3, member of the IFAC Industry Board and of the IFAC Conference Board. She was/is Principal Investigator in numerous European, international, and national projects. In particular, she was PI in the European Project ITEAM (Interdisciplinary Training Network in Multi-Actuated Ground Vehicles, Marie Skłodowska-Curie Action), 2016-2019. Among several awards, she was a co-recipient of the 2020 IEEE Transactions on Control Systems Technology Outstanding Paper Award. She is a Fellow of IEEE and Fellow of IFAC.

Title: Learning-based Methods for Model Predictive Control
Date: February 9 2024, 9:00-10:00 am
Place: Politecnico di Milano - Department of Electronics, Information and Bioengineering, "Emilio Gatti" Conference Room (Building 20)
Speaker: Prof. Alberto Bemporad, IMT School for Advanced Studies Lucca, Italy

Abstract

Machine learning has gained immense popularity in various fields, including control, due to its ability to extract mathematical models from data. In my talk, I present different machine learning techniques that can aid in designing and calibrating model predictive control (MPC) laws. I emphasize the use of offline and online methods for learning piecewise affine and recurrent neural network prediction models. Moreover, I present global and preference-based optimization techniques that rely on surrogate functions to actively learn the optimal MPC parameters and to identify critical scenarios from closed-loop experiments.

Short Bio

Prof. Alberto Bemporad received his Master's degree cum laude in Electrical Engineering in 1993 and his Ph.D. in Control Engineering in 1997 from the University of Florence, Italy. In 1996/97 he was with the Center for Robotics and Automation, Department of Systems Science & Mathematics, Washington University, St. Louis. In 1997-1999 he held a postdoctoral position at the Automatic Control Laboratory, ETH Zurich, Switzerland, where he collaborated as a Senior Researcher until 2002. In 1999-2009 he was with the Department of Information Engineering of the University of Siena, Italy, becoming an Associate Professor in 2005. In 2010-2011 he was with the Department of Mechanical and Structural Engineering of the University of Trento, Italy. Since 2011 he is Full Professor at the IMT School for Advanced Studies Lucca, Italy, where he served as the Director of the institute in 2012-2015. He spent visiting periods at Stanford University, University of Michigan, and Zhejiang University. In 2011 he co-founded ODYS S.r.l., a company specialized in developing model predictive control systems for industrial production. He has published more than 400 papers in the areas of model predictive control, hybrid systems, optimization, automotive control, and is the co-inventor of 21 patents. He is author or coauthor of various software packages for model predictive control design and implementation, including the Model Predictive Control Toolbox (The Mathworks, Inc.) and the Hybrid Toolbox for MATLAB, and other packages tailored to industrial production. He was an Associate Editor of the IEEE Transactions on Automatic Control during 2001-2004 and Chair of the Technical Committee on Hybrid Systems of the IEEE Control Systems Society in 2002-2010. He received the IFAC High-Impact Paper Award

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for the 2011-14 triennial, the IEEE CSS Transition to Practice Award in 2019, and the 2021 SAE Environmental Excellence in Transportation Award. He is an IEEE Fellow since 2010.

Poster sessions

Poster session 1, Sala Conferenze Emilio Gatti, 9/2/2024, 10.30 – 12.45

10:30-10:45 Spotlight poster presentations
10:45-12:45 Poster session

AC4MPC: Actor Critic Reinforcement Learning for NMPC
Rudolf Reiter, Andrea Ghezzi, Jasper Hoffmann, Katrin Baumgärtner, Robert D. McAllister, Moritz Diehl
University of Freiburg

A Universal Framework to Promote MPC with Learning-based Methods
Yuan Zhang, Joschka Boedecker
University of Freiburg

Learning A Generalized Switching System
Renzi Wang, Mathijs Schuurmanns, Panagiotis Patrinos
KU Leuven

Machine Learning methods for modeling and control of dynamic systems
Jing Xie, Riccardo Scattolini
Politecnico di Milano

On the stabilization of forking and cyclic trajectories for nonlinear systems with time-varying performance metric
Nicolas Kessler, Lorenzo Fagiano
Politecnico di Milano

Nonlinear Model Predictive Controller for Hydraulic Cylinders
Leonardo Cecchin[1,2], Toshiyuki Ohtsuka[3], Adrian Trachte[1], Moritz Diehl[2]
[1]Robert Bosch GmbH, [2]University of Freiburg, [3]Kyoto University

Real-time MPC with Control Barrier Functions for Autonomous Driving using Safety Enhanced Collocation
Jean Pierre Allamaa[1,2], Panagiotis Patrinos[2], Toshiyuki Ohtsuka[3], and Son Tong[1]
[1]Siemens Digital Industries Software, [2]KU Leuven, [3]Kyoto University

Optimal Control of Switched Systems Under Dwell-Time Constraints
Ramin Abbasi-Esfeden, Jan Swevers
KU Leuven

Learning Safe Stable Dynamics from Expert Demonstrations
Shaohui Yang, Roland Schwan, Colin Jones
Automatic Control Laboratory, EPFL

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Poster session 2, Sala Conferenze Emilio Gatti, 9/2/2024, 14.15 – 16.30

14:15-14:30 Spotlight poster presentations
14:30-16:30 Poster session

Time-optimal Collision-free Motion Planning: Robustification under Disturbance Conditions, and a Two-stage Approach to Formulate the Problem
Shuhao Zhang, Jan Swevers
KU Leuven

Bayesian Methods for Uncertainty-Aware Model Predictive Control
Amon Lahr, Melanie N. Zeilinger
ETH Zürich

Physics-informed learning for Model Predictive Control in industrial applications
Kristoffer Fink Løwenstein
ODYS S.r.l.

Joint Estimation of System Parameters and Noise Covariances for linear-in-the-uncertainty systems, using Maximum Likelihood Estimation
Léo Simpson[1], Jonas Asprion[1], Moritz Diehl[2]
[1]Tool-Temp AG, [2]University of Freiburg

Personalized Autonomous Driving from Pixels to Controls on a Hexapod Simulator with Differentiable NMPC
Flavia Sofia Acerbo[1], Jan Swevers[2], Tinne Tuytelaars[2], Son Tong[1]
[1]Siemens Digital Industries Software, [2]KU Leuven

The Homogeneous Formulation for Infeasibility Certification within Interior Point Methods
Katrin Baumgärtner, Andrea Ghezzi
University Freiburg

PlanNetX: Learning an Efficient Neural Network Planner from MPC
Jasper Hoffmann, Joschka Boedecker
University Freiburg

Approximate propagation of normal distributions for stochastic optimal control of non-smooth systems
Florian Messerer, Katrin Baumgärtner, Armin Nurkanovic, Moritz Diehl
University of Freiburg

Linearized ADMM for nonsmooth nonconvex optimization with nonlinear equality constraints
Lahcen El Bourkhissi[1], Ion Necoara[1], and Panagiotis Patrinos[2]
[1]University POLITEHNICA of Bucharest, [2]KU Leuven

Advisory Board meeting and session with ESRs

The advisory board (AB) met with the ELO-X ESRs throughout Friday, February 9th 2024, with both individual sessions, where single fellows presented their work to AB members, and a plenary session chaired by AB member Prof. Antonella Ferrara, partly without the participation

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of the ELO-X supervisors, where the fellows could share their experience and provide feedback on their participation to the ELO-X training network. An excerpt from the final considerations of Prof. Antonella Ferrara at the end of the plenary session is reported below.

"By now, the day is concluded. It was very nice, and I enjoyed it. Concerning the fellows: what you presented today was a very mature message. I liked it a lot. I appreciated the discussion. Initially, I thought that today would be a 'duty' - but it was educational, also for me. Concerning feedback. I don't find any major adjustments to propose. One thing to keep in mind is to always include the possibility of having experiments if desired. Also, it's possible that having a common software platform may give added value to the group. One other aspect of the project that merits feedback, concerns the secondments. Having fewer secondments that are a bit longer, would allow the fellows to be more focused during those secondments. My impression, while looking at the posters, listening to the explanations, and receiving the ESRs' feedback, was very very good. If I had, now, to give a mark, it would be a 10/10.

For the students and the supervisors, my feeling is that social interactions are also important. My wish is that we continue like this: that we be happy. The measure one has to keep in mind, even in professional life, is happiness. If you're happy, then everything can be done. You have the force that drives you to your professional objectives. And, I think we are happy.

I hope to have the possibility to have future interactions!"

Photo impressions

Below are some photo impressions of the school.

Innovation and Entrepreneurship course – Prof. A. Cavallo

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Prof. R. Scattolini, ELO-X supervisor, introducing the seminar of Prof. A. Ferrara

ELO-X fellows attending the seminar of Prof. A. Ferrara

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Poster session

Group photo at the end of the 4th seasonal ELO-X School

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