Optimal Control of Switching/Hybrid Systems with Applications to Hybrid Electric Vehicles, Dc-Dc Converters, and Autonomous Mobile Robots

Ray DeCarlo, Steve Pekarek; Purdue University, West Lafayette, IN
Miloš Žefran; University of Illinois-Chicago, Chicago, IL

This workshop will present recently developed results on the solution of the hybrid/switched optimal control problem using the embedding method developed by Bengea and DeCarlo (Automatica, January 2005). Using a variation of the collocation method, a numerical solution of the problem via sequential quadratic programming is outlined. With these tools and a model predictive control approach, application of the techniques to the switching control of a boost converter using an circuit specific estimator is then presented. Results include real time model predictive control of the boost converter at a switching speed of 10 kHz. This is followed by the model predictive control of mobile robots and groups of autonomous aerial vehicles (AUVs). Finally, a solution to the power management problem in a parallel configured hybrid electric vehicle is presented with simulation studies for a variety of driving profiles including the new EPA driving profile. The examples will not only describe appropriate models, MPC control methodologies, and simulation studies, but also highlight the broader appeal of these newly developed techniques for modeling, analysis, and design of hybrid/switched systems.

SCHEDULE: SEPTEMBER 2, 2008

08:00-9:15 The Embedding Approach to Switched/Hybrid Optimal Control
- a. Problem Statement
- b. Embedding Formulation
- c. Relations Between the Original and the Embedded Problems
- d. Existence and Uniqueness Results
- e. Miscellaneous results and techniques

09:25-10:30 Numerical Solution of the Switched/Hybrid Optimal Control Problem
- a. Collocation
- b. Choice of Basis Functions
- c. Numerical Optimization

10:30-10:45 Break/Refreshments

10:45-12:0 Switching Control of a Boost Converter
- a. Lossy Model of Converter
- b. MP Switching Control & Performance Measure
- c. Estimator Design
- d. Real time Model predictive control, Simulation Studies, and Comparison to Traditional Control Techniques

13:00-13:50 Control of Unicycle/Autonomous Mobile Robots
- a. Switching Behavior in Wheeled Vehicles
- b. Traction and Propulsion Control of Wheeled Vehicles
- c. Coordination Control of Unmanned Aerial Vehicles

14:00-15:00 Application to Hybrid Electric Vehicles
- a. General Supervisory Level Power Flow Modeling
- b. Subsystem Modeling for Power Flow Control
- c. Existence of optimal solutions

15:00-15:15 Break/Refreshments

15:15-16:30 Application to Hybrid Electric Vehicles Continued

d. Switched Optimal and Suboptimal MPC Strategies
e. Simulation Studies