Title: Workshop on Machine Learning for Automation - In Memory of Peter B. Luh

Organizers:

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Time: 10:00-17:00, August 26, 2023

Abstract: There has been tremendous development in machine learning for automation. This is not only witnessed by the successful workshop under the same title in CASE 2022, but also by the growing number of related publications in CASE/ICRA/T-ASE as well as in other journals and conferences. We would like to continue this workshop in CASE2023 to update our review on the exciting research progress as well as research opportunities in this field. This year, our workshop is unique. We organize this event in memory of Professor Peter B. Luh, a founding member of the AdHoc on Machine Learning for Automation, and a beloved friend to many of us, who passed away at the end of 2022. Peter once enthusiastically identified Machine Learning for Automation as "the next big thing" for our research community. We intend to use this workshop to share the exciting progress in this field with more members of our community.

Descriptions: This whole-day event includes in-depth discussions on machine learning for automation, including theories, methods, and applications. This year we plan to include a specific area, i.e., logistics, into our workshop, which will be application background for about half of the presentations. The rest of the talks will focus on exciting research progress in other selected application domains such as smart buildings, smart grids, data centers, manufacturing, etc.
Our planned speakers include several senior members of CASE steering committee who know the vision of Peter and can go back to talk about why this field is exciting, former PhD students, and long-term collaborators with Peter who can share great research progress in this direction. In the afternoon session, we will also include an open-floor discussion on the next step including but not limited to the creation of data hubs to host benchmark problems in this field.

Format: One day, presentation and open discussion. Each talk is about 25-minute presentation and 5-minute discussion. At the end of the afternoon session, an open floor discussion is planned when everyone is welcome to share.

Tentative schedule

09:30 Arrival morning tea
10:00 Intro
10:10 Speech 1, Barbara Hammer, Graph Neural Networks as Digital Twins of Complex Systems
10:40 Speech 2, Bengt Lennartson, Transformers, Reinforcement Learning and Model Predictive Control
11:10 Speech 3, Maria Pia Fanti, Machine Learning and Deep Reinforcement Learning in Automative, Traffic Management and Structural Health Monitoring
11:40 Speech 4, Xiaohong Guan, Zero-Carbon Intelligent Energy Systems and Energy Revolution
12:10 Lunch
13:00 Speech 5, Qianchuan Zhao, An Open-Source Distributed System Honeycomb for Smart Buildings with Applications
13:30 Speech 6, Birgit Vogel-Hauser, Data Preprocessing and Expert Knowledge as Success Factors for Machine Learning in Production Industry
14:00 Speech 7, Mengchu Zhou, Autoencoder-embedded Evolutionary Optimization Algorithms and their Applications to Scheduling Problems
14:30 Afternoon tea
15:00 Speech 8, Bing Yan, Synergistic Integration of Machine Learning and Mathematical Optimization for Sub-hourly Unit Commitment
15:30 Speech 9, Samuel Jia, Event-Based Learning and Optimization for Green Smart Grid
16:00 Open discussion
17:00 Closing time

List of Speakers (Orders are tentative)

Morning Session
Speech 1

Barbara Hammer

Title
Graph neural networks as digital twins of complex systems

Abstract
Machine learning models can play a vital role to simplify complex automation and optimization tasks. One avenue is their role within digital twins, enabling real-time and flexible simulations of complex systems by means of a fully digital `virtual' surrogate, including the possibility of simulating scenarios which should be avoided in reality. Within the talk, I will focus on water distribution systems as part of our critical infrastructure. These constitute an example of a complex spatial-temporal dynamical system with an underlying graph structure. Message-passing graph neural networks offer specific instances of

deep learning architectures which are capable of naturally dealing with such settings. We demonstrate their potential in providing efficient virtual sensors. Moreover, we demonstrate a novel physics-informed training scheme which enables us to learn the system dynamics based on underlying invariances rather than observed data .

Bio Sketch

Barbara Hammer is a full Professor for Machine Learning at the CITEC Cluster at Bielefeld University, Germany. She received her Ph.D. in Computer Science in 1999 and her venia legendi (permission to teach) in 2003, both from the University of Osnabrueck, Germany, where she was head of an independent research group on the topic 'Learning with Neural Methods on Structured Data'. In 2004, she accepted an offer for a professorship at Clausthal University of Technology, Germany, before moving to Bielefeld in 2010. Barbara's research interests cover theory and algorithms in machine learning and neural networks and their application for technical systems and the life sciences, including explainability, learning with drift, nonlinear dimensionality reduction, recursive models, and learning with non-standard data.

Speech 2

Bengt Lennartson

Title

Transformers, Reinforcement Learning and Model Predictive Control

Abstract

The main concepts in the multimodal language GPT-4, especially deep generative modelling, learning-based attention, and fine-tuning by reinforcement learning (RL), are presented in this talk. The attention mechanism involves a simple network architecture, called Transformer, which efficiently replaces standard deep convolutional and recurrent neural networks. This Transformer can also be used to improve the interaction between robots and humans in automation applications, where the robot can predict human movement intentions based on eye tracking. Fine-tuning of the multimodal language is performed by policy gradient RL. The policy gradient method is especially suitable for model-free RL control of continuous systems. A survey of the most well-known policy gradient methods is given, complemented with some promising simplified alternatives. Finally, it is illustrated how model-based and model-free RL can be unified in a recently proposed combined RL and Model Predictive Control strategy. This approach is applied to the learning-based energy reduction of a flexible robot station.

Bio Sketch

Bengt Lennartson received the Ph.D. degree from the Chalmers University of Technology, Gothenburg, Sweden, in 1986. Since 1999 he has been a Professor of the Chair of Automation at the Department of Electrical Engineering, Chalmers University of Technology, where he was the Dean of Education 2004-2007. He was the General Chair of IEEE CASE 2015, and WODES’08, and he has been Associate Editor for Automatica and IEEE Transaction on Automation Science and Engineering. He is the

(co)author of more than 300 peer reviewed international papers, and his research is currently focused on discrete-event systems, AI planning and learning, as well as sustainable production. He is a Fellow of the IEEE.

Speech 3

Maria Pia Fanti

Title

Machine Learning and Deep Reinforcement Learning in Automative, 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: 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.

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 and DRL tools are used for detecting damages in steel truss railway bridges to classify raw strain multivariate time series data.

Bio Sketch

Maria Pia Fanti (M’92-SM’02-F’17) received the Laurea degree in electronic engineering from the University of Pisa, Pisa, Italy, in 1983. She was a visiting researcher at the Rensselaer Polytechnic Institute of Troy, New York, in 1999. Since 1983, she has been with the Department of Electrical and Information Engineering of the Polytechnic University of Bari, Italy, where she is currently a Full Professor of system and control engineering and Chair of the Laboratory of Automation and Control. Her research interests include management and modeling of complex systems, such as transportation, logistics and manufacturing systems; discrete event systems; Petri nets; consensus protocols; fault detection. Prof. Fanti has published more than 335 papers and two textbooks on her research topics.

She was senior editor of the IEEE Trans. on Automation Science and Engineering and she is Associate Editor of the IEEE Trans. on Systems, Man, and Cybernetics: Systems. She was member at large of the Board of Governors of the IEEE Systems, Man, and Cybernetics Society, and currently she is member of the AdCom of the IEEE Robotics and Automaton Society, and chair of the Technical Committee on Automation in Logistics of the IEEE Robotics and Automation Society. Prof. Fanti was General Chair of the 2011 IEEE Conference on Automation Science and Engineering, the 2017 IEEE International

Conference on Service Operations and logistics, and Informatics and the 2019 IEEE Systems, Man, and Cybernetics Conference.

Speech 4

Xiaohong Guan

Title

Zero-Carbon Intelligent Energy Systems and Energy Revolution

Abstract

This speech will discuss the new structure of green energy systems and how zero carbon emission energy system can be realized. In fact, economic energy storage technology is the key for fully utilizing new renewable energy sources. Production, storage and transportation, and utilization of hydrogen as a main energy source are introduced in the speech, and it is shown that hydrogen can become a major secondary energy source as important as electricity. The hydrogen based intelligent energy system will provide a new solution for energy supply and consumption with nearly zero-carbon emission and may lead to the energy revolution in the near future.

Bio Sketch

Xiaohong Guan received his B.S. and M.S. degrees in Control Engineering from Tsinghua University, Beijing, China, in 1982 and 1985, respectively, and his Ph.D. degree in Electrical and Systems Engineering from the University of Connecticut in 1993. He was a senior consulting engineer with Pacific Gas and Electric from 1993 to 1995. He visited the Division of Engineering and Applied Science, Harvard University from 1999 to 2000. From 1985 to 1988 and since 1995 he has been with Xian Jiaotong University, Xian, China, and has been as the Cheung Kong Professor of Systems Engineering and Director of Systems Engineering Institute since 1999, was the director of the State Key Lab for Manufacturing Systems 1999-2009, Dean of School of Electronic and Information Engineering 2008-2018, and Dean of Faculty of Electronic and Information Engineering since 2019. From 2001 he has also been with the Center for Intelligent and Networked Systems, Tsinghua University, Beijing, China, and severed the Head of Department of Automation, Tsinghua University, 2003-2008. Professor Guan is the member of Chinese Academy of Science and the Fellow of IEEE. His research interests include optimization of electrical power and energy systems, manufacturing systems, etc., and cyber-physical systems.

Afternoon Session

Speech 5

Qianchuan Zhao

Title

An open-source distributed system Honeycomb for smart buildings with applications

Abstract

Restricted by the hierarchical and centralized system architecture, smart buildings face challenges such as limited adaptability and robustness, single application functionalities, and complex configurations. To address the above shortcomings, we learn from the activity patterns of natural bee swarms and propose Honeycomb, an open-source smart-building solution with fully distributed architecture. Honeycomb is a robust, flexible smart building solution without any central server or global leader. An asynchronous leaderless spanning tree-based communication pattern is developed to generate and maintain the communication topology of Honeycomb in real time. Benefiting from this communication pattern, Honeycomb has plug-and-play ability. Various distributed applications are designed for building operating tasks and are deployed in a real Honeycomb prototype including deep learning based short term indoor temperature prediction models. The prototype demonstrates significant energy efficiency improvement from the control of the heating, ventilation, and air conditioning (HVAC) system with video-based occupancy information. Feedback on our Honeycomb prototype through questionnaires of users shows high acceptance of the controlled indoor environment.

Bio Sketch

Qianchuan Zhao (Senior Member, IEEE) received the B.E. degree in automatic control, the B.S. degree in applied mathematics, in 1992, and the M.S. and Ph.D. degrees in control theory and its applications from Tsinghua University, Beijing, China, in 1996. He is currently a Professor and the Director of the Center for Intelligent and Networked Systems (CFINS), Department of Automation, Tsinghua University. He has published more than 100 research papers in peer-reviewed journals and conferences. His current research interests include the control and optimization of complex networked systems with applications in smart buildings, smart grid, and manufacturing automation. He served as the funding Chair for the Technical Committee on Smart Buildings of the IEEE Robotics and Automation Society. He is currently the Editor-in-Chief of the Results in Control and Optimization (RICO), an Editor of the IEEE TRANSACTIONS ON AUTOMATION SCIENCE AND ENGINEERING (T-ASE), and an Associate Editor of the Journal of Optimization Theory and Applications.

Speech 6

Birgit Vogel-Heuser

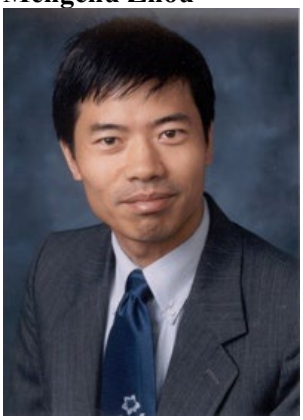
Title
Data Preprocessing and Expert Knowledge as Success Factors for Machine Learning in Production Industry

Abstract
Machine learning reveals promising optimization potentials for operation of production machines and plants. Data-driven learning methods benefit from the availability of reasonable operation data and may be enriched by expert knowledge from operators and maintenance personnel and/or engineering knowledge. The talk will address the challenges and methods to access and preprocess real data from industrial production plants by introducing a modeling notation that support software deployment as well as selected use cases including the ML approaches applied and the benefit gained.

Bio Sketch
Birgit Vogel-Heuser received Ph.D. degree in Mechanical Engineering from RWTH Aachen, Germany. She worked ten years in industry responsible for industrial automation of production plants. Since 2000 she is a full professor of Automation and Information Systems, since 2009 at Technical University of Munich (TUM, Germany) and since 2022 also Vice Dean of TUM School of Engineering Design. She was General Chair of IEEE CASE 2018. She is IEEE RAS Distinguished Lecturer, IEEE RAS TAB Automation Coordinator and a Fellow of IEEE. Her current research focuses is on intelligent adaptive physical production automation systems and software.

Speech 7

Mengchu Zhou



Title

Autoencoder-embedded Evolutionary Optimization Algorithms and their Applications to Scheduling Problems

Abstract

Many engineering optimization problems involve numerous decision variables and highy expensive performance evaluations. Exponentially expanding search space and complex landscape brought by such variables make these problems extremely challenging to be solved by traditional algorithms with limited physical/computational resources. Therefore, an Autoencoder-embedded Evolutionary Optimization (AEO) framework is invented to deal with them. To be specific, high-dimensional search space can be compressed to informative low-dimensional space by using an autoencoder as an effective dimension reduction tool. The search operation conducted in this low-dimensional space facilitates the population in convergence towards the optima. To balance the exploration and exploitation ability during optimization, two sub-populations coevolve in a distributed/parallel fashion, wherein one is assisted by an autoencoder and the other undergoes a regular evolutionary optimization process. Dynamic information exchange is conducted between them after each cycle to promote population diversity. Moreover, surrogate models can be incorporated into AEO (SAEO) to further boost its performance by reducing unnecessary expensive performance evaluations. Compared with the state-of-the-art, AEO shows extraordinarily high efficiency for these challenging problems while SAEO can greatly improve the performance of AEO in most cases, thus opening new directions for various swarm optimization and evolutionary algorithms under both AEO and SAEO paradigms to solve high-dimensional expensive optimization problems, especially complex scheduling problems.

Bio Sketch

MengChu Zhou received his B.S. degree in Control Engineering from Nanjing University of Science and Technology, Nanjing, China in 1983, M.S. degree in Automatic Control from Beijing Institute of Technology, Beijing, China in 1986, and Ph. D. degree in Computer and Systems Engineering from Rensselaer Polytechnic Institute, Troy, NY in 1990. He joined the Department of Electrical and Computer Engineering, New Jersey Institute of Technology in 1990, and is now a Distinguished Professor. His interests are in intelligent automation, robotics, Petri nets, Internet of Things, edge/cloud computing, and big data analytics. He has over 1100 publications including 14 books, over 750 journal papers including over 600 IEEE Transactions papers, 31 patents and 32 book-chapters. He is a recipient of Excellence in Research Prize and Medal from NJIT, Humboldt Research Award for US Senior Scientists from Alexander von Humboldt Foundation, and Franklin V. Taylor Memorial Award and the Norbert Wiener Award from IEEE Systems, Man, and Cybernetics Society, and Edison Patent Award from the Research & Development Council of New Jersey. He is a life member of Chinese Association for Science and Technology-USA and served as its President in 1999. He is Fellow of IEEE, IFAC, AAAS, CAA and NAI.

Speech 8

Bing Yan

Title

Synergistic Integration of Machine Learning and Mathematical Optimization for Sub-hourly Unit Commitment

Abstract

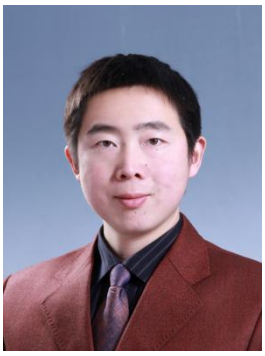
The integration of intermittent renewables into power systems presents significant challenges for operators due to increased uncertainties and greater intra-hour net load variability. Sub-hourly Unit Commitment (UC) has been suggested as a solution to quickly respond to changes in electricity supply and demand, which is more complicated than hourly UC because of a higher number of time periods, and higher dependencies among coupled periods. Traditional optimization methods could be time-consuming while machine learning (ML) may have additional feasibility concerns. To address these challenges, a hybrid approach based on synergistic integration of ML and optimization is developed. This novel approach adopts our recent decomposition and coordination Surrogate Absolute-Value Lagrangian Relaxation (SAVLR) method with efficient coordination and accelerated convergence. ML is then used to quickly predict SAVLR subproblem solutions. Compared to those of the original overall problem, subproblem solutions are much easier to learn. Nevertheless, predicting "good" subproblem solutions is still challenging because of the "jumps" of binary decisions and many types of unit-level constraints. To overcome these issues, a generic ML model, embedding recurrent neural networks (RNNs) and the Attention mechanism in the encoder-and-decoder structure, is developed. Because of the features of RNNs and Attention, this generic model can learn different subproblem solutions to reduce the training effort, and can provide accurate time-based predictions to capture dependencies. Additionally, a rule-based feasibility layer is incorporated into the generic model, ensuring feasibility with respect to unit-level constraints. Testing on the IEEE 118-bus system demonstrates the effectiveness of our approach, providing feasible and accurate subproblem solutions quickly, and obtaining near-optimal overall solutions efficiently.

Bio Sketch

Dr. Bing Yan is currently an assistant professor in the Department of Electrical and Microelectronic Engineering at the Rochester Institute of Technology. She received her B.S. degree in information management and information system from Renmin University of China in 2010, M.S. degrees in electrical engineering and statistics from the University of Connecticut in 2012 and 2017, respectively, and Ph.D. degrees in electrical engineering from the University of Connecticut in 2016. Before joining Rochester Institute of Technology, she was an assistant research professor in the Department of Electrical and Computer Engineering, University of Connecticut. Dr. Yan's research interests include planning and scheduling of intelligent manufacturing systems, self-optimizing factories, operation optimization of smart power and energy systems, and mathematical optimization of large-scale mixed-integer linear programming problems.

Speech 9

(Samuel) Qing-Shan Jia



Title
Event-Based Learning and Optimization for Green Smart Grid

Abstract
Machine learning has re-shaped many technologies in many infrastructures in modern cities. In this talk, we focus on its impact on a particular type of energy systems, namely smart grid that connects renewable energy with residential and commercial buildings. These systems are around us in our daily life. Changes in their "intelligence" are witnessed (and questioned) by the general public. To utilize the growing data and to coordinate larger systems, event-based learning and optimization intends to update decision making only when certain state transitions occur. We will review the basic ideas of this method and the latest development. For this speaker, connecting this method with smart grid applications would not be possible without Professor Peter Luh's suggestions and guidance. A few stories will be shared in the talk.

Bio Sketch
(Samuel) Qing-Shan Jia received B.S. and Ph.D. degrees from Tsinghua University, Beijing, China, in 2002 and 2006, respectively. He was a postdoc at Harvard (2006), a visiting scholar at HKUST (2010) and MIT (2013). He is currently a tenured full professor with Center for Intelligent and Networked Systems (CFINS) at Tsinghua. His main research contribution is optimization theories and methods for cyber physical energy systems. His work has received Chinese National Natural Science Award, twice, as well as several best paper awards in journals and conferences. He is an active member in IEEE Control Systems Society (CSS) and Robotics & Automation Society (RAS). He was the chair of the Discrete Event Systems TC in IEEE CSS, founding co-chair of Smart Building TC in IEEE RAS, and founding chair of IFAC TC 9.3 - Control for Smart Cities. He was an AE for IEEE T-AC and T-ASE. He is a member of the Steering Committee of IEEE CASE.

Peter Bao-Sen Luh

DECEMBER 21, 1950 – NOVEMBER 28, 2022

Peter was born on December 21, 1950, in Taipei, Taiwan, and received his BS from National Taiwan University, MS from MIT, and PhD from Harvard. Peter began his teaching career in 1980 at the University of Connecticut, where he was a professor of Electrical and Systems Engineering for 41 years. During this time, he was continually invited all over the world to act as keynote speaker at conferences, chair workshops, and assess universities' electrical engineering programs. In 2018 he was conferred the title of Board of Trustees Distinguished Professor, UConn's highest academic honor—among many other honors he received throughout his career.

Peter was also an active member of IEEE. Peter was a Life Fellow of IEEE, a member of IEEE Publication Services and Products Board (PSPB), Chair of PSPB's Publishing Conduct Committee, the founding Editor-in-Chief of T-ASE (2003-2007), and a co-founder of CASE, to name some of his auxiliary roles.