European Embedded Control Institute

EECI-HYCON2 Graduate School on Control

www.eeci-institute.eu/GSC2012

Spring 2012

18 INDEPENDENT MODULES – *one 21 hours module per week (3 ECTS)*

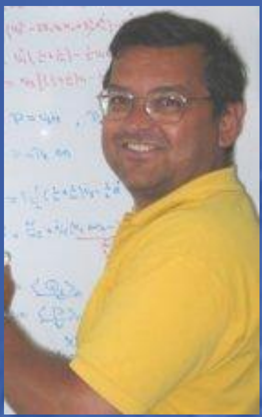
Deadline for ADVANCE REGISTRATION to each module: 16/12/2011

******Limited seating: register as soon as possible******

Locations: Supelec (South of Paris), Istanbul (Turkey), L'Aquila (Italy)

M1 30/01/2012 – 03/02/2012	*Advanced Control of Physical Systems Arising in Modern Technological Applications*	**Romeo Ortega**
M2 06/02/2012 – 10/02/2012	*Modelling, State Estimation and Vision Based Control of Aerial Robotic Vehicles*	**Robert Mahony/ Tarek Hamel**
M3 13/02/2012 – 17/02/2012	*Randomization in Systems and Control Design - the Scenario Approach*	**Marco C. Campi/ Simone Garatti**
M4 20/02/2012 – 24/02/2012	*Decentralized and Distributed Control*	**Giancarlo Ferrari-Trecate/ Marcello Farina**
M5 27/02/2012 – 02/03/2012	*Theory of Observers*	**Laurent Praly**
M6 05/03/2012 – 09/03/2012	*Introduction to Nonlinear Control*	**Hassan Khalil**
M7 12/03/2012 – 16/03/2012	*Backstepping Control of PDEs and Delay Systems*	**Miroslav Krstic**
M8 19/03/2012 – 23/03/2012	*Recent Advances of Sliding Mode Control*	**Vadim I. Utkin**
M9 26/03/2012 – 30/03/2012	*Regulation and Tracking for Nonlinear Systems, with Emphasis on Recent Advances and Open Problems*	**Alberto Isidori**
M10 02/04/2012 – 06/04/2012	*Control of Highly Nonlinear Systems*	**Claude Samson / Pascal Morin**
M11 09/04/2012 – 13/04/2012	*Nonlinear Controllability, Observability, and Optimal Control Problems in Robotics*	**Antonio Bicchi**
M12 30/04/2012 – 04/05/2012	*Quantum Control and Quantum Information Processing*	**Roger W. Brockett**
M13 07/05/2012 – 11/05/2012	*Hybrid Dynamical Systems: Stability and Control*	**Andrew Teel**
M14 14/05/2012 – 18/05/2012	*Mean Field Stochastic Systems and Control*	**Peter E. Caines**
M15 21/05/2012 – 25/05/2012	*Distributed Control*	**A. Stephen Morse**
Istanbul M16 16/04/2012 – 20/04/2012	*Controlled Synchronisation of Physical Systems*	**Antonio Loria / Elena Panteley**
Istanbul M17 23/04/2012 – 27/04/2012	*Optimality, Stabilization, and Feedback in Nonlinear Control*	**Francis Clarke**
L'Aquila M18 14/05/2012 – 18/05/2012	*Specification, Design and Verification of Distributed Control Systems*	**Richard Murray / Ufuk Topcu**

M1 30/01/2012 – 03/02/2012	*Advanced Control of Physical Systems Arising in Modern Technological Applications*



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Abstract of the course:

New engineering applications, including electrical and mechanical, as well as more recent chemical and biomedical, are characterized by the presence of strong couplings between subsystems, which operate on mutually interacting, instead of cause-effect, relations. To face these challenging problems a new control theory, focused on the energy and dissipation properties of the systems, has been developed in the last few years. The main articulating concepts of this new theory are the property of passivity, which is a reformulation of energy conservation, and the formulation of control as an interconnection of energy exchanging dynamical systems. The aim of these lectures is to introduce the basic concepts of this new theory. The theoretical principles are illustrated through many practical examples of current interest, whose main common features are the presence of nonlinearities, large parameter uncertainty and strong coupling with the environment.

Topics:

Theoretical:

- Passivity and control by interconnection
- Adaptive control of nonlinearly parameterized systems
- Passivation and adaptive PI control of nonlinear systems

Practical examples:

- Power electronic systems: power converters, active filters and power factor compensation for nonlinear loads
- Power systems: transient stability improvement, control of alternative energy generating systems (widnmills, fuel-cells and photovaltic)
- Mechanical systems: bilateral teleoperators and underactuated systems
- Electromechanical systems: sensorless control of motors, doubly-fed induction generators
- Energy management via control by interconnection.

M2 06/02/2012 – 10/02/2012	*Modelling, State Estimation and Vision Based Control of Aerial Robotic Vehicles*

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Abstract of the course:

Aerial robotic systems are poised to revolutionize a wide range of dangerous, dirty and dull jobs worldwide. With applications such as collection of data for environmental science, survey and maintenance of civil infrastructure, filming for the entertainment industry, and of course military and security applications, the potential impact of high performance aerial robotic systems is remarkable. Control of aerial robotic vehicles is a challenging topic. Such vehicles have complex and poorly known dynamic models. Their sensor systems can be noisy and poorly characterized. Task specification may require them to be flown near their performance limitations and in close proximity to unknown or only partially known, and dynamically changing physical environment.

This course provides an overview of modern nonlinear control systems theory applied to aerial robotic vehicles. We discuss the aerodynamic models for a range of important vehicle classes, introduce the state-of-the-art nonlinear control techniques, present the latest results in observer design for state estimation and finish by presenting recent results in vision based control of aerial vehicles.

Topics:

Modeling: Quadrotors, autonomous drones, helicopters, ducted fan systems.
Control: Hierachical control, robustness, adaptation, small body forces and zero dynamics.
Estimation: Attitude and pose estimation, bias estimation, sensor conditioning.
Vision based control: image based visual servo control, obstacle avoidance, landing control, terrain tracking.

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M3 13/02/2012 – 17/02/2012	*Randomization in Systems and Control Design - the Scenario Approach*

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Abstract of the course:

Randomization is an emerging topic of research in systems and control, and randomized concepts have proven powerful in addressing problems in applications where more traditional deterministic approaches fail to provide satisfactory results. In this course, the use of randomization will be motivated. The principles of randomization for optimization and design will be introduced, followed by the use of these principles in systems and control problems. Along this journey, a special emphasis will be given to the “scenario approach”, a general methodology for solving optimization problems based on random sampling.

The presentation will be gradual in order to allow an in-depth understanding of the underlying concepts. Special attention will be given to a precise mathematical formulation of the problems, and the theoretical results will be explained in detail. The versatility of the scenario approach will be illustrated through examples in prediction, model reduction, robust and optimal control.

Topics:

- Randomized algorithms
- Monte-Carlo sampling
- Uncertain convex optimization
- Scenario approach
- Applications to: prediction, model reduction, robust and optimal control
- Discussion of open problems that offer an opportunity for research

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M4 20/02/2012 – 24/02/2012	*Decentralized and Distributed Control*

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Abstract of the course:

Advances in technology and telecommunications are steadily broadening the range and size of systems that can be controlled. Examples that bring new challenges for control engineering are smart grids, that are perceived as the future of power generation, and networks of sensors and actuators, that enable the monitoring and control of processes spread over large geographical areas. As an alternative to centralized regulators, that seldom make sense for large-scale systems, decentralized and distributed approaches to control have been developed since the seventies. Particular attention has been recently given to distributed control architectures based on model predictive control that are capable to cope with physical constraints.

The first part of the course will focus on classical results on stability analysis of large-scale systems, decentralized control and decentralized controllability issues. Then, distributed control design methods will be covered. In the last part of the course, more emphasis will be given to recent advances in distributed control strategies based on optimization and receding horizon control.

Topics:

- Introduction to large-scale systems and multivariable control
- Decentralized control architectures
- Stability analysis of large-scale systems
- Decentralized controllability issues and design of decentralized control systems
- Design of distributed control systems

M5 27/02/2012 – 02/03/2012	*Theory of Observers*

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Abstract of the course:

An observer (also called, depending on the area, captor software or state reconstructor or data assimilation) is an algorithm aiming at estimating some variables internal to a dynamical system called hidden variables. It is designed from a model describing in an approximate way the dynamics of the system and works using data coming from measurements given by sensors. Its domain of application is extremely broad. For instance, for a chemical or a biological reactor, it gives estimates of concentrations without samples but from temperature and flow measurements; for an airship, it gives position, speed and attitude, from data given by an inertial platform with or without GPS; for an asynchronous electric motor, it gives flux and rotation speed from currents and voltages measurements; ...

From a technical point of view, the model is for instance expressed as a ordinary differential equation dx/dt = f(x,t) + p_x(t), where x represents the set of internal variables of the system, its state; t is the time, introduced here to take into account the effects of known exogenous actions; p_x represents perturbations, i.e. residuals not taken into account by the model described by the function f. In this context sensors, which provide the measurements, are represented by y = h(x,t) + p_y(t) where, similarly, the function h describes a model of the action and p_y is the model residual.

The problem is then, at each time T, to estimate the value of some/all the components of the state x(T) at this time, from the knowledge of a collection of measurements y(t_i) obtained at previous times t_i. Many methods have been proposed to solve this problem.

In the course we shall introduce these various approaches possibly in some unified way. This will allow us to understand why they are as they are, what can be expected from them, which knowledge they require.

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M6 05/03/2012 – 09/03/2012	*Introduction to Nonlinear Control*

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Abstract of the course:

The course is an Introduction to nonlinear system analysis and the design of nonlinear feedback control. It is a first course in nonlinear control with the target audience being engineers from multiple disciplines (electrical, mechanical, aerospace, chemical, etc.) and applied mathematicians. The course is suitable for practicing engineers or graduate students who didn't take such introductory course in their programs.

Prerequisites: Undergraduate-level knowledge of differential equations and control systems.

The course is designed around the text book: **H.K. Khalil, Nonlinear Systems, 3rd edition, Prentice Hall, 2002**

Topics:

1. Introduction and second-order systems (nonlinear phenomena; phase portraits; multiple equilibrium points; limit cycles)
2. Stability of equilibrium points (basics concepts; linearization; Lyapunov's method; the invariance principle; time-varying systems)
3. Passivity (memoryless functions & state models; positive real transfer functions; feedback systems; Circle & Popov criteria)
4. Input-state & input-output stability (ultimate boundedness; input-to-state stability; input-output stability; L stability of state models; L2 gain; the small-gain theorem)
5. Stabilization (concepts; linearization; feedback linearization; backstepping; passivity-based control)
6. Robust stabilization (sliding mode Control; Lyapunov redesign; backstepping)
7. Observers (observers with linear-error dynamics; high-gain observers; output feedback control)
8. Tracking & regulation (trajectory planning; feedback linearization; sliding mode Control; integral control)

M7 12/03/2012 – 16/03/2012	*Backstepping Control of PDEs and Delay Systems*

Abstract of the course:

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In the 1990s, the recursive backstepping design enabled the creation of adaptive and robust control algorithms for nonlinear systems with nonlinearities of unlimited growth and with uncertainties that are not matched by control.

Taking the backstepping recursion to the continuous limit provides a design methodology for boundary control of PDEs and for some key classes of delay systems. Contrary to standard PDE control that mimics LQR for finite-dimensional systems and yields virtually intractable operator Riccati equations, backstepping feedback laws come with explicit gain formulas. This course, mostly based on the instructor's book **Boundary Control of PDEs: A Course on Backstepping Designs (SIAM, 2008),** teaches how to derive such formulas for specific classes of PDE systems.

The explicit feedback laws allow the design of previously inconceivable parameter-adaptive controllers for PDE and delay systems. Backstepping also yields the first systematic method for control of large classes of nonlinear PDEs and for nonlinear systems with long delays.

Topics:

Lyapunov stability for PDEs; boundary control of parabolic (reaction-advection-diffusion) PDEs; observers with boundary sensing; complex-valued PDEs (Schrodinger and Ginzburg-Landau); wave PDEs; beam PDEs (shear beam and Euler-Bernoulli beam); first-order hyperbolic (transport-dominated) PDEs; higher-order PDEs (Kuramoto-Shivashinsky and Korteweg-de Vries); Navier-Stokes PDEs and control of turbulence; basics of motion planning for PDEs; system identification and adaptive control of PDEs; introduction to control of nonlinear PDEs; systems with input delay and predictor feedback; delay-robustness of predictor feedback; time-varying input delay; delay-adaptive predictor feedback; stabilization of nonlinear systems with long input delays; stabilization of linear ODE systems with heat and wave PDEs at the input; stabilization of PDEs with input delays.

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M8 19/03/2012 – 23/03/2012	*Recent Advances of Sliding Mode Control*

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Abstract of the course:

PART I. HIGHER ORDER SLIDING MODE CONTROL

The principal design idea of sliding mode control implies generating reduced order motion in some manifold $s(x)=0$ in the state space with the desired properties. The question of interest – whether similar effect can be reached for the cases with relative degree greater than one, or when time derivative of $s(x)$ is continuous, but the second derivative is a discontinuous state function, or ***control input is a continuous state function***. Then the range of applications of sliding mode control will be increased since not all actuators can operate with discontinuous inputs. For example high frequency switching in an output may result in damage of valves in hydraulic actuators. This problem is called "chattering" in control literature and "ripple" in power electronics literature.

In numerous publications different design methods for sliding mode control as a continuous state function were offered and the authors referred to their methods as ***high order sliding mode control***. The design methods will be discussed in the presentation except for the cases when high order sliding modes can be easily interpreted in terms of the conventional sliding modes (or first order sliding modes). The main attention will be paid to the so-called twisting and super-twisting algorithms. Homogeneity property, Lyapunov functions, estimation of the states in time domain are involved in stability analysis. The disturbance rejection properties are demonstrated along with estimation of convergence time and upper bound for disturbances.

PART II. CHATTERING SUPPRESSION

Alternative methods of chattering suppression – the main obstacle for sliding mode control implementation -- constitute the second part of the short course. As a rule chattering is caused by unmodelled dynamics. The first recipe is application of ***asymptotic observers***. They serve as a bypass for high frequency component in control and as a result the unmodelled dynamics are not excited. However under uncertainty conditions the conventional observers can not be used for chattering suppression .

Another way to reduce chattering implies ***state-dependent magnitude of discontinuous control***, since the chattering amplitude is a monotonously increasing function of the discontinuity magnitude. The methodology is not applicable for widely used electronic power converters with constant magnitude of discontinuous output. For these systems the efficient tool to suppress chattering is ***harmonic cancellation principle.*** The ides implies control of phases of high frequency oscillations in multiphase converters such that several first harmonics of periodic signals cancel after summation. It can be easily done in the frame of multidimensional sliding mode theory.

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M9 26/03/2012 – 30/03/2012	*Regulation and Tracking for Nonlinear Systems, with Emphasis on Recent Advances and Open Problems*

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Abstract of the course:

The theory of output regulation is at a crossroad of a number of important areas in analysis and design of nonlinear systems: steady-state analysis, feedback stabilization, observer design, zero dynamics. For nonlinear SISO systems, the theory of output regulation has reached a highly sophisticated and rather satisfactory degree of development. The first part of the course will cover the essentials of such theory. However, a number of relevant roadblocks still persist in the solution of the problem output regulation for nonlinear MIMO systems. While in the case of linear systems the so-called ``non resonance condition'' suffices to guarantee the existence of a (robust) solution for a stabilizable and detectable plant, the problem is still open for nonlinear systems.

The bottleneck is the fact that, while for linear systems robust regulation can be achieved by means of a controller whose internal model ``post-processes'' the regulated output, in the case of nonlinear systems it is only known how to design a ``pre-processing'' internal model, and this renders the resulting stabilization problem much more difficult to handle. The second part of the lecture will review problems and challenges arising this context.

Topics include:

- Review of the theory of output regulation for linear SISO systems.
- The steady-state behavior of nonlinear systems: limit sets and steady-state locus. Steady-state analysis of a regulated nonlinear systems.
- The concept of zero dynamics and its properties.
- Observers and the design of an internal model.
- Normal forms and robust stabilization via high-gain feesback.
- A coordinate-free approach.
- Review of the theory of output regulation for linear MIMO systems.
- Post-processing and Pre-processing.
- Open problems in extending the results to nonlinear MIMO systems.
- Design of internal models. Stabilization issues.

M10 02/04/2012 – 06/04/2012	*Control of Highly Nonlinear Systems*

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Pascal Morin
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Abstract of the course:

The course in an introduction to the Transverse Function approach recently developed by P. Morin and C. Samson to control nonlinear systems that are locally controllable at equilibria but whose linear approximation is not. Such systems are sometimes referred to as "critical" systems, and the fact that they are not state-feedback linearizable explains in part the difficulty posed by their control. The non-existence of asymptotical stabilizers in the form of continuous pure-state feedback controllers, as pointed out by a Brockett's theorem for a large subclass of critical systems, and the non-existence of "universal" feedbacks capable of stabilizing all feasible state-trajectories asymptotically, as proved in a work by Lizzaraga, are also incentives for the development of control solutions that depart from "classical" nonlinear control theory. The practical stabilization of non-feasible trajectories, a preoccupation little addressed in the control literature, constitutes a complementary incentive.

Beyond these theoretical aspects, an important motivation for the control engineer also arises from the fact that many physical systems can be modeled as critical systems. Such is the case, for instance, of nonholonomic mechanical systems (like most mobile vehicles on wheels, ranging from common car-like vehicles to ondulatory wheeled-snake robots) and of many underactuated vehicles (like ships, submarines, hovercrafts, blimps). Asynchronous electrical motors also belong to this category.

M11 09/04/2012 – 13/04/2012	*Nonlinear Controllability, Observability, and Optimal Control Problems in Robotics*

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Abstract of the course:

In this course, I will introduce and discuss applications of classical and advanced nonlinear control concepts and tools to the field of Robotics. The goals of the course are to illustrate via physically grounded and practical examples the power of nonlinear control techniques, and to present open problems which could motivate young researchers to further existing analysis and synthesis methods. The course will start by introducing some motivational examples of intrinsically nonlinear systems, i.e. systems where approximate linearization can destroy some crucial structural properties, and which therefore a nonlinear system theoretic treatment.

I will then briefly review the main mathematical tools necessary to tackle nonlinear system analysis. The goal here will not be that of providing new or very advanced results, rather mainly of establishing a common vocabulary and notation, with a rather utilitaristic approach to provide a "mathematical toolbox" for the practitioner.

Topics:

The main part of the course will focus on the application of nonlinear control, observation, and optimization methods to Robotics systems. The nonlinear control part will use nonlinear controllability tools to study reachability of different locomotion systems, continuous and discrete nonholonomic systems, motions of formations of flying vehicles. In the nonlinear observation section of the course, we will review observability tools and apply them to problems such as Simultaneous Localization and Mapping (SLAM), shape from motion, and appearance-based visual servoing. Finally, we will review applications of optimal control theory to nonlinear systems, characterizing shortest paths for robotic as well as natural locomotion systems subject to constraints of both kinematic and sensorial nature, such as e.g. the limited field-of-view of their vision systems.

M12 30/04/2012 – 04/05/2012	*Quantum Control and Quantum Information Processing*

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Abstract of the course:

The field of quantum control has emerged over the last two decades as both an exciting intellectual exercise and a practical tool for solving technological problems. From the prospective of control theory the problems it poses involve a full range of problems, linear, Lie algebraic, stochastic, optimization, infinite dimensional, etc. From the point of view of physics and chemistry, the control point of view offers a new and insightful point of view on a range of conceptual and technological problems.

In this course we will begin with a discussion of the control of spin systems and their controllability properties and move on to other finite level systems described in terms of density operators. We will discuss the use descent methods to optimize control inputs with an emphasis on the intrinsic geometry of the set of density operators. Stochastic models of the Lindblad type will then be derived and optimization problems will be formulated in this context. Infinite dimensional systems arising in the context of the wave equation will be treated from several points of view. The course will conclude with a discussion of problems in quantum information processing.

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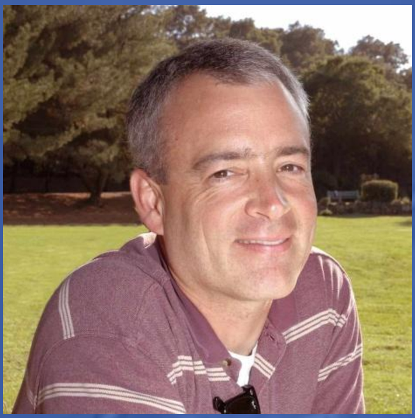
M13 07/05/2012 – 11/05/2012	*Hybrid Dynamical Systems: Stability and Control*



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Abstract of the course:

This course provides an introduction to hybrid dynamical systems. Hybrid dynamical systems contain state variables that change continuously at some locations in the state space and change instantaneously at other locations in the state space. Hybrid systems can be used to model mechanical systems with impacts, the interaction of logic-based feedback with continuous-time dynamics, and the interaction of discrete-time and continuous-time effects in sampled-data and networked control systems. While the behavior of hybrid dynamical systems is more complex than the behavior of classical differential equations, most of the stability theory for hybrid systems is very similar to stability theory for classical systems.

The purpose of this course is to expose the student to modeling of hybrid systems and to equip them with stability analysis tools that can also be used to motivate hybrid feedback control design.

Topics will be drawn from the following list:

1) Modeling of hybrid systems
2) The solution concept
3) Basic stability theory, including Lyapunov functions
4) The effect of perturbations on solutions and stability
5) Advanced stability theory, including a description of robustness, a reduction principle, singular perturbation and averaging theory, the invariance principle, and a linearization principle
6) Feedback control applications

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M14 14/05/2012 – 18/05/2012	*Mean Field Stochastic Systems and Control*

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Abstract of the course:

Multi-agent competitive and cooperative systems occur in a vast range of designed and natural settings such as communication, economic, environmental, epidemiological and transportation systems. However, the complexity of such large population stochastic dynamic systems, and frequently their inherent nature, make centralized control infeasible or irrelevant and standard game theoretic analysis intractable. The central idea of Mean Field (MF) stochastic control (or Nash Certainty Equivalence (NCE) control) is that when the agent population is very large individual feedback strategies exist so that the agent is approximately in a Nash equilibrium with the precomputable behaviour of the mass of other agents.

The infinite population Mean Field Equations yield control laws in the form of a (deterministic) mass feedback combined with a (stochastic) local state feedback; when these are applied in systems with finite populations the Nash approximation error goes to zero as the population tends to infinity.

This course will present the basic results and a selection of recent developments in the rapidly advancing area of Mean Field stochastic systems and control.

Topics:

1. Fundamental Framework for MF Systems
2. Basic Results for LQG MF Systems
3. Non-linear MF Systems
4. MF Adaptive Stochastic Control
5. MF Flocking and Swarming
6. Egoists, Altruists and Coalition Formation

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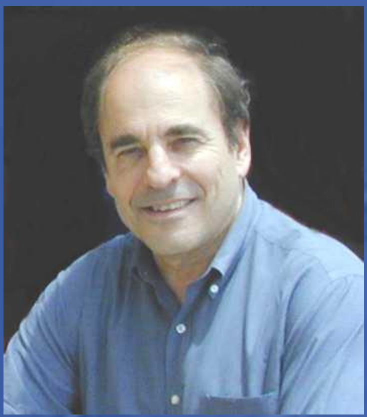
M15 21/05/2012 – 25/05/2012	*Distributed Control*



A. Stephen Morse
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Abstract of the course:

Over the past decade there has been growing in interest in distributed control problems of alltypes. Among these are consensus and flocking problems, the multi-agent rendezvous problem, distributed averaging and the distributed control of multi-agent formations. The aim of these lectures is to explain what these problems are and to discuss their solutions. Related concepts from spectral graph theory, rigid graph theory, nonhomogeneous Markov chain theory, stability theory,and linear system theory will be covered.

Topics include:

1. Flocking and consensus
2. Distributed averaging via broadcasting
3. Gossiping and double linear iterations
4. Multi-agent rendezvous
5. Control of formations
6. Contraction coefficients
7. Convergence rates
8. Asynchronous behavior
9. Stochastic matrices, graph composition, rigid graphs

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Istanbul M16 16/04/2012 – 20/04/2012	*Controlled Synchronisation of Physical Systems*

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Abstract of the course:

To be completed soon

Topics:

To be completed soon

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Istanbul M17 23/04/2012 – 27/04/2012	*Optimality, Stabilization, and Feedback in Nonlinear Control*

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Abstract of the course:

This course presents some modern tools for treating truly nonlinear control problems, including non smooth calculus and discontinuous feedback. The need for such tools will be motivated, and applications will be made to central issues in optimal and stabilizing control. The context throughout is that of systems of ordinary differential equations, and the level will be that of a graduate course intended for a general control audience.

Topics include:

1. Dynamic optimization: from the calculus of variations to the Pontryagin Maximum Principle
2. Some constructs of nonsmooth analysis, and why we need them
3. Lyapunov functions, classical to modern
4. Discontinuous feedback for stabilization
5. Sliding modes and hybrid systems

European Embedded Control Institute

L'Aquila M18 14/05/2012 – 18/05/2012	*Specification, Design and Verification of Distributed Control Systems*

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Control and Dynamical Systems
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Abstract of the course:

Increases in fast and inexpensive computing and communications have enabled a new generation of information-rich control systems that rely on multi-threaded networked execution, distributed optimization, sensor fusion and protocol stacks in increasingly sophisticated ways. This course will provide working knowledge of a collection of methods and tools for specifying, designing and verifying distributed control systems. We combine methods from computer science (temporal logic, model checking, reactive synthesis) with those from dynamical systems and control (Lyapunov functions, sum-of-squares certificates, receding horizon control) to analyze and design partially asynchronous control protocols for continuous systems. In addition to introducing the mathematical techniques required to formulate problems and prove properties, we also describe a software toolbox that is designed for analyzing and synthesizing hybrid control systems using linear temporal logic and robust performance specifications.

The following topics will be covered in the course:

* Transition systems and automata theory
* Specification of behavior using linear temporal logic
* Algebraic certificates for continuous and hybrid systems
* Approximation of continuous systems using discrete abstractions
* Verification of (asynchronous) control protocols using model checking
* Synthesis of control protocols and receding horizon temporal logic planning
* Case studies in autonomous navigation and vehicle management systems