Graduate Student Workshop on Automotive Control 2013

September 7-8, 2013, Sophia University, Tokyo, Japan

Organizer and Sponsor

- Faculty of Science and Technology, Sophia University (Japan)
- Japan Science and Technology Agency (JST)
- SICE-JSAE Joint Committee on Automotive Control

Technical Co-Sponsor

- IFAC-AAC2013
- State Key Laboratory of Engines, Tianjin University (China)
- Korea Advanced Institute of Science and Technology (Korea)

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The goal of GSW-AC 2013 is to provide students and young researchers with an opportunity to better understand the challenges and academic trends in automotive control. Four tutorial lectures will be given by world-leading experts, and graduate students from different lab groups will have an opportunity to either give a 20 minute oral or poster presentation at the oral session or the interactive session.

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Prof. Choongsik Bae (KAIST, Korea)

Contact Information

Sophia University, 7-1 Kioi-cho, Chiyoda-ku Tokyo 102-8554 Japan

Tel: 81+3-32383306
Email: zhangjy@sophia.ac.jp (Dr. Jiangyan Zhang)
kangmx@sophia.ac.jp (Mr. Mingxin Kang)

Workshop Program

Saturday, September 7
in Central Building Room 304, National Olympics Memorial Youth Center

13:30-14:45 **Tutorial Lecture I: Control of Complex Powertrain Systems**
Dr. Christopher H. Onder (*ETH, Switzerland*)

14:45-15:00 Break

15:00-16:15 **Tutorial Lecture II: Developments in Automotive Engine Control**
Prof. Ilya V. Kolmanovsky (*The University of Michigan, USA*)

Sunday, September 8
in International Conference Room, 17F, Building No. 2, Yotsuya Campus, Sophia University

09:45-11:45 **Oral Presentation**
(Research Presentations by Graduate Students)

13:30-14:45 **Tutorial Lecture III: Optimal Energy Management of Hybrid Electric Vehicles: 15 years of development at the Ohio State University**
Prof. Giorgio Rizzoni (*The Ohio State University, USA*)

14:45-15:00 Break

15:00-16:15 **Tutorial Lecture IV: Integrated traction-braking-Steering Control in Electric Vehicles with Independent in-Wheel Induction Motors**
Prof. Riccardo Marino (*The University of Rome "Tor Vergata", Italy*)

16:15-18:00 **Interactive Session**
(Discussion with Posters from Graduate Students)

18:15-20:15 Farewell Reception

References

1. Lino Guzzella and Christopher H. Onder, Introduction to Modeling and Control of Internal Combustion Engine systems (2nd Edition), Springer, 2010
2. Luigi del Re, Frank Allgower, Luigi Glielmo, Carlos Guardiola and Ilya V. Kolmanovsky (Eds.), Automotive Model Predictive Control: Models, Methods and Application, Springer, 2010
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4. Riccardo Marino, Patrizio Tomei, Cristiano M. Verrelli, Induction Motor Control Design (Advances in Industrial Control), Springer, 2010
5. Riccardo Marino and Patrizio Tomei, Nonlinear Control Design: Geometric, Adaptive and Robust (Prentice Hall Information and System Sciences), Prentice Hall, 1995

Saturday, September 7

Tutorial Lecture
Chair: Prof. Hong Chen — Central Building Room 304, National Olympics Memorial Youth Center

13:30-14:45	I	Control of Complex Powertrain Systems Dr. Christopher H. Onder ETH, Switzerland
14:45-15:00		Break
15:00-16:15	II	Developments in Automotive Engine Control Prof. Ilya V. Kolmanovsky The University of Michigan, USA

Sunday, September 8

Oral Presentation
Chair: Kang Song, Jiangyan Zhang
International Conference Room, 17F, Building No. 2, Yotsuya Campus, Sophia University

09:45-10:05	O1	Bank to Bank Balancing Control in V6 Gasoline Engine Kazuma Takatani Sophia University, Japan
10:05-10:25	O2	A Sensitivity Analysis of City Bus Fuel Consumption to Driving Style under Different Driving Conditions Hongjie Ma Tianjin University, China
10:25-10:45	O3	Effects of Operating Parameters on Mode Transition between LTC and Conventional Combustion Kihyun Kim KAIST, Korea
10:45-11:05	O4	Predictive Energy Management in Conventional Heavy Trucks Mohammad Khodabakhshian KTH, Sweden
11:05-11:25	O5	Quasi-Systematic Engine Air Path Control Strategy Based on Explicit Nonlinear Model Predictive Control Jamil EL HADEF University of Orleans and Renault SAS, France
11:25-11:45	O6	Utilizing Repetition in Operation for Optimal Control of a Wheel Loader Tomas Nilsson Linkoping University, Sweden

Sunday, September 8

Tutorial Lecture
Chair: Prof. Hui Xie — International Conference Room, 17F, Building No. 2, Yotsuya Campus,Sophia University

13:30-14:45	III	Optimal Energy Management of Hybrid Electric Vehicles: 15 years of development at the Ohio State University Prof. Giorgio Rizzoni The Ohio State University, USA
14:45-15:00		Break
15:00-16:15	IV	Integrated traction-braking-Steering Control in Electric Vehicles with Independent in-Wheel Induction Motors Prof. Riccardo Marino The University of Rome “Tor Vergata”, Italy

Sunday, September 8

Interactive Session
Chair: Kihyun Kim, Kazuma Takatani, Kosuke Umehara

International Conference Room, 17F, Building No. 2, Yotsuya Campus, Sophia University

16:15-18:00	P01	**Effect of Engine Parameters on Exhaust Emissions in a Spray-guided DISI Engine under lean Stratified Operation** Heechang Oh KAIST, Korea
	P02	**VGT-EGR Decoupling Control in Diesel Engines** Kang Song Tianjin University, China
	P03	**Model for Developing an Eco-driving Strategy of a City Bus based on Traffic Information** Denggao Huang Tianjin University, China
	P04	**Quantitative Diagnosability Analysis and Sensor Placement** Daniel Erksson Linkoping University, Sweden
	P05	**Optimal Transients Control Trajectories in Diesel-electric Systems** Martin Sivertsson Linkoping University, Sweden
	P06	**A Torque Demand Control Strategy of IC Engines for Fuel Consumption Improvement** Mingxin Kang Sophia University, Japan
	P07	**Stochastic Modeling and Control Problems of Air-fuel Ratio with Residual Gas of SI Engines** Jun Yang Sophia University, Japan
	P08	**A Statistical Likelihood based Knock Control Scheme** Haoyun Shi Sophia University, Japan
	P09	**Model-based Engine Speed Control: Modeling and A Nonlinear Receding Horizon Control Approach** Fei Li Sophia University, Japan
	P10	**Simulation Method of Fuel Consumption** Kosuke Umehara Sophia University, Japan
	P11	**Optimal Control of Stochastic System** Furuto Koshino Sophia University, Japan
	P12	**Pros and Cons of using Multilevel Converter as an Integrated Cell Balancer and Motor Driver in xEVs** Altaf Faisal Chalmers Univ. of Technology, Sweden
	P13	**Cylinder Pressure based Combustion Control to Reduce Emission Dispersions for Common Rail Diesel Engines** Jaesung Chung Hanyang University, Korea
	P14	**Optimal Control for Steady State Drifting of RWD Vehicle** Ronnapee Chaichaowarat Chulalongkorn University, Thailand

Sunday, September 8

Interactive Session
Chair: Kihyun Kim, Kazuma Takatani, Kosuke Umehara
International Conference Room, 17F, Building No. 2, Yotsuya Campus, Sophia University

16:15-18:00	P15	Low Temperature Combustion Engines: Challenges and Chances Thiva Albin RWTH Aachen, Germany
	P16	Moving Horizon Control for Vehicle Yaw Stability Based on States Observer Hongyan Guo Jilin University, China
	P17	Shift Control of 2-Speed I-AMT in Electric Vehicle Qiong Liang Jilin University, China
	P18	Nonlinear Control of Fuel Rail Pressure Regulation for GDI Engines Qifang Liu Jilin University, China
	P19	Mild merging path generation method with optimal merging point based on MPC Wenjing Cao Kyushu University, Japan
	P20	A Battery Management System using Nonlinear Model Predictive Control for a Hybrid Electric Vehicle Kaijiang Yu Kyushu University, Japna
	P21	Vehicle Mass Estimation Based on High-Frequency-Information Extraction Wenbo Chu Tsinghua University, China
	P22	The Impacts of Large Scale Electric Vehicles Charging Behaviour on Distribution System and Local Traffic System Tao Zhu Tsinghua University, China
18:15-20:15		Farewell Reception

Tutorial Lecture I: Control of Complex Powertrain Systems

Dr. Christopher H. Onder
Thermotronics
ETH, Zurich, Switzerland

Abstract: Global optimization techniques, such as dynamic programming, serve mainly to evaluate the potential fuel economy of a given powertrain configuration. Unless the future driving conditions can be predicted during real-time operation such results are of limited value. However, the results obtained using this noncausal approach establish a benchmark for evaluating the optimality of realizable control strategies. Real-time controllers must be simple in order to be implementable with limited computation and memory resources. Moreover, manual tuning of control parameters should be avoided. In this talk two approaches will be presented, namely, feedback controllers and ECMS. Both of these approaches can lead to system behavior that is close to optimal, with feedback controllers based on dynamic programming. Additional challenges stem from the need to apply optimal energy-management controllers to advanced powertrain architectures, such as combined and plug-in HEVs, as well as to optimization problems that include performance indices in addition to fuel economy.

Christopher H. Onder is a research associate and senior lecturer at ETH, Swiss Federal Institute of Technology. He coordinates all the engine system activities of the Institute of Dynamic Systems and Control at ETH. The Institute of Dynamic Systems and Control has numerous research contracts with car manufacturers and suppliers. Various projects have been successfully led by Dr. Onder. They include the fully automated control design for the series production air/fuel ratio control, the PAC-Car project which aimed at achieving the lowest fuel consumption according to the rules of the Shell Eco-marathon, deriving physical models for the fuel path of SI engines, and modeling and control of engine-out and tailpipe emissions. His main research interests are system modeling and automated parameter identification, model-based robust control, and optimal control.

Dr. Onder holds a diploma and a doctoral degree in Mechanical Engineering from ETH Zurich. He is the author and co-author of numerous articles and a book on modeling and control of engine systems. The list of his awards includes the BMW scientific award, the ETH silver medal, the Vincent Bendix award, the Crompton Lanchester Medal, and the Arch T. Colwell award

Tutorial Lecture II: Developments in Automotive Engine Control

Professor Ilya V. Kolmanovsky
Department of Aerospace Engineering
The University of Michigan, MI, USA

Abstract: Engine control systems are becoming increasingly more sophisticated to accommodate new engines, improve emissions, fuel economy, and drivability, and reduce calibration time and effort. In the first part of the presentation, the speaker will provide an overview of several conventional engine control and estimation algorithms. Then, in the second part of the presentation, opportunities for the applications of more advanced control techniques, that may use prediction, optimization and/or adaptation, will be examined and illustrated with several examples, including idle speed control and air-to-fuel ratio control. Topics in air path control of turbocharged gasoline and diesel engines with focus on predictive control and constraint handling will be also discussed. The talk will end with the speaker's outlook on several research opportunities in engine control.

Ilya V. Kolmanovsky received his M.S. and Ph.D. degrees in aerospace engineering, and the M.A. degree in mathematics from the University of Michigan, Ann Arbor, in 1993, 1995, and 1995, respectively. He is presently a professor in the department of aerospace engineering at the University of Michigan with research interests in control of automotive and aerospace engines and propulsion systems, and in control theory for systems with state and control constraints. Prior to joining the University of Michigan, Dr. Kolmanovsky was with Ford Research and Advanced Engineering in Dearborn, Michigan, for close to 15 years. He has co-authored over 300 refereed journal and conference articles and is named as an inventor on 86 United States patents on control systems to improve energy efficiency and reduce emissions of automotive engines.

Prof. Kolmanovsky is a Fellow of IEEE, and a past recipient of the Donald P. Eckman Award of American Automatic Control Council, and of IEEE Transactions on Control Systems Technology Outstanding Paper Award.

Tutorial Lecture III: Optimal Energy Management of Hybrid Electric Vehicles: 15 Years of Development at The Ohio State University

Professor Giorgio Rizzoni
Mechanical and Aerospace Engineering
The Ohio State University, OH, USA

Abstract: The seminar documents 15 years of hybrid vehicle optimal energy management research at the Ohio State University Center for Automotive Research. The activities described in this tutorial began in the second half of the 1990s, and have taken place in parallel with the commercial introduction of hybrid vehicles, dating back with the first offering of the Toyota Prius in Japan in 1998, and of the Honda Insight in the USA in 1999.

In 1993, eight agencies of the U.S. government formed a partnership with the three major North-American automotive OEMs to advance vehicle technology, with the goal of producing highly fuel-efficient vehicles. The *Partnership for a New Generation of Vehicles*, PNGV, involved DaimlerChrysler, Ford, and General Motors, through the United States Council for Automotive Research (USCAR); its most widely publicized (but not only) goal was to put in production vehicles capable of achieving 80 miles per gallon (approximately 3 liters per 100 km) by 2003. The program ended in 2001, due to the transition between the Clinton-Gore and the Bush administrations, with the automakers having demonstrated (but not launched production of) the GM Precept, the Ford Prodigy and the Chrysler ESX. All of these vehicles were characterized by the use of lightweight materials, hybrid powertrains, and other technological innovations. PNGV provided

the opportunity for a number of US universities to collaborate with USCAR and with federal agencies towards the development of fuel-efficient vehicles.

The Ohio State University was engaged in programs focused on the development of vehicle prototypes and on the development of energy management strategies and algorithms, as early as 1996. In particular, during the PNGV years the U.S. Department of Energy collaborated with USCAR in creating a series of competitions that were part of the Advanced Vehicle Technology Competitions (AVTC) program and which focused on the development of high-fuel-economy vehicle prototypes that were in practice almost invariably hybrids. Through these competitions, which have continued without interruption since 1996, OSU students have developed 7 hybrid vehicle prototypes based on mid-size sedans (FutureCar 1996-97 and 1998-99, and EcoCAR 2 2012-14), full-size SUVs (FutureTruck 2000-01 and 2002-04), and crossover SUVs (ChallengeX 2005-08 and EcoCAR 2009- 11).

Further, the OSU Center for Automotive Research has been continuously engaged in research programs related to hybrid vehicle development with a number of industry and government research sponsors, and focusing on military, commercial and passenger vehicles. Supervisory energy management of the hybrid powertrain is a critical element in each of these projects.
The seminar will review the evolution of energy management strategies from the early rule-based efforts to optimal-control based developments and adaptive and ITS inspired methods in recent years.

Giorgio Rizzoni received his BS, MS and PhD in Electrical and Computer Engineering in 1980, 1982 and 1986 from the University of Michigan. He is the Ford Motor Company Chair in Electromechanical Systems, is a Professor of Mechanical and Aerospace Engineering at The Ohio State University. Prof. Rizzoni also holds courtesy appointments in the Department of Electrical and Computer Engineering and in the Department of Design. Since 1999, he has been the Director of The Ohio State University Center for Automotive Research. His research activities are related to advanced propulsion systems for ground vehicles, energy efficiency, alternative fuels, the interaction between vehicles and the electric power grid, vehicle safety and intelligence, and policy and economic analysis of alternative fuels and vehicle fuel economy.
Prof. Rizzoni is a Fellow of SAE, a Fellow of IEEE, a recipient of the 1991 National Science Foundation Presidential Young Investigator Award, and of several other technical and teaching awards.

Tutorial Lecture IV: Integrated Traction-Braking-Steering Control in Electric Vehicles with Independent in-Wheel Induction Motors

Professor Riccardo Marino
Electronic Engineering Department
The University of Rome "Tor Vergata", Rome, Italy

Abstract: Induction motors have a simple, rugged, reliable structure, tolerate significant overloading and can produce higher torque by lower weight and smaller size in comparison to other electric motors. They constitute the first choice in railway traction and are likely to become widely used in road electric vehicles.

An electric induction motor torque response is 10/100 times faster than the torque responses of an internal combustion engine or an hydraulic braking systems since its time constant is few milliseconds and is comparable to the vehicle yaw response time constant. Moreover the torque delivered by an induction motor can be quickly and precisely estimated by an adaptive observer on the basis of stator voltages and currents, and of rotor speed measurements while the torque generated by an internal combustion engine or by an hydraulic brake is largely uncertain. Consequently if an electric vehicle is equipped by in wheel induction motors, the traction and the braking forces between each tire and the road surface can be estimated in real time and controlled precisely and quickly: this constitutes a definite advantage with respect to internal combustion vehicles. In fact this allows the estimation of the adhesion coefficient for each wheel so that the traction forces or the braking forces can be optimally distributed between front and rear axles. Moreover the flux level of each induction motor can be simultaneously and independently controlled to achieve maximum efficiency.

The motion of an electric vehicle equipped with four independent in wheel induction motors can be controlled by coordinating the action of at most six actuators: four independent motors, the front wheel steering angle and possibly the rear wheel steering angle. Since the vehicle equations of motion, the induction motor dynamics and the forces exerted by the tires are highly nonlinear, the overall control problem is multivariable, nonlinear and possibly redundant since three outputs, longitudinal, lateral speed and yaw rate are to be controlled by a minimum of three controls to a maximum of six controls. In the case of redundancy an optimal tire forces distribution can be obtained. The determination of the adhesion coefficients for each wheel allows to develop an integrated Antilock Braking Systems (ABS) and a Traction Control System (TCS) to avoid slipping when maximum accelerations and decelerations are required. Regenerative braking can be performed if in wheel motors are used. If maximum forces are exerted by each wheel an Active Front/Rear Steering System can be integrated with the ABS and TCS systems to keep automatically the vehicle yaw rate at the desired reference value. Similarly active steering and differential torque generation can be integrated to control both the vehicle yaw rate and lateral speed when sudden torque disturbances such as wind gusts appear.

Several examples of integrated traction-braking-steering controls will be discussed, illustrated and simulated for electric vehicles with two/four independent in wheel induction motors and front/rear active steering.

Riccardo Marino received the degree in Nuclear Engineering in 1979 and the master in Systems Engineering in 1981 from the University of Rome "La Sapienza". He obtained in 1982 the "Doctor of Science" degree in Systems Science and Mathematics from Washington University in St. Louis, Missouri, U.S.A. Since 1984 he is with the University of Rome 'Tor Vergata", Department of Electronic Engineering, where he is currently Professor of System Science since 1990. He visited several academic institutions: University of Illinois at Urbana-Champaign, USA, Twente University in Enschede, The Netherlands, Polytechnik of Kiev, Ukraine, University of California at Santa Barbara, USA, University of Waterloo, Canada, Ecole des Mines de Paris, Fontainebleau, France, Sophia University, Tokyo, Japan. His scientific interests and contributions are on adaptive and nonlinear control and its applications to electric motors, power systems and vehicle control.

O1: Bank to Bank Balancing Control in V6 Gasoline Engine

Kazuma Takatani
Sophia University, Japan

Abstract: These days, regulation for the environment becomes severer and exhaust gas of the vehicle is also the target of the regulation. VVT system which is the main object of this study has the property that it can change the exhaust gas and torque of the vehicle. Therefore, VVT system is very important for both aspects of environmental and output performance.

This topic deals with a Bank to Bank air charge and torque balancing problem using the VVT system for V-type gasoline engines with multi-cylinders. First, two on-line air charge imbalance detecting methods are presented. Using the air charge estimation method we extend the method for estimation the air charge imbalance for each bank. And we propose another estimation method based on VVT angle. By comparing these two estimation methods, prefer better is chosen for a deviation indicator. Following the indicator, we conduct air charge balancing control. Second, we suppress the variation in the average torque output of each bank during steady operation mode. This estimation is based on engine speed at each cylinder Bottom dead center (BDC) along the crank angle. Following the estimation, torque balancing control is conducted. Third, we conduct combination verification. Under air charge control, fuel injection command is set according to air charge. At that time we validate the torque imbalance by using the estimation indicator.

O2: A Sensitivity Analysis of City Bus Fuel Consumption to Driving Style under Different Driving Conditions

Hongjie Ma
Tianjin University, China

Abstract: This topic aims to investigate the relationship between driving style and fuel consumption in different driving cycle. Firstly, by comparing the driving operations of simulator driver and real-world driver, we put forward three kinds and 29 driving style parameters based on the engine efficiency characteristics. And then we analyzed the correlation between the fuel consumption and the driving style parameters in urban, suburb and highway driving cycle, using 40541km vehicle data collected in real traffic.

The correlation analysis results suggested that the fuel efficiency have significant differences in different driving cycle. In urban driving cycle, the fuel efficiency is sensitive to the driver operation in vehicle acceleration process, such as the proportion of time in gear 2. In highway driving cycle the fuel efficiency is sensitive to the driver operation in normal driving such as the average depth of accelerator pedal in gear 4. While in suburb driving cycle, average depth of accelerator pedal in gear 3 and gear 2 have a significant influence on the fuel efficiency.

O3: Effects of Operating Parameters on Mode Transition between LTC and Conventional Combustion

Kihyun Kim
KAIST, Korea

Abstract: An experimental study on the mode transition between low-temperature combustion and conventional combustion was carried out in a light-duty diesel engine. The characteristics of combustion mode transition with various operating parameters, including rate of exhaust gas recirculation rate change, residual gas, exhaust gas recirculation path length, fuel injection pressure and engine speed, were analyzed based on the in-cylinder pressure and hydrocarbon emission of each cycle. In the case of mode transition from low-temperature combustion to conventional combustion, rapid decreases in indicated mean effective pressure and hydrocarbon emission occurred due to the improper injection timing and the decrease of the exhaust gas recirculation rate. On the other hand, indicated mean effective pressure and hydrocarbon emission changed slowly during mode transition from conventional combustion to low-temperature combustion owing to the thermal effect of hot residual gas from conventional combustion. Faster mode transition could be achieved by the use of a shorter exhaust gas recirculation path. Although the trends of mode transition in terms of indicated mean effective pressure were similar, the noise levels, as represented by the maximum pressure rise rate, and hydrocarbon emissions were significantly affected by residual gas, fuel injection pressure and engine speed. In addition, smooth combustion mode transition could be achieved by cycle-by-cycle injection modulation without rapid changes of indicated mean effective pressure and maximum pressure rise rate. Pilot injection addition to single main injection was found to be effective to attenuate the combustion noise level during the mode transition.

O4: Predictive Energy Management in Conventional Heavy Trucks

Mohammad Khodabakhshian
KTH, Sweden

Abstract: More than 30% of operational cost of transportation companies is the fuel cost. Considering todays transportation, the importance of fuel efficiency improvement is obvious. A lot of new technologies have been introduced in the past few years in order to decrease fuel consumption in the vehicles. Hybridization and electrification of powertrain systems are two of the most promising ways which are still expensive technologies. The batteries that are used for hybrid and electric vehicles are usually more expensive than normal batteries. Other components for hybrid vehicles are also costly compare to conventional vehicles, which make the total cost of a hybrid vehicle more expensive than a conventional vehicle. When we look at the heavy vehicles, the price for hybridization is even higher.

The solution that we are proposing is optimizing the energy management using prediction in the conventional vehicles. Optimizing the energy management in the hybrid vehicles is a hot research topic, but in the conventional vehicles, it is rarely discussed. The idea is to manage any available energy buffer in the vehicle such as fuel, battery, vehicle kinematic energy, coolant temperature, cabin temperature, etc. in order to reduce the energy waste. For example, Coolant which cools the engine can be considered as an energy buffer, since its temperature rises when the engine is working, and the high temperature means energy in the system. By using the prediction unit, the vehicle controller knows what the situation in the upcoming driving conditions is and controls different energy buffers in an optimal way. A method similar to ECMS method which is used in hybrid electric vehicles and MPC based methods are the prime candidates for the controller.

This idea is beneficial in different ways. It does not require any changes in the hardware. Apart from some sensors, no extra component is needed. No change of architecture is needed. And no extra charge (apart from the sensors) will be added to the vehicle cost.

O5: Quasi-Systematic Engine Air Path Control Strategy Based on Explicit Nonlinear Model Predictive Control

Jamil EL HADEF
University of Orleans and Renault SAS, France

Abstract: Pollutant emissions and fuel economy objectives have led car manufacturers to develop innovative and more sophisticated engine layouts. The control challenge has also grown since engines are now considered as highly nonlinear multi-input multi-output systems with saturated actuators. In order to reduce time-to-market and development costs, car manufacturers are investigating the idea of a systematic engine control development approach. In this context, model predictive control might not be the only possibility but it is clearly predetermined to considerably reduce test bench tuning work requirements.

The approach that is proposed here relies on the combination of a zero-dimension engine model and nonlinear model predictive control. By solving the associated multi-parametric nonlinear problem, an explicit form of this control law can be computed. Finally, using a binary search tree to determine the control to be applied online consciously fulfills the criteria for a real-time implementation on current electronic control units (ECU).

O6: Utilizing Repetition in Operation for Optimal Control of a Wheel Loader

Tomas Nilsson
Linkoping University, Sweden

Abstract: Wheel loaders and their operation differ from on-road vehicles in several aspects. The machine need power for both propulsion and for bucket operation, and the operation is in general extremely transient and highly repetitive. To deal with this type of operation, present transmissions are designed for mechanical robustness, but these also lack in efficiency. Changing to a cvt-type transmission, such as a diesel-hydraulic, allows for increased efficiency, but require active control.

In the work I will present, the aim is to utilize the repetitiveness of the operation for creating a prediction of future operation, and using this prediction for transmission control through dynamic optimization.

Some of the challenges encountered are the high level of disturbances from driver and environment, the number of control degrees of freedom and the rapid, large and unceasing transients.

The focus of the presentation will be on describing the problem - both the possibilities and the challenges, but will of course also touch some of the ideas and approaches for solving this applied optimal control problem.

P1: Effect of Engine Parameters on Exhaust Emissions in a Spray-guided DISI Engine under lean Stratified Operation

Heechang Oh
KAIST, Korea

Abstract: An experimental study was carried out to investigate the effects of the injection timing on the spray and combustion characteristics in a spray-guided direct-injection spark-ignition (DISI) engine under lean stratified operation. Metal engine test and visualization techniques were applied to investigate detailed effects of injection timing in a spray guided DISI engine under stratified combustion condition. In-cylinder pressure analysis and emissions measurement were conducted to investigate combustion and emission behaviors for various injection timings. In-cylinder spray and combustion were visualized to provide a comprehensive understanding of the combustion and mixture formation.

In complete combustion emissions such as hydrocarbons and carbon mono oxide were found to be influenced by in-cylinder mixture characteristics. Over-mixing and under-mixing effects corresponding to the injection timing significantly increase these emissions. Smoke emission was found to be significantly affected by mixture characteristics also mixing controlled flame originated from under-mixed inhomogeneous mixture distribution was identified the main contributor of smoke emission. NOx emissions were found to be decreased as combustion phasing is retarded. Time delay between combustion and peak in-cylinder pressure was verified to be important parameter of engine out NOx emission.

P2: VGT-EGR Decoupling Control in Diesel Engines

Kang Song
Tianjin University, China

Abstract: Exhaust Gas Recirculation (EGR) systems together with Variable Geometry Turbochargers (VGT) are effective solutions to fulfill the legislated emission limits for diesel engines, as both the intake pressure and intake air mass can be flexibly managed. The VGT-EGR system is complicated two-input system two output system with sign reversal, overshoot and non-minimum phase behavior.

This presentation proposed a novel decoupling solution for VGT-EGR system. A map-based static feed forward control and a model-based dynamic feed forward control are designed. All the remaining uncertainties including the un-modeled cross-coupling and external disturbances are all treated as total disturbances, estimated and mitigated in real time by active disturbance rejection control (ADRC). Simulation and experimental results confirmed the superiority of the proposed solution in terms of fast response, high tracking accuracy and good disturbance rejection ability.

P3: Model for Developing an Eco-driving Strategy of a City Bus based on Traffic Information

Denggao Huang
Tianjin University, China

Abstract: Driving cycle is key information for vehicle control strategy design and test. Driving cycle for a special bus line is not very easy to synthesize for researchers and engineers. For city bus, when the structure and parameters of vehicle is definite, the motivation is also seated. Step Forward, the running of bus is following a fixed schedule, with the daily cycle of the city road condition, and there is a regular for their driving cycle section.

This post proposes a model to abstract the driving cycle curve with a relative high probability and fuel economy. The model is based on kinematic formula of bus and the ideal bus driver is also proposed. The basic information of distribution of bus station and cross road with light is picking by Google map, and some experiment data of three buses is also recorded. As the boundary conditions of vehicle state, and driver operate habits is seated, an ideal vehicle speed curve is extracted. However, this ideal driving speed line is affected by traffic flows and Traffic habits, comparing the highest property of driving cycle. With the regress of driving cycle parameters, the transfer formula for this different is get. The experimental results confirmed that this way can generate the optimal driving cycle for a special route for bus and the highly possibility driving cycle of city bus is also achieved by the state transition equation.

P4:Quantitative Diagnosability Analysis and Sensor Placement

Daniel Erksson
Linkoping University, Sweden

Abstract: The demand for functional safety and reliability, especially in the automotive industry, has drawn significant research in model-based fault diagnosis. Tougher legislations on required fault detectability and isolability performance but also larger and more complex systems require lots of development time to design on-board diagnosis systems. Thus, during the development of the diagnosis system, knowledge of achievable diagnosability performance given a model of the system is useful. Such information indicates if a test with certain performance can be created or if more sensors are necessary to achieve required diagnosability performance.

The main contribution of this work is a method, called distinguishability, to quantify detectability and isolability properties of a model when taking model uncertainties and fault time profiles into consideration. Some examples are shown of how this can be used for fault diagnosability analysis and how it can be used during the design of the diagnosis system such as positioning of sensors. The method is applied to a dynamic non-linear mean-value model of a heavy-duty diesel engine to analyze how fault diagnosability performance varies for different operating points.

P5: Optimal Transients Control Trajectories in Diesel-electric Systems

Martin Sivertsson
Linkoping University, Sweden

Abstract: Optimal control of a diesel-electric powertrain in transient operation is studied. The attention is on how the generator model affects the solution, as well as how the addition of an energy storage can assist in the transients. Two different types of problems are solved, minimum fuel and minimum time, with different generator limits as well as with an extra energy storage. In the optimization both the output power and engine speed are free variables. In the optimization a 4-state mean value engine model is used together with models for the generator and energy storage losses. The considered transients are steps from idle to target power with different amounts of freedom, defined as requirements on produced energy, before the requested power has to be met. The main characteristics are seen to be independent of generator model and limits, it however shifts the peak efficiency regions and therefore the end-point of the transients. For minimum fuel transients the energy storage remains virtually unused for all requested energies, for minimum time it does not. The generator limits are found to have the biggest impact on the fuel economy, whereas an energy storage could significantly reduce the response time. The possibility to reduce the response time is seen to hold for a large range of values of energy storage parameters, and so does the minimum fuel solution. Close to the minimum time solution the fuel consumption with low required energy is quite sensitive to variations in duration, for larger energies it is not. Near the minimum fuel solution changes in duration have only minor effects on the fuel consumption.

P6: A Torque Demand Control Strategy of IC Engines for Fuel Consumption Improvement

Mingxin Kang
Sophia University, Japan

Abstract: One challenge of torque-based control strategy for gasoline engines is to achieve engine torque tracking control accurately and quickly. In this study, a nonlinear model predictive control (NMPC) scheme has been proposed to improve the torque tracking performance. The engine torque production model was derived from intake air pressure dynamics and the engine throttle was the only manipulated variable to control the torque following the desired value. The precise torque estimation model based on a static torque detection map determined by engine intake manifold pressure and engine speed has been adopted here. In order to verify the control effect, the engine-in-the-loop simulation test has been conducted. The driver accelerator pedal signal would be translated to the demand torque and given to the proposed controller. The NMPC control algorithm applied continuation-GMRES methods (T. Ohtsuka) to obtain the real-timely receding horizon control. The experimental results proved that the proposed controller can achieve the precise torque tracking control.

P7: Stochastic Modeling and Control Problems of Air-fuel Ratio with Residual Gas of SI Engines

Jun Yang
Sophia University, Japan

Abstract: The stochastic air-fuel ratio modeling and control problems for SI engines taking into consideration the cyclic variation of the residual gas are addressed. By following the physics, a cylinder pressure-based measurement of the residual gas fraction is derived. A dynamic model to describe the cyclic variation of the air charge, fuel charge, and combustion products is presented, where the residual gas fraction is modeled as a Markov chain. Based on the model, a stochastic optimal control scheme is proposed and validated with simulations and experimental results.

P8: Statistical Likelihood Based Knock Control Scheme

Haoyun Shi
Sophia University, Japan

Abstract: A new likelihood-based knock controller is implemented and tested for the first time on a full-scale engine control test bench equipped with a production V6 gasoline engine. The binomial probability theory, and maximum likelihood estimation, which underly the algorithm are described in detail, and the control law which adjusts the spark advance according to the likelihood of the observed knock events relative to the target knock probability is presented.

P9: Model-based Engine Speed Control: Modeling and A Nonlinear Receding Horizon Control Approach

Fei Li
Sophia University, Japan

Abstract: Control-oriented modeling and control problem for gasoline engines are studied. First, the static function fitting technique and the dynamic parameter identification algorithm are adopted to obtain the unknown structure and parameters in engine mean-value model. Then, a model-based control scheme is proposed that consists of the receding horizon optimization regarding the speed tracking performance with the throttle opening. Model validation results show that the identified model can estimate the behaviors of the real engine at transient conditions. Experiments also have been done to demonstrate the performance of proposed controller. The data used for identification and the controller performance's validation both are conducted on a gasoline engine with six cylinders.

P10: Simulation Method of Fuel Consumption

Kosuke Umehara
Sophia University, Japan

Abstract: This study is control technique for the purpose of the improvement of the fuel consumption using the simulation software. Using simulation software by AVL company, I calculate the fuel consumption of each model such as HEV or EV. Specifically, using software specialized in a vehicle parameter called CRUISE, I enable modeling of HEV and EV. Furthermore, based on software specialized in the real-time behavior analysis in a virtual vehicle model called CarMaker, I simulate the behavior of various vehicle models. Simulation is performed for various problems by letting the software cooperate. We are working on connecting this system with a real engine. Accurate inspection is enabled about innumerable run patterns in a laboratory if this can be realized.

P11: Optimal Control of Stochastic System

Furuto Koshino
Sophia University, Japan

Abstract: Optimal control method of stochastic system modeled by stochastic differential equations is studied. Mathematical side and simulation method of control of stochastic systems are focused on. The definition of stochastic differential equations is presented. There are two types of stochastic differential equations, Ito and Stratnovich. Simulation method of stochastic systems modeled by stochastic differential equations is established. Since stochastic differential equations have different property from ordinary differential equations, it is necessary to be careful in simulating stochastic differential equations. Some numerical methods for solving stochastic differential equations are presented. Then, an algorithm for simulating stochastic differential equations using numerical computing software such as MATLAB/Simulink is established. Stochastic optimal control method based on stochastic differential equation is presented. The stochastic dynamic programming method is employed for solving stochastic optimal control problems. Simulation results for stochastic optimal control problem using MATLAB/Simulink are presented.

P12: Pros and Cons of using Multilevel Converter as an Integrated Cell Balancer and Motor Driver in xEVs

Altaf Faisal
Chalmers University of Technology, Sweden

Abstract: The use of a multilevel converter (MLC) as an integrated cell balancer and motor driver is investigated for application in EVs/HEVs/PHEVs (xEVs). MLCs allow each battery cell in a battery pack to be independently switched on and off, thereby enabling the potential non-uniform use of battery cells. By exploiting this property and the brake regeneration phases in the drive cycle, MLCs can balance both the state-of-charge (SoC) and temperature differences between cells, which are two known causes of battery wear.

The MLC-based optimal control policy (OP) that considers both battery cell temperatures and SoC dynamics is studied in detail for *DC motor applications*. The complete state-space electro-thermal model of a battery sub-module is derived under the switching action of MLC, resulting in OP being derived by the solution of a convex optimization problem. Results show that OP provides significant reductions in temperature and SoC deviations compared with the uniform use of all cells. The temperature uniformity in battery packs can also be achieved by reciprocating coolant flow. However, MLC-based OP achieves this, without any need of reciprocating coolant flow, by *redistributing the power losses optimally among the cells* depending on their resistances and positions in the cell string. Thus, in *DC applications*, the MLC-based OP offers great potential benefits.

However, in *three-phase (3-ϕ) AC applications*, there is a drawback as well of using MLC as an integrated cell balancer and motor driver in xEVs. The study shows that in such applications there is an issue of significant additional battery losses caused by the flow of reactive and/or harmonic power from each power cell of the 3-ϕ MLC battery system. These losses increase battery temperature that is detrimental to the battery lifetime. The study also investigates the size of shunt capacitor required for compensation of the losses to acceptable level. However, it is concluded that the size of the required capacitor is too big for automotive applications unless some other active compensation technique is used as well. Thus, the use of MLC as an integrated cell balancer and motor driver in 3-ϕ AC applications in xEVs poses a serious issue of extra losses. This issue must be addressed otherwise it is unreasonable to adopt this technology, for the said purpose, being motivated just by its great balancing efficiency.

P13: Cylinder Pressure based Combustion Control to Reduce Emission Dispersions for Common Rail Diesel Engines

Jaesung Chung
Hanyang University, Korea

Abstract: The combustion feedback control is effective to have consistent performance and meet the stringent emission regulations during engine lifetime. In this study, a combustion control algorithm using the feedback information obtained from in-cylinder pressure is presented for fuel system control of common rail diesel engine. To reduce the combustion variations and the dispersions of NOx and PM emissions regardless of different circumstances, engine aging, and production tolerance, mass fraction burnt 50 % (MFB50) and the maximum rate of heat release (ROHRmax) were selected as control variables. MFB50 is a highly related combustion phase to NOx emissions, and the ROHRmax has close correlation with soot release and oxidation. As the combustion is controlled by MFB50 or ROHRmax, the effect of MFB50 and ROHRmax control on combustion and the dispersions NOx and PM were analyzed. As a result, NOx dispersions were reduced by MFB50 control and PM dispersions were decreased by ROHRmax control. Furthermore, the simultaneous MFB50 and ROHRmax control reduced the variations of the combustion phase and the gradient of heat release. Therefore, the dispersions of both the NOx and PM emissions were effectively reduced during engine parameter changes.

P14: Optimal Control for Steady State Drifting of RWD Vehicle

Ronnapee Chaichaowarat
Chulalongkorn University, Thailand

Abstract: Drifting is a cornering technique with large angle of sideslip, which might be useful in some cornering conditions when full handling capacity over the linear region of the wheel slip-tire friction characteristic is imperative. In this work, steady state cornering of a RWD vehicle on plane, with constant speed, sideslip and radius of curvature, was simplified via the single track vehicle model. In addition, BNP magic formula, along with MNC tire model, was used to estimate tire frictions. The computer program was developed, based on EOMs derived via body fixed coordinate, in order to calculate a suitable cornering speed and corresponding open-loop driving control inputs, consisting of steering angle and rear slip ratio, for a given radius of curvature and vehicle sideslip. The other set of EOMs, in terms of vehicle states and driving control inputs, was derived refer to n-t coordinate; also, linearized so that the state space description could be constructed. Eventually, LQR stabilizing controller had been designed and simulated via MATLAB. According to the results of simulation, any state deviation could be regulated to the desired steady state. The development of automatic drifting assistant may be feasible in the very near future.

P15: Low Temperature Combustion Engines: Challenges and Chances

Thiva Albin
RWTH Aachen, Germany

Abstract: One of the main goals of current powertrain development for passenger cars is the reduction of carbon dioxide (CO_2) emissions, while at the same time minimizing other pollutants. A promising technology concerning the combustion method is the low temperature combustion (LTC), which offers the possibility to achieve high fuel efficiency while simultaneously minimizing the pollutant emissions. Beside these positive characteristics, several challenges arise which stand in the way of a widespread application of LTC in passenger cars. The major challenge concerns the closed-loop control of the combustion process. The talk presents these arising challenges with a special focus on the closed-loop control requirements.

P16: Moving Horizon Control for Vehicle Yaw Stability Based on States Observer

Hongyan Guo
Jilin University, China

Abstract: In order to make the vehicle stable driving under different operating conditions, moving horizon control scheme based on state observer is presented. First, 2 degrees of freedom vehicle model is built. Then, the state observer is designed for sideslip angle estimation. Second, the error between actual yaw rate and sideslip angle are used as control value, and the additional yaw moment is obtained by using moving horizon schemes. Third, the stable condition for yaw stability controller is achieved by stability analysis. To verify the effectiveness of the proposed method, hardware-in-the-loop simulation is carried out under the representative running conditions. The simulation results show that the proposed method could improve the handling and stability effectively.

P17: Shift Control of 2-Speed I-AMT in Electric Vehicle

Qiong Liang
Jilin University, China

Abstract: We put forward a 2-speed inverse automated manual transmission (I-AMT) for electric vehicle. The design of this transmission permits seamless gear shifting. In order to make the transmission output torque change smoothly during shift process, a control method is put forward. The control method contains a linear feedforward control for motor and clutch during the shift torque phase and a PID controller for motor during the inertia phase. The principles of the control system are conformed through test on an AMESim simulation model of the transmission system. The simulation results indicate that the control algorithm of the transmission system can improve the ride comfort and power performance of pure electric vehicle.

P18: Nonlinear Control of Fuel Rail Pressure Regulation for GDI Engines

Qifang Liu
Jilin University, China

Abstract: The precise control of rail pressure in Gasoline Direct Injection (GDI) engines is considered as an important issue. To make the rail pressure track the given reference , a model-based rail pressure nonlinear control scheme is presented. Firstly, a mathematical model is derived for the fuel rail injection system and simplified reasonably for the controller design. In order to deal with system nonlinear, a nonlinear controller is derived by using backstepping and rearranged in the structure of feedforward-feedback. The feedforward is related to the reference dynamics and the gain is state-dependent, while the feedback includes a state-dependent PD/PID error feedback and a state feedback related to the characteristics of the fuel rail system. The structure of the controller benefits potentially to the engineering-oriented implementation. Secondly, robustness is analyzed in the framework of input-to-state stability, where the error induced from the controller implementation, disturbances and uncertainties are lumped as an additive input. And the designed control scheme is tested in the more realistic simulation model established in the AMESim environment and results are satisfying.

P19: Mild merging path generation method with optimal merging point based on MPC

Wenjing Cao
Kyushu University, Japan

Abstract: A merging path generation method which is able to optimize the merging point, the motions of the merging vehicle and the relevant main vehicle, is proposed in this paper. In this method the merging problem is formulated into an optimization problem. Longitudinal motions of the vehicles are related to the lateral motions of them respectively to make them move on designed trajectories. A parameter of the merging trajectory of the merging vehicle is employed as a state variable and optimized in the optimization problem, so that the merging point can be optimized during merging. Therefore, with this method the merging vehicle can modify its trajectory according to the motion of the main lane vehicle. To be realistic video of merging scenes are shot from helicopter. With data derived from a typical helicopter-shot merging scene, computer simulations are conducted. Simulation results validate the effectiveness of the proposed method.

P20: A Battery Management System using Nonlinear Model Predictive Control for a Hybrid Electric Vehicle

KaijiangYu
Kyushu University, Japan

Abstract: This present paper introduces a battery management system using nonlinear model predictive control for a hybrid electric vehicle. This paper adds two new contributions to this field. First, the apparent relationship between the battery power and the future road load is addressed in the cost function of the fuel economy optimal control problem with a simplified hybrid electric vehicle energy management system model. Second, it examines quantitatively the effects of operating the engine along the best efficiency line of the engine with a continuously variable transmission using a commercially available hybrid electric vehicle energy management electronic control unit simulator. Effectiveness of the proposed algorithm is validated by the JSAE-SICE benchmark problem 2 simulator.

P21: Vehicle Mass Estimation Based on High-Frequency-Information Extraction

Wenbo Chu
Tsinghua University, China

Abstract: Vehicle mass directly affects driving/braking demands as well as vehicle active control. This paper proposed a method for vehicle mass estimation based on high-frequency-information extraction, which only uses the information of longitudinal force and acceleration. First, a high-pass filter is designed to extract high-frequency-information of longitudinal driving force and acceleration. Then, recursive least square algorithm is implemented to estimate vehicle mass. Both simulation and experimental results show that the novel method can estimate vehicle mass accurately. Particularly, this method takes obvious advantages over other approaches: (1) decoupled estimation of vehicle mass and road grade, (2) minimized dependency on sensor-based information, (3) fast convergence of estimated result and reliable robustness.

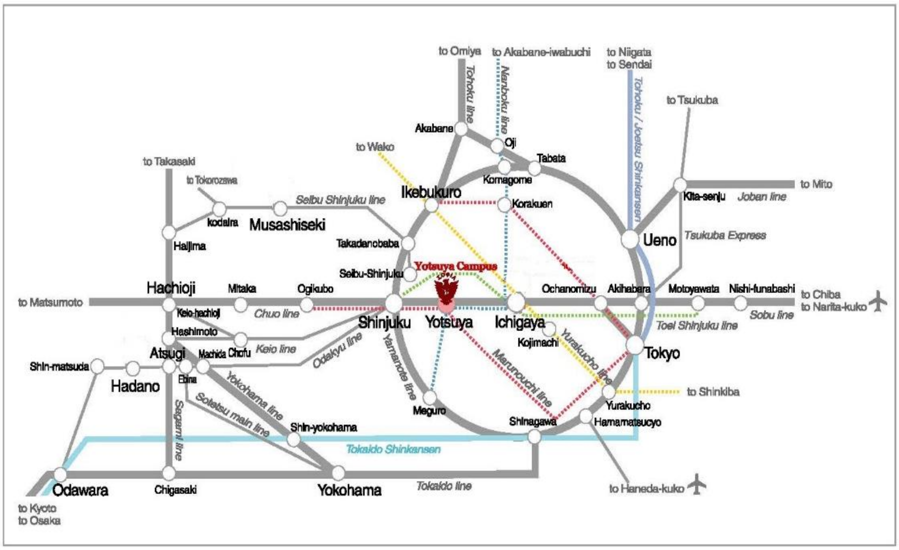
P22: The Impacts of Large Scale Electric Vehicles Charging Behavior on Distribution System and Local Traffic System

Tao Zhu
Tsinghua University, China

Abstract: Large scale electric vehicles (EVs) will be deployed in the future, but there is no systematic research on how their charging behaviour would impact power distribution system and local traffic system. This paper proposes an architecture of “road network – distribution network – large scale EVs” for further research, upon which a road network model, a distribution network model (charging stations included) and a large scale EVs model are established. An evaluation system model is also built in consideration of the characteristics and the interrelations of these subsystems. On this basis, a case of 30,000 EVs operating in the fast charging pattern at a particular period of time within the third ring of Beijing is simulated. The analysis draws the conclusions that the charging behavior of large scale EVs will cause excessive voltage decrease and power loss in the distribution network as well as local congestion in the road network; also, different distributions of charging stations and different distribution network structures will cast different impacts on the whole system.

Transportation and Venue Location

- **Venue:** International Conference Room, 17F, Bldg. No. 2, Yotsuya Campus, Sophia University,
  7-1 Kioicho, Chiyoda-ku, Tokyo 102-8554 JAPAN.
- **Traffic:** JR Chuo line, Marunouchi subway line, Nanboku subway line / 5 minutes from Yotsuya Station



Railway Access Guide

Surrounding of Yotsuya Campus

Yotsuya Campus Map