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Abstracts & Biographical Notes

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Control of Networked Embedded Systems

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Abstract

Networked control systems offer significant advantages and present serious challenges. These challenges can be addressed perhaps only by bringing together areas such as communication, control and computing, and by conducting research at their intersection, while continuing to learn from networks in biological systems. After an introduction to the many challenges and opportunities in networked embedded systems research, this talk will focus on the problem of guaranteeing stability and certain level of performance in networked control systems, and a model-based approach to the problem will be presented.

Today, advances in sensor, actuator and microprocessor technology (MEMS and nano-technology) have enabled distributed implementation of sensor and control actions over sensor/actuator networks. Such networks may consist of a large number of embedded processors typically of limited processing power, which should perform well under severe resource constraints and under unreliable and limited communication conditions over wide geographic areas and for long periods of time. These networked systems may be required to exhibit certain degree of autonomous behavior, while they are working together towards common goals. Designing such systems is of great importance today and it will be more so in the future. Networked systems have also been becoming of interest in several other areas including micro-satellites, telescope mirror and large space antenna segments, aerial unmanned vehicles, sensor and actuator networks in refineries and manufacturing plants. There are of course many connections to autonomous, intelligent, discrete event and hybrid systems research.

Biographical note

Panos J. Antsaklis is the H.C. and E.A. Brosey Professor of Electrical Engineering and the Director of the Center for Applied Mathematics of the University of Notre Dame.

He received his M.S. and Ph.D. degrees from Brown University and his undergraduate degree from the National Technical University of Athens (NTUA), Greece. He has held faculty positions at Brown University, Rice University, and Imperial College of the University of London in London, England. During sabbatical leaves he has lectured and conducted research at MIT, Imperial College, NTUA and the Technical University of Crete, Greece.

His research addresses problems of control and automation and examines ways to design engineering systems that will exhibit high degree of autonomy in performing useful tasks. Application areas include manufacturing, transportation and power systems as well as computer and communication networks. His work includes analysis of behavior and design of control strategies for complex autonomous, intelligent, learning and reconfigurable systems. His research is funded by federal agencies (NSF, ARO, DARPA) and companies. His recent research focuses on networked embedded systems and addresses

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problems in the interdisciplinary research area of control, computing and communication networks, and on hybrid and discrete event dynamical systems.

He has authored a number of publications in journals, conference proceedings and books. He has authored the research monograph "Supervisory Control of Discrete Event Systems Using Petri Nets" (Kluwer Academic 1998; with J. Moody) and the graduate textbook "Linear Systems" (McGraw-Hill 1997; with A.N. Michel). He has edited four books on Intelligent Autonomous Control and on Hybrid Systems: "An Introduction to Intelligent and Autonomous Control" (Kluwer Academic 1993; with K. Passino), "Hybrid Systems II" & "Hybrid Systems IV" (Springer-Verlag 1995 and 1997; with W. Kohn, A. Nerode and S. Sastry) and "Hybrid Systems V" (Springer-Verlag 1999; with W. Kohn, M. Lemmon, A. Nerode, and S. Sastry).

He currently serves in the Editorial Board of the Journal of Discrete Event Dynamic Systems, of the International Journal of Intelligent Control and Systems, the Information Sciences Journal and he is Associate Editor at Large of the IEEE Transactions on Automatic Control.

He has served as Associate Editor of the IEEE Transactions on Automatic Control and of the IEEE Transactions on Neural Networks and as an Editor of the IEE Control Engineering Book Series. He was the Guest Editor of the 1990 and 1992 Special Issues on "Neural Networks in Control Systems" of the IEEE Control Systems magazine (CSM) and the Guest Editor of the 1995 Special Issue on "Intelligence and Learning" in the IEEE CSM. He was Guest Editor of special issues on Hybrid Control Systems in the IEEE Transactions on Automatic Control (with A. Nerode; 1998) and in the Journal of Discrete Event Dynamic Systems (with M. Lemmon; 1998). He was the Guest Editor of the Special Issue on Hybrid Systems in the Proceedings for IEEE (July 2000).

He currently serves as the President of the Mediterranean Control Association (MCA), as the Chair of the Technical Committee on Fuzzy and Neural Systems of the International Federation of Automatic Control (IFAC) and as the chair of the Awards committee of the IEEE Control Systems Society.

He was the 1997 President of the IEEE Control Systems Society (CSS), the 1996 CSS President-Elect, Vice President-Conferences in 1994 and 1995, an elected member of the CSS Board of Governors 1991-1996, and the General Chair of the 1995 34th IEEE Conference on Decision and Control (CDC) in New Orleans. He was the Program Chair of the 30th IEEE CDC in England in 1991, and he has served as the General Chair of the 1993 8th IEEE International Symposium on Intelligent Control in Chicago. He served as the IEEE Director and Alternate Director of the American Automatic Control Council, the U.S. National Member Organization of the International Federation of Automatic Control from 1994 to 1997. He was the Honorary Chair of the 1996 4th IEEE Mediterranean Symposium on Control and Automation in Crete, Greece and the General co-Chair of the 8th IEEE Mediterranean Symposium on Control and Automation in July 2000.

He has been plenary and keynote speaker in a number of conferences and research workshops, and he was a recipient of the John Kaneb Award for Excellence in Teaching and Curriculum Development at the University of Notre Dame. He is an IEEE Fellow for his contributions to the theory of feedback stabilization and control of linear multivariable systems, a Distinguished Lecturer of the IEEE Control Systems Society, a recipient of the IEEE Distinguished Member Award of the Control Systems Society, and an IEEE Third Millennium Medal recipient.

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Advances in robotics and mechatronics (from space to surgery)

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Abstract

The talk first briefly comments the development and evolvement of industrial robots over the past 20 years. It emphasizes the importance of mechatronic concepts and sensory feedback for more precision and autonomy in the future. The progress and perspectives in space robotics are addressed next. Space technology is characterized as major driver for a new generation of power-saving ultralightweight arms and articulated hands - an important prerequisite for the emerging field of mobile production assistants and service robotics. The technological potentials are demonstrated by DLR`s newest light weight arm and four-finger hand generation, which are fully joint-torque-controlled and thus are provided with programmable Cartesian impedance - a feature which allows for new programming techniques and "human-friendly" operational modes. One of the most challenging application fields for these new technologies is surgical robotics; its state of the art and perspectives are briefly outlined.

Biographical note

Prof. Dr. Ing. Gerd Hirzinger received his Dipl.-Ing. degree and the doctor's degree from the Technical University of Munich, in 1969 and 1974 respectively. In 1969 he joined DLR (the German Aerospace research establishment) where he first worked on fast digital control systems. 1976 he became head of the automation and robotics laboratory of DLR, where he and his co-workers soon got several awards for innovative technology transfer from robotics research to applications. In 1991 he received a joint professorship from the Technical University of Munich.

Since 1992 he has been director at DLR's institute for "robotics and mechatronics". He has published more than 200 papers in robotics, mainly on robot sensing, sensory feedback, mechatronics, man-machine interfaces, telerobotics and space robotics. He was prime investigator of the space robot technology experiment ROTEX, the first remotely controlled robot in space, which flew onboard shuttle COLUMBIA in April 93. He is senior member of IEEE, he was vice-program chairman of the IEEE Conference on Robotics and Automation 1994 and 1995, program chairman of IROS (Intelligent Robot Systems Conference) 1994 and organizer of the 7th International Symposium on Robotics Research. In a large number of other international robot conferences he was program committee member or invited plenary speaker. For many years he has been chairman of the German council on robot control and administrative committee member of the IEEE Society on Robotics and Automation. He rejected a number of chairs offered to him by different European Universities. He received several national and international awards, e.g. in 1994 the Joseph-Engelberger-Award for achievements in the robotic science and in 1995 the Leibniz-Award, the highest scientific award in Germany and the JARA (Japan robotics association) Award. In 1996 he received the Karl-Heinz-Beckurts-Award, Germany's most important award for outstanding promotion of the partnership between science and industry, and in 1997 the IEEE-fellow award. In 2002 he got the Golden Hermann-Oberth-Medal and was finalist in the World Technology Award. Today his institute with around 120 co-workers is one of the largest and most acknowledged robotics institutes worldwide.

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Hybrid Systems - A Control Engineering Perspective

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Abstract

Hybrid systems - loosely defined as systems comprised of continuous and discrete/switched components - are prevalent in all domains of engineering. Over the last few years this system class has attracted much attention and various tools have emerged for studying and affecting its behavior. In this presentation I will describe a recently developed approach for modeling, analysis and controller synthesis that is built on mixed integer mathematical programming. I will illustrate the merits of the technique on a wide range of examples from the automotive, the electrical power and the biomedical domains.

I will start by describing a new framework for modeling, analyzing and controlling systems whose behavior is governed by interdependent physical laws, logic rules, and operating constraints, denoted as Mixed Logical Dynamical (MLD) systems. They are described by linear dynamic equations subject to linear inequalities involving real and integer variables. MLD models are equivalent to various other system descriptions like Piece-Wise Affine (PWA) systems and Linear Complementarity (LC) systems. They have the advantage, however, that all problems of system analysis (like controllability, observability, stability and verification) and all problems of synthesis (like controller design and filter design) can be readily expressed as mixed integer linear or quadratic programs, for which many commercial software packages exist.

In the second part of the talk I recall some concepts of mathematical programming and show their connections with optimal control. In particular, I point out that finite time optimal control problems with constraints can be expressed as mathematical programs that depend on the initial state as a parameter, so called multi-parametric programs. "Solving" a multi-parametric program is synonymous with finding the solution of the mathematical program as an explicit function of the parameter. In the control context, solving the multi-parametric program is synonymous with finding the optimal state feedback controller. I will review the various algorithms that have emerged for the solution of multi-parametric (mixed integer) linear and quadratic programs and describe the broad range of controller synthesis problems that can be addressed with these new tools.

In the final part of the presentation I will discuss in detail some practical applications that have been tackled with these new tools. I will look at the traction control problem where the underlying hybrid model is piece-wise affine and various constraints must be obeyed. The synthesized controller is also piece-wise affine and can be implemented conveniently as a look-up table. The controller was tested successfully on a Ford Focus. The second example described in detail will be the control of pain relief (analgesia) during anesthesia. The modeling and controller design will be discussed and the test results obtained during operations on different patients will be shown (work jointly with the University Hospital in Berne, Switzerland). Finally, we will briefly review applications in other areas like optimal control of co-generation power plants, the control of voltage collapse in power grids, Direct Torque Control of electrical machines (all with ABB), electronic throttle control (with Ford and U. of Zagreb), and Driver Assistance Systems (with Daimler-Chrysler).

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Biographical note

In 1994 Manfred Morari was appointed head of the Automatic Control Laboratory at the Swiss Federal Institute of Technology (ETH) in Zurich. Before that he was the McCollum-Corcoran Professor of Chemical Engineering and Executive Officer for Control and Dynamical Systems at the California Institute of Technology. He obtained the diploma from ETH Zurich and the Ph.D. from the University of Minnesota, both in chemical engineering. His interests are in hybrid systems and the control of biomedical systems. In recognition of his research contributions, he received numerous awards, among them the Donald P. Eckman Award of the Automatic Control Council, the Allan P. Colburn Award and the Professional Progress Award of the AIChE, the Curtis W. McGraw Research Award of the ASEE and was elected to the National Academy of Engineering (U.S.). Professor Morari has held appointments with Exxon R & E and ICI and has been consulted internationally for a number of major corporations.

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Control of Networks of Unmanned Vehicles

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(joint work with Hyoun Kim, David Shim, John Koo, Peter Ray,
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Abstract

At Berkeley we have been interested in design schemes for network of complex networks of semi-autonomous agents. These networks are characterized by interaction between discrete decision making and continuous control. The control of such systems is often frequently organized in hierarchical fashion to obtain a logarithmic decrease in complexity associated with the design. We have used as examples three classes of systems to motivate the design approach:

1. Intelligent Vehicle Highway Systems (IVHS)
2. Air Traffic Management Systems (ATMS)
3. Unmanned Aerial Vehicles

Over the last five years or so, a group of us have developed a set of design approaches which are aimed at designing control schemes which are live, deadlock free, and "safe". Our design methodology is to be considered an alternative to the verification based approaches to hybrid control systems design, and is an interesting blend of game theoretic ideas, planning and fault handling in a probabilistic framework, mathematical and temporal logic and planning ideas from robotics. In this talk, I will focus on design problems involved in coordinating groups of Unmanned Aerial Vehicles (UAVs). Problems to be addressed include:

1. Design of embedded software for real-time control,
2. Vision based landing and navigation,
3. Pursuit Evasion problems for multi-UAV missions.

The last set of issues touches on issues of decentralized map making, computationally tractable solutions of pursuit evasion games with partial information and probabilistic verification.

Biographical note

S. Shankar Sastry received the PhD degree from the University of California, Berkeley, in 1981.

He became Chairman, Department of Electrical Engineering and Computer Sciences, the University of California, Berkeley, in January 2001. The previous year, he served as Director of the Information Technology Office at the Defense Advanced Research Programs Agency (DARPA). From 1996 to 1999, he was the Director of the Electronics Research Laboratory at the University of California, Berkeley, an organized research unit on the Berkeley campus conducting

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research in computer sciences and all aspects of electrical engineering. During his Directorship from 1996 to 1999, the laboratory grew from 29M to 50M in volume of extra–mural funding. He is the Professor of Electrical Engineering and Computer Sciences and a Professor of Bioengineering. He was on the faculty of the Massachusetts Institute of Technology (MIT), Cambridge, as an Assistant Professor from 1980 to 1982, and Harvard University, Cambridge, MA as a chaired Gordon Mc Kay Professor in 1994. He has held visiting appointments at the Australian National University, Canberra, the University of Rome, Italy, Scuola Normale and University of Pisa, Italy, the CNRS laboratory LAAS, Toulouse, France (poste rouge), Professor Invite at Institut National Polytechnique de Grenoble, France (CNRS laboratory VERIMAG), and as a Vinton Hayes Visiting Fellow at the Center for Intelligent Control Systems at MIT. His areas of research are embedded and autonomous software, computer vision, and computation in novel substrates such as DNA, nonlinear and adaptive control, robotic telesurgery, control of hybrid systems, embedded systems, sensor networks, and biological motor control. *Nonlinear Systems: Analysis, Stability and Control* (New York: Springer-Verlag, 1999) is his latest book, and he has coauthored over 250 technical papers and six books. He has co-edited *Hybrid Control II*, *Hybrid Control IV*, *Hybrid Control V* (New York: Springer-Verlag, 1995, 1997 and 1999, respectively). *Hybrid Systems: Computation and Control* (New York: Springer-Verlag , 1998), and *Essays in Mathematical Robotics* (New York: Springer-Verlag IMA Series). Books on Embedded Software and Structure from Motion in Computer Vision are in progress.

Dr. Sastry has served as Associate Editor for numerous publications, including the IEEE TRANSACTIONS ON AUTOMATIC CONTROL, IEEE CONTROL MAGAZINE, THE IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS, the *Journal of Mathematical Systems, Estimation, and Control*, the *IMA Journal of Control and Information*, the *International Journal of Adaptive Control and Signal Processing*, and the *Journal of Biomimetic Systems and Materials*. He was elected into the National Academy of Engineering in 2001 "for pioneering contributions to the design of hybrid and embedded systems." He also received the President of India Gold Medal in 1977, the IBM Faculty Development award for 1983-1985, the National Science Foundation Presidential Young Investigator Award in 1985, and the Eckman Award of the American Automatic Control Council in 1990, an M.A. (honoris causa) from Harvard University, Cambridge, MA, in 1994, the distinguished Alumnus Award of the Indian Institute of Technology in 1999, and the David Marr prize for the Best Paper at the International Conference in Computer Vision in 1999.

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