Workshop on Machine Learning for Automation

The enormous interest in artificial intelligence and especially machine learning (ML) among scientists in different research fields has recently also influenced the focus of our CASE conference. This is manifested by the main themes at IEEE CASE 2018-2021: Knowledge-based Automation, Smart Automation, Automation Analytics, and Data-Driven Automation. Since learning is such an important tool in many automation solutions, including data-based model generation, online optimization, and adaptive control, it is crucial to increase our activities in this field even further, to become an important player in the tough scientific race around ML that is going on right now.

The goal of this workshop is therefore to create a deeper interest and understanding of ML, but also to identify niche areas of ML in automation, where our research community should take the lead. More specifically, we want to present some interesting ongoing research activities, but also to discuss and propose what we believe are important research directions where automation can play an important role in this dynamic research area.

The presentations in this workshop will be given by members of a recently created AdHoc on Machine Learning for Automation. This AdHoc is focused on how to strengthen research activities, but also organization and infrastructure around ML research within automation. The workshop will therefore conclude with an open discussion to get interesting inputs for future activities within this challenging research field.

Organizers:

Bengt Lennartson, Professor, Division of Systems and Control, Department of Electrical Engineering, Chalmers University of Technology, Gothenburg, Sweden.
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Schedule

09:00-10:00	Bengt Lennartson. Introduction to Machine Learning for Automation.
10:00-10:40	Qing-Shan Jia (Online), Event-Based Reinforcement Learning for Cyber-Physical Energy Systems – Smart Buildings, Smart Grid, and Smart Cities.
10:40-10:50	Coffee break.
10:50-11:30	Maria Pia Fanti. Machine learning and deep reinforcement learning in automotive, traffic management and structural health monitoring.
11:30-12:10	Peter B. Luh. Synergistic Integration of Machine Learning and Mathematical Optimization for Difficult Optimization Problems.
12:10-13:00	Lunch.
13:00-13:40	Jingang Yi. Learning-enabled wearable inertial sensor-based limb lameness detection and pose estimation for horses.
13:40-14:20	Karinne Ramirez-Amaro. Explainable AI meets Robotics - Robots that Learn and Reason from Experiences.
14:20-15:00	Workshop panel discussion.

Speakers

Bengt Lennartson, Professor, Division of Systems and Control, Department of Electrical Engineering, Chalmers University of Technology, Gothenburg, Sweden. E-mail: bengt.lennartson@chalmers.se

Title: Introduction to Machine Learning for Automation

Abstract: A brief survey of machine learning will be given, introducing the main principles in regression and classification and their relation to classical system identification. Special emphasis will be given on kernal methods and support vector machines, due to their convexity property, still being able to model nonlinear phenomena in a flexible way. A more detailed presentation of reinforcement learning will then follow, both its basic discrete version and its approximate version, based on function approximations for high dimensional discrete and infinite dimensional continuous state-space problems. Tools to improve exploration based on Monte Carlo Tree search, reward shaping, and added temporal logic and automata specifications are also presented. Some additional concepts relating ML and automation will be discussed, such as digital twins supported by learning, and adaptive control based on reinforcement learning.

Bio: Bengt Lennartson is a Professor of the Chair of Automation since 1999 at Chalmers University of Technology, Gothenburg, Sweden. He is IEEE Fellow for his contributions to hybrid and discrete event systems for automation and sustainable production. He has been Associate Editor for Automatica and IEEE Transaction on Automation Science and Engineering, General Chair of IEEE CASE 2015, WODES 2008 and Dean of Education at Chalmers. He is the (co)author of more than 300 peer reviewed international papers, and his research is currently focused on AI planning and learning, as well as sustainable production.

Qing-Shan Jia, Professor, Center for Intelligent and Networked Systems, Tsinghua University, Beijing, China. Email: jiaqs@tsinghua.edu.cn

Title: Event-Based Reinforcement Learning for Cyber-Physical Energy Systems – Smart Buildings, Smart Grid, and Smart Cities.

Abstract: Cyber physical energy system (CPES) is where information and energy merges together to improve the overall system performance including economic, comfort, and safety aspects. Artificial intelligence which are enabled by internet of things (IoT), big data, and cloud computing, has a big role in the optimization of CPES. In this talk, we focus on event-based reinforcement learning (eRL) which makes decisions according to events instead of states. This method provides a scalable solution for large-scale

multi-stage decision making problem in which an accurate model may not be available. The performance of this method will be demonstrated by examples in smart buildings, smart micro-grid of buildings, and smart cities, and in particular on the problem of stochastic matching between the renewable power generation and the uncertain charging demand from the plug-in electric vehicles (PHEVs) in a city. We will also discuss extensions of this method to distributed optimization. We hope this work sheds light to the optimization of CPES.

Bio: Qing-Shan Jia is a full professor at Center for Intelligent and Networked Systems, Department of Automation, Tsinghua University, Beijing, China. His research interest is to develop an integrated data-driven, statistical, and computational approach to find designs and decision-making policies which have simple structures and guaranteed good performance. His work relies on strong collaborations with experts in manufacturing systems, energy systems, autonomous systems, and smart cities. He was an AE of IEEE T-ASE and T-AC, and is a member of the IEEE CASE Steering Committee.

Maria Pia Fanti, Professor, Department of Electric and Information Engineering, Polytechnic University of Bari, Italy. Email: mariapia.fanti@poliba.it

Title: Machine learning and deep reinforcement learning in automotive, traffic management and structural health monitoring.

Abstract: The increasing availability of data coming from sensors is changing the way to take decisions in important industrial areas. The talk will present some results about machine learning (ML) and deep reinforcement learning (DRL) techniques applied in different automation fields: automotive, traffic management and structural health monitoring. Autonomous braking systems based on an intelligent agent trained with DRL can interact with the environment, collect data and react by controlling the vehicle speed when uncontrolled events require an action. Supervised ML algorithms are applied to the predictive maintenance of electro-injector of diesel engine by novel non-invasive approaches. DRL approaches are used for efficiently handling by intelligent traffic lights road traffic in road intersections where priority issues are important. Innovative methods based on ML tools are used for detecting damages in steel truss railway bridges to classify raw strain multivariate time series data.

Bio: Maria Pia Fanti has been with the Department of Electrical and Information Engineering of the Polytechnic of Bari, Italy, since 1983 and she is currently a full professor of system and control engineering. Her research interests include management and modeling of complex systems, such as transportation, logistics and manufacturing systems. Prof. Fanti has published more than 315 papers and two textbooks on her research topics. She was senior editor of the IEEE TASE and she is AE of the IEEE Trans. on SMC: Systems. She was member at large of the Board of Governors of the IEEE SMCS, and currently she is member of the AdCom of the IEEE RAS, and chair of the RAS. Prof. Fanti was General Chair of the 2011 IEEE CASE and the 2019 IEEE SMC.

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Title: Synergistic Integration of Machine Learning and Mathematical Optimization for Difficult Optimization Problems.

Abstract: Many important optimization problems in manufacturing and power systems involve discrete decision variables, and the complexity to obtain an optimal solution increases exponentially as the problem size increases, limiting solution quality or problem sizes that can be practically solved. Also, there is “no learning” in optimization – after a problem is solved, to solve a different instance, we usually start all over again. When machine learning is used to solve such problems, success is generally limited to small problems because of complexity. In this talk, a fundamental resolution of such problems is presented through a synergistic integration of machine learning and optimization for near-optimal solutions. The novelties include:

• a novel decomposition and coordination approach exploiting the exponential reduction of complexity upon decomposition;

• using machine learning to provide "good enough" subproblem solutions – much easier than solving the original problem; and

• novel integration of supervised and unsupervised learning for enhanced offline/online learning.

Bio: Peter Luh was with U. Connecticut 1980-2020, and was a Board of Trustees Distinguished Professor and the SNET Professor of Communications & Information Technologies upon retirement. He is now a Distinguished Chair Professor at National Taiwan University. He was the founding EiC of T-ASE, a Co-Founder of CASE, and is a member of the IEEE Publication Services and Products Board, and the Chair of its Publishing Conduct Committee. His research includes intelligent manufacturing, smart grid, and energy-smart buildings, with optimization cutting across them. He received RAS 2013 Pioneer Award, 2017 George Saridis Leadership Award, and T-ASE 2019 Best Paper Award.

Jingang Yi, Professor, Department of Mechanical and Aerospace Engineering, Rutgers, The State University of New Jersey, USA. E-mail: jgyi@rutgers.edu

Title: Learning-enabled wearable inertial sensor-based limb lameness detection and pose estimation for horses.

Abstract: Automation technologies are increasingly used for precision agriculture but few have focused on monitoring individual animals in open field for precision livestock farming. Limb lameness detection and pose estimation in open field is labor-intensive, unsafe for farmers, and inefficient. I will present a machine learning-enabled, wearable inertial measurement unit (IMU)-based design to provide an effective and efficient approach for horse limb lameness detection and pose estimation applications. The gait event and lameness detection are first built on a recurrent neural network (RNN) with long short-term memory (LSTM) cells with four IMUs with each on lower limb. A learned low-dimensional motion manifold is parameterized by a phase variable with a Gaussian process dynamic model. Experimental results show that the RNN-LSTM-based approach achieves 95% lameness detection accuracy and the pose estimation scheme can predict the 24 limb joint angles with average errors less than 5 and 10 degs under normal and induced lameness conditions, respectively. Because the design is built on wearable inertial sensors, it can be potentially used for potential real-time applications in open field.

Bio: Dr. Jingang Yi received the B.S. degree in electrical engineering from Zhejiang University, China, in 1993, the M.Eng. degree in precision instruments from Tsinghua University, China, in 1996, and the M.A. degree in mathematics and the Ph.D. degree in mechanical engineering from the University of California, Berkeley, CA, USA, in 2001 and 2002, respectively. He is currently a Professor of Mechanical Engineering at Rutgers University. His research interests include autonomous robotic systems and automation science and engineering, with applications to biomedical systems, civil infrastructure, and transportation systems. Dr. Yi is a fellow of the ASME and a Senior Member of IEEE. He serves as a Senior Editor for the IEEE Robotics and Automation Letters and IEEE Trans on Automation Science and Engineering.

Karinne Ramirez-Amaro, Associate Professor, Division of Systems and Control, Department of Electrical Engineering, Chalmers University of Technology, Gothenburg, Sweden. E-mail: karinne@chalmers.se

Title: Explainable AI meets Robotics - Robots that Learn and Reason from Experiences.

Abstract: The advances in Collaborative Robots (Cobots) have rapidly increased with the development of novel data- and knowledge-driven methods. These methods allow robots, to some extent, to explain their decisions. This research area is known as Explainable AI and is gaining importance in the robotics community. One advantage of such methods is the increase of human trust towards Cobots since robots could explain their decisions, especially when errors occur or when facing new situations. Explainability is a challenging and important component when deploying Cobots into real and dynamic environments. In this talk, I will introduce a novel semantic-based learning method that generates compact and general models to infer human activities. I will also explain our current learning approaches to enable Cobots to learn from

experience. Reasoning and learning from experiences are key when developing general-purpose machine learning methods. These experiences will allow robots to remember the best strategies to achieve a goal. Therefore, the new generation of robots should reason based on past experiences while providing explanations in case of errors. Thus, improving the autonomy of robots and human's trust to work with robots.

Bio: Dr. Karinne Ramirez-Amaro is an Associate professor at Chalmers University of Technology since March 2022. Previously, she was a post-doctoral researcher at the Technical University of Munich (TUM), Germany. She completed her Ph.D. (summa cum laude) at the Department of Electrical and Computer Engineering at TUM in 2015. She has received different awards, e.g. the price of excellent Doctoral degree for female engineering students and the Google Anita Borg scholarship. In 2022, Karinne was elected as member of the Administrative Committee (AdCom) from the IEEE Robotics and Automation Society (RAS) and she is the chair of the IEEE RAS Women in Engineering (WiE). Her research interests include Explainable AI, Semantic Representations, Cause-based Learning Methods, Collaborative Robotics, and Human Activity Recognition and Understanding.