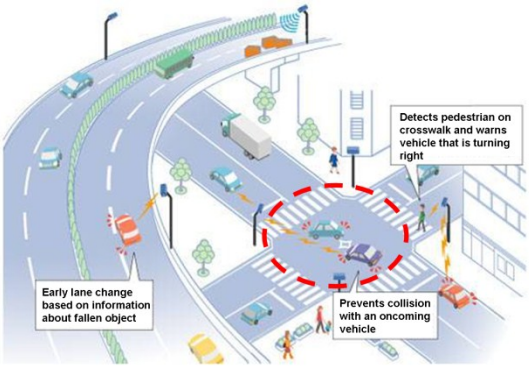
ACC 2012 Full Day Workshop

Analysis and Design of Cyber-Physical Transportation Systems: Challenges, Progress, and Future Directions

Organizer: Domitilla Del Vecchio (MIT)



Overview

The decreasing costs of embedded computing and communication technologies are taking several engineering systems toward increased levels of autonomy. A remarkable example is that of transportation systems, whether on the ground, in the air, or in the sea. The growing employment of cyber infrastructure, both for in-vehicle and intra-vehicle applications, is leading the way to an exciting nearby future in which vehicles will be "connected" with each other and with the surrounding infrastructure through wireless networks. These vehicle networks will be capable of coordinating, predicting and avoiding collisions, increasing traffic throughput, improving fuel efficiency, and optimizing routes in real-time based on distributed estimation of global congestion information. Human operators will be assisted in all their decisions and will be warned and guided toward optimal and safe behavior.

There are a large number of challenges that must be overcome for cyber-physical transportation systems to reach their full potential. First of all, these systems are software-intensive while being physical, that is, they are "hybrid". Yet, they must be designed so that their physical and computational parts interoperate correctly. Additionally, these systems have large state spaces and hence any control/optimization task has to overcome complexity bottlenecks. Finally, they involve human operators, and hence humans should be accounted for in any analysis and design task. In this workshop, we will provide an overview of the current state of the art, technical and technological challenges, and future research directions. Specifically, the workshop will provide a *technology overview*, including state of the art in driver-assist technology and current trends in automotive companies and the government, *formal methods for safety* verification and design both for inter-vehicle and intra-vehicle systems, *scheduling and routing problems* for both air and ground vehicle networks, and design *problems with human-in-the-loop*.

Intended Audience

The target audience has two main groups:

- Graduate students and researchers in controls interested in exploring application of control and dynamical systems theory to modern and future transportation systems;
- Industry practitioners interested in exploring cutting-edge techniques for solving concrete engineering questions.

To this end, the workshop aims at:

- Introducing key technologies and the state of the art in intelligent transportation;
- Providing tutorials on control theoretic tools and their application to the analysis and design of cyber-physical transportation systems.

Presenters

Derek Caveney, Manager, Toyota Motor Engineering & Manufacturing North America, Ann Arbor

Umit Ozguner, Professor, Department of Electrical & Computer Engineering, Ohio State University

Matthias Althoff, Post-doctoral researcher, Bruce Krogh Group, CMU

Alessandro Colombo, Post-doctoral researcher, Del Vecchio Group, MIT

Brandon Luders, PhD Candidate, Department of Aeronautics and Astronautics, Jon How Group, MIT

Domitilla Del Vecchio, Associate Professor, Department of Mechanical Engineering, LIDS, MIT

Hasma Balakrishnan, Associate Professor, Department of Aeronautics and Astronautics, MIT

Emilio Frazzoli, Associate Professor, Department of Aeronautics and Astronautics, LIDS, MIT

Daniel Work, Assistant Professor, Department of Civil and Environmental Engineering, University of Illinois at Urbana-Champaign

Tentative Schedule

PART I: INTRODUCTION TO ITS

Future Intelligent Transportation Systems (ITS): Technology, Techniques, Challenges, and Opportunities, Derek Caveney (9AM-9:45AM)

- overview of driver-assist technology and objectives
- levels of intervention
- current technical needs

Simulation and Testing of Cyber-Physical Transportation Systems, Umit Ozguner (9:45AM-10:30AM)

- overview of CPS transportation projects at the Ohio State University
- advanced simulation environments to model network layer, physical layer, driver behavior and vehicle traffic

PART II: SAFETY PROBLEMS

Guaranteeing Crash Avoidance of Autonomous Cars, Matthias Althoff (10:30AM-11:15AM)

- brief tutorial on reachability analysis
- application to verify maneuvers planned by autonomous vehicles in traffic

Efficient Algorithms for Collision Avoidance at Traffic Intersections, Alessandro Colombo (11:15AM-12PM):

- overview of job-scheduling
- mapping collision avoidance problems to job-scheduling problems
- using job-scheduling results to obtain polynomial complexity algorithms for collision avoidance

Lunch break (12PM-1:15PM)

Driver Behavior Classification and Threat Assessment in Uncertain Urban Environments, Brandon Luders (1:15PM-2PM)

- classification of driver behavior at intersections using support vector machines and hidden Markov models
- trajectory prediction of uncertain driver behavior using Gaussian processes
- probabilistically safe motion planning to avoid dynamic obstacles

Designing Collision Avoidance Systems that Account for Driver Behavior: Theory, Computational Techniques, and Experiments, Domitilla Del Vecchio (2PM-2:45PM)

- employing Hidden Mode Hybrid Systems models to design controllers that ensure safety in the presence of hidden players (humans)
- computational techniques leveraging domain-specific knowledge (vehicle network dynamics)
- experimental trials on collision avoidance instances at traffic intersection with and without human drivers

PART III: TRAFFIC ESTIMATION AND ROUTING PROBLEMS

Real-Time Motion Planning for Autonomous Urban Driving, Emilio Frazzoli (2:45PM-3:30PM)

- stability and robustness of dynamic flow networks
- resilient control of transportation networks
- distributed algorithms for traffic flow control

Improving Air Traffic Control Efficiency, Hasma Balakrishnan (3:30PM-4:15PM)

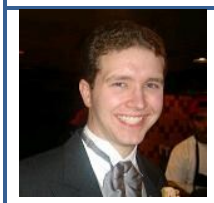
- overview of the National Airspace System (NAS)
- predictive models
- improving efficiency

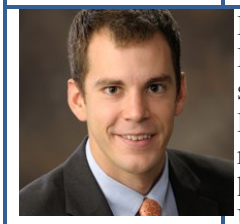
Real-Time traffic monitoring, Dan Work (4:15PM-5PM)

- Overview of the mobile Millennium system
- Traffic sensing with smartphones
- Estimating traffic on networks

PART IV: WRAP UP AND PANEL DISCUSSION (5PM-5:30PM)

Speakers Bio

	Derek Caveney received the Bachelor degree from Queen's University (Canada) in 1999, and the Master and PhD degrees from the University of California, Berkeley in 2001 and 2004, respectively. He was a post-doctoral researcher in the Center for Collaborative Control of Unmanned Vehicles, Berkeley until September 2005. He then joined the Toyota Technical Center of Ann Arbor (MI), where he currently is Manager for Research and Advanced Engineering. Dr. Caveney has several publications and patents on safety, liveness, and efficiency in multi-vehicle systems.
	Umit Ozguner received the Master degree from Istanbul Technical University in 1971 and the Ph.D. degree from the Electrical Engineering Department of the University of Illinois in 1975. He was President of the IEEE ITS Council in 1999 and 2000; he has been a member of the Executive Committee, ITS Ohio from 1994; he is currently the Director of the OSU Center for Intelligent Transportation Research (CITR). Professor Ozguner specializes in large-scale, intelligent systems modeling and optimization, hybrid systems, decentralized control, automotive (ABS, active suspension, integrated vehicle dynamics), and transportation systems (optimal routing and relation to signalization), Automated Highway Systems and all aspects of ITS.
	Matthias Althoff is currently a postdoctoral researcher in the group of Prof. Bruce Krogh, department of Electrical and Computer Engineering at Carnegie Mellon University. In 2010, he received his Ph.D. degree in electrical engineering and in 2005 his diploma engineering degree in mechanical engineering, both from the Technische Universität München, Germany. His research interests include (stochastic) reachability analysis of continuous and hybrid systems, and its application to the safety verification of technical systems.
	Alessandro Colombo obtained the master degree from École Nationale Supérieure de Techniques Avancées (France) in 2005, and the PhD in Systems and Control from Politecnico di Milano (Italy) in 2009. He is currently transitioning between a postdoctoral associate position in the Control Networks Group at MIT, and an assistant professorship in the Department of Electronics and Information at Politecnico di Milano. His research interests include the analysis of bifurcations and singularities of hybrid systems, and abstraction and equivalence techniques for the control with safety specifications of large multi-agent systems.
	Brandon Luders is a Ph.D. candidate in Aeronautics and Astronautics at MIT, and is a member of the Aerospace Controls Laboratory under Prof. Jonathan How. He obtained the Bachelor degree in Aerospace Engineering from Georgia Tech in 2006, and the Master degree in Aeronautics and Astronautics from MIT in 2008. He participated in the Agile Robotics for Logistics program at MIT and received the AIAA GNC Best Paper Award (2011). His research interests include path planning under uncertainty, sample-based motion planning, and their application to autonomous vehicles.

	Domitilla Del Vecchio received the Ph. D. degree in Control and Dynamical Systems from CalTech, Pasadena, and the Laurea degree in Electrical Engineering from the University of Rome at Tor Vergata in 2005 and 1999, respectively. From 2006 to 2010, she was an Assistant Professor in EECS at the University of Michigan, Ann Arbor. In 2010, she joined the Department of Mechanical Engineering and LIDS at MIT, where she is currently the W. M. Keck Career Development Associate Professor in Biomedical Engineering. She is a recipient of the Donald P. Eckman Award from the AACC (2010), the NSF CAREER Award (2007), the Crosby Award, University of Michigan (2007), the American Control Conference Best Student Paper Award (2004), and the Bank of Italy Fellowship (2000). Her research interests include analysis and control of nonlinear and hybrid dynamical systems and the analysis and design of bio-molecular networks.
	Hamsa Balakrishnan is an Assistant Professor of Aeronautics and Astronautics at the Massachusetts Institute of Technology. She received a B.Tech in Aerospace Engineering from the Indian Institute of Technology, Madras and a PhD in Aeronautics and Astronautics from Stanford University. Prior to joining MIT, she was a researcher at the University of California, Santa Cruz and the NASA Ames Research Center. Her research interests address various aspects of air transportation systems, including algorithms for air traffic scheduling and routing, integrating weather forecasts into air traffic management and minimizing aviation-related emissions; air traffic surveillance algorithms; and resource allocation mechanisms. She is the recipient of an NSF CAREER Award (2008), and the 2012 AIAA Lawrence Sperry Award.
	Emilio Frazzoli is an Associate Professor of Aeronautics and Astronautics with the LIDS at MIT. He received a Laurea degree in Aerospace Engineering from the University of Rome, “Sapienza” , Italy, in 1994, and a Ph. D. degree in Navigation and Control Systems from the Department of Aeronautics and Astronautics of the Massachusetts Institute of Technology, in 2001. Between 1994 and 1997 he worked as an officer in the Italian Navy, and as a spacecraft dynamics specialist for the European Space Agency Operations Centre (ESOC) in Darmstadt, Germany, and Telespazio, in Rome, Italy. From 2001 to 2004 he was an Assistant Professor of Aerospace Engineering at the University of Illinois at Urbana-Champaign. From 2004 to 2006 he was an Assistant Professor of Mechanical and Aerospace Engineering at the University of California, Los Angeles. He was the recipient of a NSF CAREER award in 2002. Dr. Frazzoli's main research interests lie in the general area of planning and control for mobile cyber-physical systems, with a particular emphasis on autonomous vehicles, mobile robotics, and transportation networks.
	Dan Work is an Assistant Professor in the Department of Civil and Environmental Engineering at the University of Illinois at Urbana-Champaign. He earned his bachelor of science degree (2006) from the Ohio State University, and a master of science (2007) and Ph.D. (2010) from the University of California, Berkeley, each in civil engineering. He has research interests in control, estimation, and optimization of transportation systems. His honors include receiving the Dwight David Eisenhower Transportation Fellowship from the U.S. Department of Transportation in 2008 and an Eno Fellowship from the Eno Transportation Foundation in 2010.