Titels and abstracts

Alberto Bemporad

Lecture 1 – Model Predictive Control for Cyber-Physical Systems

Abstract:
Model Predictive Control (MPC) is one of the most successful techniques adopted in industry to control multivariable systems in an optimized way under constraints on input and output variables. In MPC, the manipulated inputs are computed in real-time by solving a mathematical programming problem, most frequently a Quadratic Program (QP). In my lecture, I will first introduce the basic concepts of MPC, showing how it can be used as the control component of a cyber-physical system (CPS). As most CPS's run under fast sampling and limited CPU and memory resources, I will then cover methods to solve QP's within a CPS with high throughput, using simple code and executing arithmetic operations under limited machine precision, and with tight estimates of execution time, also showing numerical evidence obtained under fixed and floating point precision. Finally, I will also show how MPC based on hybrid dynamical models can be used as an effective tool for control of CPS's.

Kanat Camlibel

Lecture 1 – Controllability of Systems Defined on Graphs

Abstract:
The study of networks of dynamical systems became one of the most popular themes within systems and control theory in the last two decades. This talk focuses on controllability of networks consisting of identical dynamical systems. For such networks, the overall dynamics determined by the (identical) dynamics of the individual systems as

well as the graph capturing the network structure. In this talk, we investigate the relationship between controllability of such a network and the underlying graph topology.

Lecture 2 – Model Reduction of Multi-Agent System

Abstract:
In this talk we establish a projection based model reduction method for multi-agent systems defined on a graph. Reduced order models are obtained by clustering the vertices (agents) of the underlying communication graph by means of suitable graph partitions. In the reduction process the spatial structure of the network is preserved and the reduced order models can again be realized as multi-agent systems defined on a graph. The proposed model reduction technique reduces the number of vertices of the graph (which is equal to the dynamic order of the original multi-agent system) and yields a reduced order multi-agent system defined on a new graph with a reduced number of vertices. This new graph is a weighted symmetric directed graph. It is shown that if the original multi-agent system reaches consensus, then so does the reduced order model.

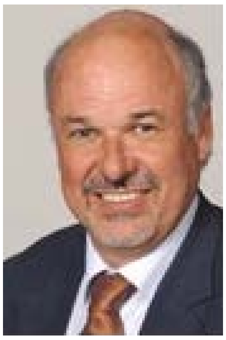
Ming Cao

Lecture 1 – Coordination and Control of Multi-agent Systems

Abstract:
In this talk I will cover some problems in the coordination and control of multi-agent systems from the perspective of cyber-physical systems. I start with the motivating example of the ocean sampling tasks using teams of underwater robots that involve remotely human experts in their closed control loops. Then zooming in on the specific robotic formation control problem, I demonstrate how graph theoretic tools become handy and show how the internal model principle can be used to deal with measurement noises. Continuing with the discussion on formation control, I illustrate when robots are autonomous and may make decisions for themselves repeatedly over time, evolutionary game theory can be powerful to model, predict and control the group decision-making dynamics.

Bart De Schutter

Lecture 1 – Multi-level Control of Large-Scale Systems with Applications to Water and Traffic



Sebastian Engell

Lecture 1 – Research Challenges in Cyber-Physical Systems of Systems

Abstract:
We will present four real-life cases of cyber-physical systems of systems and characterize the properties of such systems and the challenges in their operation and engineering. The results of the CPSoS project on a European Roadmap for Research and Innovation in Cyber-physical Systems of Systems will be presented and exemplified by current results of the EU-project DYMASOS - Dynamic Management of Phyically Coupled Systems of Systems.

Maurice Heemels

Lecture 1 – Resource-aware control

Abstract:
Recent developments in computer and communication technologies are leading to an increasingly networked and wireless world. In the context of networked control systems this raises new challenging questions, especially when the computation, communication and energy resources of the system are limited. To efficiently use the available resources it is desirable to limit the control actions to instances when the system really needs attention. Unfortunately, the classical time-triggered control paradigm is based on performing sensing and actuation actions periodically in time (irrespective of the state of the system) rather than when the system needs attention. Therefore, it is of interest to consider event-triggered control as an alternative resource-aware paradigm, as it seems much more natural to trigger control actions by well-designed events involving the system's state, output or other available information, i.e. bringing feedback in the sensing, communication and actuation processes. In this talk, we discuss the basics of event-triggered control, recent advances and important challenges ahead of us in this growing research field. Moreover, side trips will be made to related areas such as self-triggered control and hybrid systems.

Kim Larsen

Lecture 1 – Formal Methods for CPS -- A Computer Science Perspective (Real Time & Hybrid Model Checking & Synthesis)

Abstract:
Timed automata and games, priced timed automata and energy automata have emerged as useful formalisms for modeling real-time and energy-aware systems as

found in several embedded and cyber-physical systems. During the last 20 years the real-time model checker UPPAAL has been developed allowing for efficient verification of hard timing constraints of timed automata. Moreover a number of significant branches exists, e.g. UPPAAL CORA providing efficient support for optimization, and UPPAAL TIGA allowing for automatic synthesis of strategies for given safety and liveness objectives. Most recently, the branch UPPAAL SMC, a highly scalable new engine has been released supporting (distributed) statistical model checking (and synthesis) of stochastic hybrid automata (and games).

The lecture will review the various branches of UPPAAL and their concerted applications to a range of real-time and cyber-physical examples including schedulability and performance evaluation of mixed criticality systems, modeling and analysis of biological systems, energy-aware wireless sensor networks, smart grids and energy aware buildings and battery scheduling. Also, we shall see how other branches of UPPAAL may benefit from the new scalable engine of UPPAAL SMC in order to improve their performance as well as scope in terms of the models that they are supporting. This includes application of UPPAAL SMC to counter example generation, refinement checking, controller synthesis, and optimization.

Girish Nair

Lectures 1 and 2 – Nonstochastic Information Theory for Feedback Control

Abstract:
Shannon's probabilistic concept of information is a central tool for delineating fundamental performance limits in communication systems. With the advent of networked control systems, information has also gained renewed appreciation as a concept in control theory, and it is now understood that stochastic control performance is related to the amount of information flowing in the feedback loop. However, unlike in communications, disturbances in control are often modelled as deterministic unknowns with bounded magnitude or power. In such systems, Shannon's original probabilistic framework is inapplicable. This raises the question of whether it is possible to construct useful analogues of independence, Markovness and information for estimation and control, without having to assume a statistical model. This talk describes a recent framework for doing so, leading to the construction of nonstochastic versions of

information and directed information. It is shown that the largest nonstochastic information rate through an error-prone channel coincides exactly with its operational zero-error capacity and, similarly, that the largest nonstochastic directed information yields the operational zero-error feedback capacity. These results lead to tight conditions for estimating or controlling the state of a linear system over an erroneous communication channel, under the requirement of bounded estimation errors or states.

Ricardo Sanfelice

Lecture 1 – CPS: History, Overview, Applications and Challenges
Lecture 2 – Dynamical Models of Cyber-physical Systems
Lecture 3 – Control Theoretical Tools for Analysis and Design of CPSs

Paulo Tabuada

Lecture 1 – CPS: History, Overview, Applications and Challenges
Lecture 2 – Formal Methods in CPS – A Control Perspective