Graduate Student Workshop on Automotive Control 2013

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

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.

Workshop Program

Saturday, September 7
in the National Olympics Memorial Youth Center

13:30-14:45 **Tutorial Lecture I: Control of Complex Powertrain Systems**
Prof. Lino Guzzella (*ETH, Switzerland*)

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 the Sophia University Library

09:45-12:15 **Oral Presentation**
(Research Presentations by Graduate Students)

13:15-14:30 **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*)

14:45-16:00 **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. Lino Guzzella and Antonio Sciarretta, Vehicle Propulsion Systems: Introduction to Modeling and Optimization, Springer, 2005
3. Luigi del Re, Frank Allgower, Luigi Glielmo, Carlos Guardiola and Ilya V. Kolmanovsky (Eds.), Automotive Model Predictive Control: Models, Methods and Application, Springer, 2010
4. Giorgio Rizzoni and Simona Onori, Optimal Energy Management of Hybrid Electric Vehicles: 15 Years of Development at the Ohio State University, IFAC Workshop on Engine and Powertrain Control, Simulation and Modeling (E-COSM'12), pp.177-185, 2012
5. Riccardo Marino, Patrizio Tomei, Cristiano M. Verrelli, Induction Motor Control Design (Advances in Industrial Control), Springer, 2010
6. Riccardo Marino and Patrizio Tomei, Nonlinear Control Design: Geometric, Adaptive and Robust (Prentice Hall Information and System Sciences), Prentice Hall, 1995

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Introduction for Participants

GSW-AC 2013 is **free** for all participants, but the participants will be required to register by contact us at: zhanjy@me.sophia.ac.jp

Help for getting **visa** will be provided by the workshop organizer.

Participants who will give an Oral Presentation or be part of the Interactive Session, please also contact us at: zhanjy@me.sophia.ac.jp

Tutorial Lecture I: Control of Complex Powertrain Systems

Professor Lino Guzzella
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.

Lino Guzzella received the Diploma degree in mechanical engineering and the Dr. Sc. Techn. degree in control engineering from the Swiss Federal Institute of Technology, Zurich, in 1981 and1986, respectively. From 1987 to 1989, he was with the R&D Department, Sulzer Bros., Winterthur, Switzerland. From 1989 to 1991, he was an Assistant Professor for automatic control with the Department of Electrical Engineering, ETH. He then joined Hilti R&D, Schaan, Liechtenstein, where he was the Head of the Department of Mechatronics from 1992 to 1993. He is currently Professor for Thermotronics with the Institute of Dynamic Systems and Control, Department of Mechanical and Process Engineering, ETH. He is co-author of several patents in the area of mechatronic and automotive systems and lecturer of block courses and distance teaching classes at various universities and companies. His research interests are the modeling of dynamic systems, nonlinear and robust control, and applications of these ideas to thermal and, particularly, automotive systems.
Prof. Guzzella is a Fellow of IFAC, a Fellow of IEEE, and a recipient of several technical and teaching awards.

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.