Ph.D. Short Course on

Sustainable Mobility and System Control Sciences

August 19-25, 2018, Sophia University, Tokyo, Japan

This short course aims at introducing system modelling, control theory, learning and optimization theory, as well as applications in sustainable automotive powertrain systems. Topics range from system identification, learning dynamical systems, model predictive control (MPC) and optimization to fundamentals of extreme learning machine (ELM) and future trends of machine learning. Applications of advanced engine combustion control and powertrain control will also be highlighted. An interactive poster session will be held during the course. Besides, an industrial technical tour at Toyota Higashi-Fuji Technical Center will be organized for attenders.

Lecturers:

Takehisa Yairi, Associate Professor, The University of Tokyo, Japan
Masakazu Mukai, Associate Professor, Kogakuin University, Japan
Per Tunestål, Professor, Lund University, Sweden
Lars Eriksson, Professor, Linkoping University, Sweden
Guang-bin Huang, Professor, Nanyang Technological University, Singapore

Prospective Participants*

Ph.D course students from any Japanese universities including MIRAI partners (Master's students are also welcome)
Ph.D course students from Swedish MIRAI partners

*1) The participants are required to register in advance by e-mail;
*2) The Participant who intends to contribute a Poster Presentation, please send your title and abstract in advance.

Organizer

Sophia University

Co-Sponsor

MIRAI
- Connecting Swedish and Japanese Universities through Research, Education and Innovation

Steering Committee

Tielong Shen
(Prof., Sophia Univ., Japan)

Lars Eriksson
(Prof., Linkoping Univ., Sweden)

Per Tunestål
(Prof., Lund Univ., Sweden)

Contact:

Dr. Yahui Zhang (Sophia Univ.)
Dr. Xun Shen (Sophia Univ.)
E-mail:
zhangyahui@eagle.sophia.ac.jp
shenxun@eagle.sophia.ac.jp

Program at a Glance

Time Schedule	10:30-12:00	13:30-15:00	15:30-17:00	17:00-	Place
8/19 SUN	• Registration (Bldg.#8-201)	• Registration	• Registration		• Sophia University
8/20 MON	• Lecture I-1 • Prof. Takehisa Yairi	• Lecture II-1 • Prof. Masakazu Mukai	• Lecture II-2 • Prof. Masakazu Mukai	• Poster Session • Welcome Reception	• Sophia University
8/21 TUE	• Lecture I-2 • Prof. Takehisa Yairi	• Lecture III-1 • Prof. Per Tunestål	• Lecture III-2 • Prof. Per Tunestål		• Sophia University
8/22 WED	• Lecture IV-1 • Prof. Lars Eriksson	• Lecture IV-2 • Prof. Lars Eriksson	• Lab Tour		• Sophia University
8/23 THU	• Lecture IV-3 • Prof. Lars Eriksson	• Lecture IV-4 • Prof. Lars Eriksson	• Lecture V-1 • Prof. Guang-Bin Huang		• Sophia University
8/24 FRI	• Industrial Technical Tour: Toyota Higashi-Fuji Technical Center	• Lecture V-2 • Prof. Guang-Bin Huang	• Lecture VI-1 • Lecture VI-2 • Toyota Experts (to be announced)	• Move to Hotel (Mount Fuji) • Farewell Reception	• Toyota Higashifuji Research Center • Gotemba Kogen Hotel
8/25 SAT	• Return to Tokyo				• Sophia University

Tutorial Lecture I : Machine Learning for System Identification

Takehisa Yairi
Associate Professor, Artificial Intelligence Laboratory, The University of Tokyo, Japan

Abstract: Constructing mathematical models of dynamical systems based on observation data is one of the most fundamental topics in many research fields from science, engineering to economics. In control engineering, this problem is known as system identification and has been exhaustively studied for long time, which leads to a variety of methods considering the characteristics of target systems. On the other hand, there have been a lot of interests in learning dynamical systems from big time-series data in the machine learning community too. Recently, the state-of-the-art machine learning techniques such as deep neural network and Gaussian process regression are combined with these studies, which extends the applicable area remarkably. In this course, we classify the methods of learning dynamical systems into (1) maximum likelihood approach, (2) spectral approach and (3) neural networks approach, and explain the fundamental ideas, theories and representative methods of each category. In addition, we will introduce a study of data-driven anomaly detection and health monitoring for complex artificial systems such as spacecraft as an application case study. The course is divided into five modules:

(1) Basics of learning dynamical systems, State space and latent variable models.

(2) Maximum likelihood approach, EM algorithm, Extension to non-linear systems

(3) Spectral approach and subspace identification

(4) Neural network approach and recent trends

(5) Application: anomaly detection and health monitoring for complex systems

Takehisa Yairi received the B.Eng., MSc., and Ph.D. degrees in aerospace engineering from the University of Tokyo, Tokyo, Japan, in 1994, 1996, and 1999, respectively. He is currently a Full-Time Associate Professor in the Department of Aeronautics and Astronautics, School of Engineering, the University of Tokyo. His research interests include anomaly detection, health monitoring, fault diagnosis, learning dynamical systems, nonlinear dimensionality reduction, as well as application of machine learning and probabilistic inference to aerospace systems.

Tutorial Lecture II : Model Predictive Control of Mixed Logical Systems

Masakazu Mukai
Associate Professor, Kogakuin University, Japan

Abstract: Model predictive control (MPC) is a dominant control approach that can handle constraints. This tutorial lecture presents the model predictive control method for systems integrating logical representation and dynamics. The logical representations include proportional logic. The model predictive control problem is formulated as a mixed integer programing. As an application of the model predictive control with logical representation, the automatic longitudinal control with traffic signal information is presented:

Module 1: Model predictive control

Module 2: Mixed logical systems

Module 3: Applications, automatic longitudinal control with traffic signal information

Many examples from academic and industrial contexts are used to illustrate the concepts included in the course.

Masakazu Mukai received the B.E., ME. and Dr. of Engineering degrees in Electrical Engineering from Kanazawa University, Japan, in 2000, 2002, and 2005, respectively. He had been working with the Graduate School of Information Science and Electrical Engineering, Kyushu University since 2005 to 2014. He is currently with the Department of Electric and Electrical Engineering, Kogakuin University. His research interests include model predictive control and automotive control. He is a member of the SCIE, ISCIE, IEEJ, and IEEE.

Tutorial Lecture III: Engine Combustion Control (tentative)

Per Tunestål
Professor, Lund University, Sweden

Abstract: Combustion control is the art of achieving a desired combustion specification in real time using the available actuators, sensors and computational hardware. Traditionally, combustion control is primarily based on maps with engine speed and load as independent variables but modern combustion concepts as well as ever stricter emission standards require closed loop control of the combustion process based on sensors both inside and outside the combustion chamber.
The lecture includes a brief overview of conventional and advanced engine combustion concepts and their respective control requirements. An overview of available sensors and actuators is presented as well as methods to extract combustion information from the sensors. Application examples from SI, Diesel, HCCI and PPC control are included in order to present a comprehensive picture of sensing, computation, actuation and the result on combustion and performance. Various control design methods are covered in light of the examples, such as PID, LQG, MPC and mid-ranging. Adequate gas path control is a prerequisite for combustion control and is also covered in the module.

Per Tunestål received his PhD in Mechanical Engineering at the University of California, Berkeley in 2000. He presently holds a position as Professor at Lund University where he is in charge of the engine control activities. Per Tunestal also serves as Director of The KCFP Engine Research Center, a consortium financed by The Swedish Energy Agency, Lund University and 14 member companies world-wide. Special interests are engine control based on in-cylinder measurements and cylinder-pressure based parameter estimation. Per Tunestal holds more than 100 scientific publications within the combustion engine field and he has served as chairman of the Control and Calibration committee within the Society of Automotive Engineers. Lund university was founded in 1666. Today it is an international center for research and education that has approximately 48 000 students and 7500 employees. Lund University is respected as one of the top universities in Sweden with an excellent academic reputation and a large number of visiting professors and international students. Lund University is also consistently ranked as one of the top 100 universities in the world.

Tutorial Lecture IV : Modeling and Control of Engines and Drivelines (tentative)

Lars Eriksson
Professor, Dept. of Electrical Engineering, Linkoping University, Sweden

Abstract: Control systems have come to play an important role in the performance of modern vehicles with regards to meeting goals on low emissions and low fuel consumption. To achieve these goals, modeling, simulation, and analysis have become standard tools for the development of control systems in the automotive industry.

Modeling and Control of Engines and Drivelines provides an up-to-date treatment of the topic from a clear perspective of systems engineering and control systems, which are at the core of vehicle design. This lecture can be divided into four modules:

Module 1: *Signals, Systems, and Control in Modern Vehicles.*

Module 2: *Basic Dynamics of Internal Combustion Engines and Drivelines.* It has been important to provide measurements from real processes, to explain the underlying physics, to describe the modeling considerations, and to validate the resulting models experimentally.

Module 3: *Modeling and Control of Turbocharged Engines.* The talk covers recent results on modeling and analysis of turbochargers for of nominal operation. A modeling framework for extensible models for turbocharged engines is described. The methodology is applied to an analysis of surge and a control strategy is developed for surge detection and avoidance in parallel turbocharged engines. Experimental validation has been made on a car with a turbocharged V6 engine in a dynamometer.

Module 4: *Optimal Control of the Powertrain and Driving.* Trajectory of a Wheel Loader A wheel loader is modelled and the driving profile for a gravel loading cycle is optimized using optimal control. The application gives an interesting example of how optimal control can be used to evaluate trade-offs between time and fuel consumption as well as to give insights into the design and component selection in the driveline.

Lars Eriksson received the M.Sc. degree in Electrical Engineering 1995 and the Ph.D. in Vehicular Systems, 1999, both from Linköping University. His main research interests are modeling, simulation and control of vehicle propulsion system where he has a special interest in issues related internal combustion engines and vehicle powertrains. The following list topics describe the research areas that Lars Eriksson has a high interest in: Ion sensing, Zero-dimensional in-cylinder pressure models, Calculation of chemical equilibrium, Modeling and control of turbocharged SI and DI engines, Turbocharger modeling.

Tutorial Lecture V: Extreme Learning Machines: Fundamental to Big Data Analytics and Towards Brain-alike Learning? (tentative)

Guang-Bin Huang
Professor, School of Electrical and Electronic Engineering, Nanyang Technological University, Singapore.

Abstract: Neural Networks (NN) and Support Vector Machines (SVM) played key roles in machine learning and data analysis in the past 2 to 3 decades. However, it is known that these popular learning techniques face some challenging issues such as intensive human intervention, slow learning speed and poor learning scalability. This talk will introduce a next generation of learning theory – the resultant biologically inspired learning technique referred to as Extreme Learning Machine (ELM) and its wide applications. ELM not only learns up to thousands of times faster than NN and SVMs, but also provides unified implementation for feature learning, clustering, regression, binary and multi-class applications. ELM produces good results for sparse datasets and is also efficient for large size applications. From both theoretical and practical points of view, NN and SVM/LS-SVM may only produce suboptimal solutions to ELM. Our preliminary study also shows that ELM outperforms Deep Learning in both learning accuracy and learning speed (up to thousands of times faster). ELM is efficient in time series, online sequential and incremental applications. More and more researchers are studying ELM and its potential applications in face recognition, EEG signal processing, brain computer interface, medical image processing, bioinformatics, disease prediction/detection, object recognition, knowledge discovery, data privacy, security, image quality assessment, semantic web, hardware implementation, cloud computing, and many other industrial applications.

Guang-Bin Huang is a Full Professor in the School of Electrical and Electronic Engineering, Nanyang Technological University, Singapore. He is a member of Elsevier's Research Data Management Advisory Board. He is one of three Expert Directors for Expert Committee of China Big Data Industry Ecological Alliance organized by China Ministry of Industry and Information Technology, and a member of International Robotic Expert Committee for China. He was a Nominee of 2016 Singapore President Science Award, was awarded by Thomson Reuters "Highly Cited Researcher" (in two fields: Engineering and Computer Science), and listed in Thomson Reuters's "The World's Most Influential Scientific Minds." He received the best paper award from IEEE Transactions on Neural Networks and Learning Systems (2013). His two works on Extreme Learning Machines (ELM) have been listed by Google Scholar in 2017 as Top 2 and Top 7, respectively in its "Classic Papers: Articles That Have Stood The Test of Time" – Top 10 in Artificial Intelligence.

He serves as an Associate Editor of Neurocomputing, Cognitive Computation, neural networks, and IEEE Transactions on Cybernetics.

He is Principal Investigator of BMW-NTU Joint Future Mobility Lab on Human Machine Interface and Assisted Driving, Principal Investigator (data and video analytics) of Delta – NTU Joint Lab, Principal Investigator (Scene Understanding) of ST Engineering – NTU Corporate Lab, and Principal Investigator (Marine Data Analysis and Prediction for Autonomous Vessels) of Rolls Royce – NTU Corporate Lab. He has led/implemented several key industrial projects (e.g., Chief architect/designer and technical leader of Singapore Changi Airport Cargo Terminal 5 Inventory Control System (T5 ICS) Upgrading Project, etc).

One of his main works is to propose a new machine learning theory and learning techniques called Extreme Learning Machines (ELM), which fills the gap between traditional feedforward neural networks, support vector machines, clustering and feature learning techniques. ELM theories have recently been confirmed with biological learning evidence directly, and filled the gap between machine learning and biological learning. ELM theories have also addressed "Father of Computers" J. von Neumann's concern on why "an imperfect neural network, containing many random connections, can be made to perform reliably those functions which might be represented by idealized wiring diagrams."

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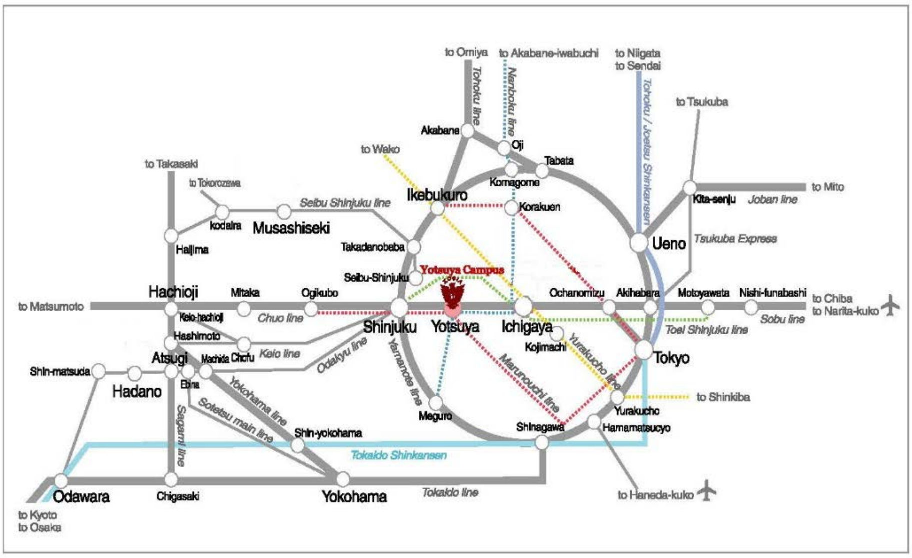
8/23 THU	• Lecture IV-3: Modeling and Control of Engines and Drivelines • Prof. Lars Eriksson	• Lecture IV-4: Modeling and Control of Engines and Drivelines • Prof. Lars Eriksson	• Lecture V-1: Extreme Learning Machines - Fundamental • Prof. Guang-Bin Huang		• Sophia University
8/24 FRI	• Industrial Technical Tour: Toyota Higashi-Fuji Technical Center	• Lecture V-2: Extreme Learning Machines - Towards Brain-alike Learning • Prof. Guang-Bin Huang	• Lecture VI-1: Benchmark Problem of Engine Control • Lecture VI-2: The future of intelligent vehicle control • Toyota Experts (to be announced)	• Move to Hotel (Mount Fuji) • Farewell Reception	• Toyota Higashifuji Technical Center • Gotemba Kogen Hotel
8/25 SAT	• Return to Tokyo				• Sophia University

Venue Access

- **Venue:** Yotsuya Campus of Sophia University, 7-1 Kioicho,Chiyoda-ku Tokyo,102-8554
  （〒102－8554　東京都千代田区紀尾井町7－1）
- **Transportation:**
  JR Chuo line, Marunouchi subway line, Nanboku subway line / 5 minutes from Yotsuya Station
  （JR中央線、東京メトロ丸ノ内線・南北線/四ッ谷駅　麹町口・赤坂口から徒歩5分）

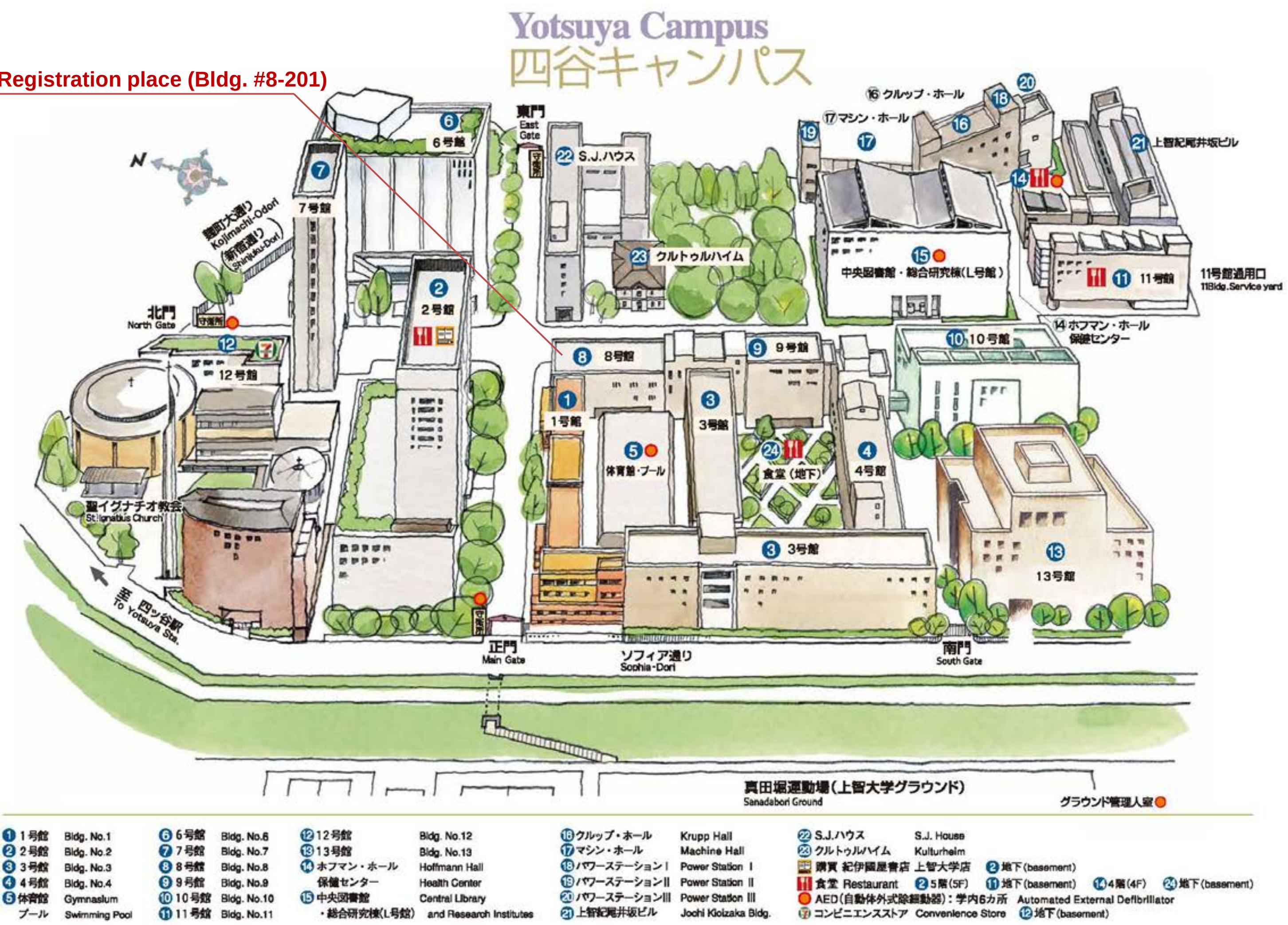
Case 1: (From Narita Airport) Narita Airport —*Kesei Line Skyliner*→ Nippori —*JR Yamanote line*→ Akihabara —*JR Chūō-Sōbu Line*→ Yotsuya Sta.

Case 2: (From Haneda Airport) Haneda Airport —*Keikyu Line*→ Shinagawa —*JR Yamanote line*→ Tokyo —*JR Chūō Line*→ Yotsuya Sta.



❑ **Train Access Guide**　　❑ **Yotsuya Station to Sophia Univ.**

❑ **Registration place (Bldg. #8-201)**



❑ **Yotsuya Campus of Sophia University**