# 8 seminars on Control Theory in parallel to the EECI Graduate School on Control 2010

The European Embedded Control Institute and the Laboratoire des Signaux et Systèmes are happy to invite you to the following seminars, to be held in Supélec in parallel to the EECI Graduate School on Control 2010. The abstract of each presentation and the biography of each lecturer are provided below. All these seminars will be held at:

**Salle du Conseil du L2S - Supelec, 4th floor, stairs B. Gif sur Yvette, France**

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| Thu. 18th Feb. 16:00 | **Cooperative Control of Multiple Autonomous Vehicles for Ocean Exploration: Theoretical Challenges and Practical Issues** | Antonio Pascoal<br>Inst. Sup. Tecnico Lisboa, Portugal |
| Thu. 18th Feb. 17:00 | **Minimum-Energy State Estimation for a Class of Nonlinear Systems** | Antonio P. Aguiar<br>Inst. Sup. Tecnico Lisboa, Portugal |
| Thu. 18th March 15:00 | **Control Design in the Presence of Resource Constraints** | Vijay Gupta<br>Univ. of Notre Dame, USA |
| Thu. 18th March 16:00 | **Event-based control for wireless systems** | Karl H. Johansson<br>KTH, Sweden |
| Fri. 26th March 14:30 | **Necessary Conditions in Optimal Control Theory: an Overview** | Francis Clarke<br>Institut univ. de France et Univ. de Lyon |
| Tue. 6th April 14:30 | **Memristive Port-Hamiltonian Systems** | Dimitri Jeltsema<br>Delft Institute of Applied Mathematics, NL |
| Wed. 7th April 14:30 | **Port-Hamiltonian dynamics on graphs** | Arjan Van Der Schaft<br>University of Groningen, NL |
| Fri. 16th April 10:30 | **Control of Solar Energy Systems** | Eduardo F. Camacho<br>Univ. of Seville, Spain |
| Thu. 6th May 14:00 | **Modeling Interconnected Systems** | Jan C. Willems<br>K.U. Leuven, Belgium |
| Thu. 6th May 15:00 | **Quadratic differential forms and (two of) their applications** | Paolo Rapisarda<br>University of Southampton,UK |

**Thursday 16th February, 16:00**

## Cooperative Control of Multiple Autonomous Vehicles for Ocean Exploration: Theoretical Challenges and Practical Issues

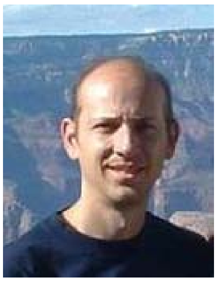
Antonio Pascoal
Inst. Sup. Tecnico Lisboa, Portugal

António Pascoal received his PhD in Control Science from the Univ. Minnesota, Minneapolis, MN, USA. From 1987-88 he was a Research Scientist with Integrated Systems Incorporated, Santa Clara, California where he participated in the development of advanced robotic systems for the US Air Force and Army. He was the coordinator of two EC funded projects that led to the development of the first European civilian autonomous underwater vehicle (AUV) named MARIUS. He has been active in the design, development, and operation of autonomous underwater and surface vehicles for scientific applications. Recently, he has been involved in three large European projects on Cooperative Autonomous Marine Vehicle Navigation and Control (GREX), Marine Technology for Underwater Archaeology (VENUS), and Underwater Cognitive Robotics (COG3AUVs). He is a Professor of Control and Robotics at the Instituto Superior Técnico (IST, Lisbon, Portugal) and Coordinator of the Dynamical Systems and Ocean Robotics Lab of ISR (Institute for Systems and Robotics) of IST. His areas of expertise include Dynamical Systems Theory, Navigation, Guidance, and Control of Autonomous Vehicles, and Cooperative Motion Control of Marine Robots. He has an interest in the history of science and in the application of robotics to underwater archaeology.

**Thursday 16th February, 17:00**

## Minimum-Energy State Estimation for a Class of Nonlinear Systems

Antonio P. Aguiar
Inst. Sup. Tecnico Lisboa, Portugal



António Pedro Aguiar received the Licenciatura, M.S., and Ph.D. degrees in Electrical and Computer Engineering from the Instituto Superior Técnico (IST), Technical University of Lisbon, Portugal in 1994, 1998 and 2002, respectively. From 2002 to 2005, he was a post-doctoral researcher with the Center for Control, Dynamical Systems, and Computation at the University of California, Santa Barbara (UCSB). Currently, Dr. Aguiar holds an Assistant Professor position with the Department of Electrical and Computer Engineering, Instituto Superior Técnico, and a Senior Researcher position with the Institute for Systems and Robotics, Instituto Superior Técnico (ISR/IST). His research interests include modeling, control, navigation, and guidance of autonomous robotic vehicles, nonlinear control, switched and hybrid systems, tracking, path-following, performance limitations, nonlinear observers, the integration of machine vision with feedback control, networked control, and coordinated/cooperative control of multiple autonomous robotic vehicles.

## Thursday 18th March, 15:00

# Control Design in the Presence of Resource Constraints

Vijay Gupta
University of Notre Dame

**Abstract**
As Cyberphysical systems become ubiquitous, new system designs need to be developed that combine control, communication, and processor scheduling algorithms. We will discuss two problems. In the first problem, a routing algorithm useful for estimation of a dynamic process is developed. In the second part, an anytime control algorithm suitable for time-varying and uncertain processor availability is considered.

Vijay Gupta is an assistant professor in the Department of Electrical Engineering at the University of Notre Dame, Indiana, USA. He received the BTech degree from IIT Delhi in 2001, and MS and PhD degrees from Caltech in 2002 and 2007 respectively, all in Electrical Engineering. His research interests include cyberphysical systems, networked control systems, computation constrained control, and other problems at the intersection of control, communication and computation.

**Thursday 18th March, 16:00**

## Event-based control for wireless systems

Karl H. Johansson
KTH, Sweden

**Abstract**

There is a growing deployment of wireless networks in industrial control systems. The lower installation cost and easier system reconfiguration for wireless devices can have a major influence on future distributed control systems. There is however a lack of theory for the design of these networked control systems. Traditional sampled-data control theory is often not suitable for wireless control systems, because of cross-layer couplings and resource constraints not present in wired systems. In this talk, we will present a new design paradigm for networked control that handles uncertainty and limited resources using cross-layer information. Event-triggered sensing and control provides a more scalable and efficient trade-off between control performance and communication cost. By making transmissions only when needed and taking decisions locally at the sensor and actuator nodes, it is possible to minimize the use of communication resource. A novel design framework that allows the system developer to utilize the freedom provided by recently proposed event- and time-triggered communication protocols will be outlined. The talk will be supported by ongoing case studies with Swedish industry. The presentation is based on joint work with collaborators at KTH.

Karl H. Johansson received an M.Sc. and a Ph.D. in Electrical Engineering in 1992 and 1997, respectively, both from Lund University in Sweden. He is Director of the ACCESS Linnaeus Centre and Professor at the School of Electrical Engineering, Royal Institute of Technology, Sweden. He holds a Senior Researcher Position at the Swedish Research Council. He has held visiting positions at UC Berkeley (1998-2000) and California Institute of Technology (2006-07). His research interests are in networked control systems, hybrid and embedded control, and control applications in automotive, automation and communication systems. He is the Chair of the International Federation of Automatic Control (IFAC) Technical Committee on Networked Systems since 2008. He has served on the Executive Committees of the European research projects HYCON and RUNES, both on networked embedded systems. He is on the editorial boards of IEEE Transactions on Automatic Control and IET Control Theory & Applications, and previously of Automatica. He is a Wallenberg Scholar for 2010-2014 supported by the Knut and Alice Wallenberg Foundation. He was awarded a six-year Individual Grant for the Advancement of Research Leaders from the Swedish Foundation for Strategic Research in 2005. He received the triennial Young Author Prize from IFAC in 1996 and the Peccei Award from the International Institute of System Analysis, Austria, in 1993. He received Young Researcher Awards from Scania in 1996 and from Ericsson in 1998 and 1999.

## Friday 26th March, 14:30

Necessary Conditions in Optimal Control Theory: an Overview

Francis Clarke
Institut universitaire de France et Université de Lyon

**Abtsract**
This is a non-technical survey of the nonsmooth analysis approach to developing necessary conditions in optimal control theory, and some of the issues that arise in connection with it. Some ancient and some recent results will be mentioned.

Francis Clarke was born in 1948 in Montréal. His PhD is from the University of Washington (1973); he became full professor at the University of British Columbia in 1978. In 1984 he was named director of the Centre de Recherches Mathématiques (CRM) at l'Université de Montréal. During his nine-year tenure, CRM evolved into Canada's first national research center for mathematics and its applications. Clarke was also founding director of ISM, a mathematics institute spanning Montréal's four universities. He is now a faculty member at l'Université de Lyon, in l'Institut Camille Jordan, and also holds a chair in mathematical control theory at l'Institut universitaire de France. Francis Clarke's research interests lie in nonsmooth analysis (a term he coined), differential equations, control theory, optimization, and the calculus of variations. His contributions have involved the development of nonsmooth calculus, its applications to dynamic optimization, regularity and existence theory in the calculus of variations, Hamiltonian mechanics, generalized solutions of the Hamilton- Jacobi equation, and feedback control synthesis. Francis Clarke is the author of the book Optimization and Nonsmooth Analysis (Wiley 1983, now in SIAM's Classics in Applied Mathematics Series), which has been translated into Russian. A Fellow of the Royal Society of Canada, he has received the Coxeter-James and the Archambault research prizes, and a Killam Fellowship. He has been a featured speaker at the International Congress of Mathematicians (Helsinki 1978), plenary speaker at the CDC (Brighton 1991) and the ECC (Porto 2001), and keynote speaker at the Congress of Nonlinear Analysts (Athens 1996). In 2004 he was president of the scientific committee for the first joint meeting of the six mathematical societies of Canada and France. http://igd.univ-lyon1.fr/~clarke/Clarke-english.html

## 6th April 2010, 14.30
## Memristive Port-Hamiltonian Systems

Dimitri Jeltsema
Delft Institute of Applied Mathematics

**Abstract**
In the early seventies, the existence of a new basic electrical circuit element, called the memristor, was postulated. The memristor, a contraction of memory and resistance that refers to a resistor with memory, completes the family of the well-known existing fundamental circuit elements: the resistor, inductor, and capacitor. Although a variety of physical devices, including thermistors, discharge tubes, Josephson junctions, and even ionic systems like the Hodgkin-Huxley model of a neuron, were shown to exhibit memristive effects, a physical passive two-terminal memristive prototype could not be constructed until very recently scientists of Hewlett-Packard Laboratories announced its realization. One of the main reasons why the memristor concept has not yet played a major role in modeling problems can most likely be explained from the fact that so far the majority of practical devices are reasonably well modeled by some (though often artificial) combination of resistors, inductors, and capacitors, and their nonlinear and multi-port versions. However, as nanoscale electronic devices become more and more important and complex, it might be beneficial, and on the longer term even necessary, to enlarge our repertoire of modeling building blocks that establishes a closer connection between the mathematics and the observed physics. In this talk, we show how memristive elements, including their generalizations to other engineering domains, can be included in the port-Hamiltonian modeling framework and discuss its properties. Apart from enlarging our repertoire of modeling building blocks, the inclusion of memristive elements in the existing port-Hamiltonian formalism possibly opens up new ideas for controller synthesis and design.

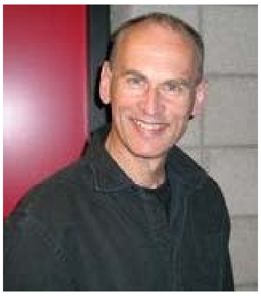
Dimitri Jeltsema received the B.Eng. degree in electrical engineering from the Rotterdam University of Applied Science, The Netherlands, and the M.Sc. degree in systems and control engineering from the University of Hertfordshire, United Kingdom in 1996 and 2000, respectively. In May 2005 he received the Ph.D. degree (with honors) from Delft University of Technology, The Netherlands. Until 2007 he has been a post doctoral researcher and lecturer at the Delft Center for Systems and Control. Currently he is an assistant professor at the Mathematical Systems Theory Group of the Delft Institute of Applied Mathematics. His research interests include modeling, analysis and control of nonlinear circuits and systems.
See http://www.dcsc.tudelft.nl/~jeltsema/ for further info.

**7th April 2010, 14.30**

# Port-Hamiltonian dynamics on graphs

Arjan Van Der Schaft
University of Groningen

**Abstract**
A topic of great current interest, motivated by diverse applications, is the subject of dynamics on networks. In this talk we discuss how one can define generalized Hamiltonian dynamics (possibly including resistive elements, algebraic constraints, and external ports) on graphs in an intrinsic way. Main tool in this endeavor is the definition of two Dirac structures determined by the graph. (A Dirac structure is a geometric object generalizing at the same time symplectic forms and Poisson brackets).
The first Dirac structure, dating back to the classical work by Kirchhoff, is the appropriate Dirac structure for e.g. defining the dynamics of RLC electrical circuits in a port-Hamiltonian way. In this case the dynamics is associated to the edges of the graph. The second Dirac structure allows to associate dynamics to every vertex of the graph, and is the natural Dirac structure for formulating the dynamics of consensus algorithms of multi-agent systems, or the dynamics resulting from coordination control strategies. Finally, we will discuss the extension of this framework from graphs to 1-complexes, thereby allowing for a port-Hamiltonian description of chemical reaction networks.



Arjan van der Schaft received the undergraduate, graduate, and Ph.D. degrees in Mathematics from the University of Groningen, The Netherlands. In 1982 he joined the University of Twente, where he was appointed as a full professor in 2000. In 2005 he returned to Groningen as a full professor in Mathematics. He has served as Associate Editor for Systems & Control Letters, Journal of Nonlinear Science, SIAM Journal on Control, and the IEEE Transactions on Automatic Control. Currently he is Associate Editor for Systems and Control Letters, Journal of Geometric Mechanics, and Editor-at-Large for the European Journal of Control. He is (co-)author of a number of books, including Nonlinear Dynamical Control Systems (1990, with H. Nijmeijer), L_2-Gain and Passivity Techniques in Nonlinear Control (1996, 2000), and An Introduction to Hybrid Dynamical Systems (2000, with J.M. Schumacher). Recurrent theme in his
research is the modeling, analysis and control of open dynamical systems. Present focus is on network modeling and analysis of complex systems and their geometric formulation as open Hamiltonian systems, the compositional modeling, analysis and control of systems with interacting continuous and discrete dynamics, and their applications in multi-physics systems, embedded systems and systems biology. See http://www.math.rug.nl/~arjan/ for further info. Arjan van der Schaft is Fellow of the IEEE.

## 16th April 2010, 10:30

## Control of Solar Energy Systems

Eduardo F. Camacho
University of Seville, Spain

**Abstract:** The use of renewable energy, such as solar energy, experienced a great impulse during the second half of the seventies just after the first big oil crisis. At that time economic issues were the most important factors and the interest in these types of processes decreased when the oil prices fell. There is a renewed interest in the use of renewable energies nowadays driven by the need of reducing the high environmental impact produced by the use of fossil energy systems. There are two main drawbacks of energy systems: a) the resulting energy costs are not yet competitive and b) solar energy is not always available when needed. Considerable research efforts are being devoted to techniques which may help to overcome these drawbacks, control is one of those techniques. A solar power plant basically consists of a system where the solar energy is collected, then concentrated and finally transferred to a fluid. The thermal energy of the hot fluid is then used for different purposes such as generating electricity, the desalination of sea water etc. While in other power generating processes, the main source of energy (the fuel) can be manipulated as it is used as the main control variable, in solar energy systems, the main source of power which is solar radiation cannot be manipulated and furthermore it changes in a seasonal and on a daily base acting as a disturbance when considering it from a control point of view. Solar plants have all the characteristics needed for using advanced control strategies able to cope with changing dynamics, nonlinearities and uncertainties. As fixed PID controllers cannot cope with some of the mentioned problems, they have to be detuned with low gain, producing sluggish responses or if they are tightly tuned they may produce high oscillations when the dynamics of the process vary, due to environmental and/or operating conditions changes. The use of more efficient control strategies resulting in better responses would increase the number of operational hours of the plants. The talk describes the main solar energy plants and the control problems involved and how control systems can help in increasing their efficiency. Some illustrative examples are given.

Eduardo F. Camacho received his doctorate in Electrical engineering from the University of Seville where he is now a full professor of the Department of System Engineering and Automatic Control. He has written the books: Model Predictive Control in the Process industry (1995), Advanced Control of Solar Plants (1997) and Model Predictive Control (1999), (2004 second edition) published by Springer-Verlag, Control e Instrumentación de Procesos Quimicos published by Ed. Sintesis and Control of Dead-time Processes published by Springer-Verlag (2007). He has served on various IFAC technical committees and chaired the IFAC publication Committee from 2002-2005. He was the president of the European Control Association (2005-2007) and chaired the IEEE/CSS International Affairs Committee (2003-2006). Currently he is the Chair of the IFAC Policy Committee and a member of the IEEE/CSS Board of Governors. He has acted as evaluator of projects at national and European level and was appointed Manager of the Advanced Production Technology Program of the Spanish National R&D Program (1996-2000). He was one of the Spanish representatives on the Program Committee of the Growth Research program and expert for the Program Committee of the NMP research priority of the European Union. He has carried out review and editorial work for various technical journals and many conferences. At present he is one of the editors of the IFAC journal, Control Engineering Practice, has been associate editor of the European Journal of Control until 2006 when he was promoted to editor at large and subject editor of the journal Optimal Control: Methods and Applications. He was Publication Chair for the IFAC World Congress b.02 and General Chair of the joint Control and Decision Conference and European Control Conference (CDC-ECC.05).

**Thursday 6th May 2010, 14:00**

# Modeling Interconnected Systems

Jan C. Willems
K.U. Leuven

**Abstract**

In Systems Theory, it is customary to view a system in terms of inputs and outputs, and interconnection as output-to-input assignment, as in series connection and feedback. However, input/output thinking is not suitable for modeling physical systems. The aim of this lecture is to explain the behavioral approach to dynamical systems as an alternative. In this setting, a system is defined as simply a family of trajectories. Modeling interconnected systems by tearing, zooming, and linking will be discussed. Linking, the basis of interconnection, means sharing variables. The question emerges how energy is transferred between systems, and leads to the distinction between ports and terminals. Terminals are for interconnection, ports are for energy transfer. The development will be illustrated by electrical circuits and mechanical systems.

Jan C. Willems was born in Bruges in Flanders, Belgium. He received the Ph.D. degree in electrical engineering from MIT in 1968. He was an assistant professor in the department of electrical engineering at MIT from 1968 to 1973, when he was appointed Professor of Systems and Control in the Mathematics department of the University of Groningen. In 2003, Professor Willems became emeritus. Presently he is guest professor at the K.U. Leuven, Belgium. He served terms as chairperson of the European Union Control Association and of the Dutch Mathematical Society (Wiskundig Genootschap). He has been on the editorial board of a number of journals, in particular, as managing editor of the SIAM Journal of Control and Optimization and of Systems & Control Letters. In 1998, he received the IEEE Control Systems award. His research area is Systems and Control Theory. He worked on stability of feedback systems, on the theory of dissipative systems, and on geometric control and other topics in linear systems theory. He developed the behavioral approach to dynamical systems and control. His publications may be found on his website:
http://homes.esat.kuleuven.be/~jwillems/

## Thursday 6th May 2010, 15:00

Quadratic differential forms and (two of) their applications

Paolo Rapisarda
University of Southampton, Great Britain

**Abstract**

When considering modeling and control problems often one must study functionals of the system variables and their derivatives: this happens for example in optimal control, in the theory of Lagrangian or Hamiltonian mechanics, in Lyapunov stability theory, etc. When studying linear systems, such functionals are usually taken to be bilinear or quadratic. Given the predominance of the state-space paradigm in system and control theory, usually only (integrals of) functionals of the state and of the input of the system are considered. However, in reality linear systems are hardly ever described by state-space models: the result of a first principles modeling procedure is usually a set of higher-order differential equations possibly involving algebraic relations among the variables. Consequently, the need arises to develop a theory of bilinear- and quadratic functionals of the variables of a linear system described by such a model, without transforming it first in state-space form. These functionals necessarily involve, besides the variables of the system, also their higher-order derivatives. An efficient representation of such functionals by means of two-variable polynomial matrices has been proposed by Willems and Trentelman, who introduced the concepts of bilinear- and quadratic differential form. The association of BDFs and QDFs with two-variable polynomials allows to develop a calculus that has applications in various areas of systems and control theory. In such calculus, operations and properties of the bilinear- or quadratic functionals correspond to algebraic operations and properties of the two-variable polynomial matrices representing the functionals. In the first part of this talk some of the basic concepts of bilinear- and quadratic differential forms are introduced; the second part deals with a couple of applications to system- and control theory problems such as the modelling of linear Hamiltonian systems, and an equipartition of energy principle.

Paolo Rapisarda got a Laurea (M.Sc.) degree in Computer Science at the University of Udine, Italy; and a Ph.D. in Mathematics at the University of Groningen, The Netherlands, working under the supervision of Jan C. Willems and Harry L. Trentelman. He has worked as a Lecturer at the Department of Electrical, Computer and Electronics Engineering of the University of Trieste, Italy; and at the Department of Mathematics of the University of Maastricht, The Netherlands. Currently he is Senior Lecturer at the Information: Signals, Images, Systems group of the School of Electronics and Computer Science of the University of Southampton, United Kingdom.