

EDITORIAL

Robust adaptive control: legacies and horizons

The field of adaptive control has grown and evolved over the past 50 years—from its early infancy, to its emergence as a major topic that dominated the American Control Conference (ACC) and Conference on Decision and Control (CDC) programs in the 70s and 80s, to its present advanced state at which activity continues at a healthy rate. The concepts, methods, and tools of the field have become cornerstones for many new fields and technical branches, and their applications are so widespread and deeply embedded in engineering to the point that the origins of the concepts that have arisen out of adaptive control are not always easily discernible.

The growth and success of the field of adaptive control are closely associated with several key individuals whose seminal contributions and professional service have generated major theoretical and technological advances. Their pioneering work opened the doors for and inspired generations of researchers who followed in their paths. The students they mentored, and the students of their students, became key players at the forefront of adaptive control, its daughter fields, and many of its closely related cousins. Their papers are read 30 years later and their impact remains high as the field evolves and the interests change.

Professor Petros Ioannou is undoubtedly one of such central figures in the field of adaptive control. More than 30 years ago, together with his PhD advisor Professor Petar Kokotovic, he published his first seminal work on error analysis of adaptive systems in the presence of unmodeled dynamics. Since then, with eight books, over 200 technical papers, and more than 30 PhD students, Professor Ioannou has left a legacy in the field of adaptive control theory, particularly in robust adaptive control. He led the development of theory and analysis for robust adaptive systems, thereby laying the solid theoretical foundation for practical applications of adaptive control. His early work on instability analysis and robust redesign of adaptive systems still provides profound insight in the fundamental issues and powerful tools for developing robust solutions. His persistent investigation over the last 30 years of various aspects of adaptive design for time-varying and multi-variable systems has led to a comprehensive collection of scholarly publications in top journals.

While continuing his pioneering theoretical work on adaptive control, Professor Ioannou has also ventured into other fields such as artificial neural networks where he made substantial contributions. Throughout his career, he pursued practical projects that demonstrated applicability of adaptive control on many different real-world systems, including ground vehicles, aircrafts, and marine systems. He is one of the first to work on intelligent transportation systems. His early paper on ‘intelligent cruise control’ is the top cited paper on this subject.

To salute Professor Petros Ioannou for his remarkable technical contributions and accomplishments, we have put together this special issue on the occasion of his 60th birthday. Thanks to the enthusiastic and overwhelming response of many colleagues and his former students, we are proud to present this special issue on ‘Robust Adaptive Control: Legacies and Horizons’. The quality and breadth of the papers in this collection are testimony to, and reflection of, Professor Ioannou’s legacy:

Annaswamy *et al.* [1] presented recent results in robust ‘adaptive flight control systems’ and showcased the advantages, properties, and performance of the AFCS pertaining to time delays and partial state feedback.

Serrani [2] explored the connection between the classic solution of the model reference adaptive control problem and the recent development in the theory of adaptive output regulation, and provided new insight on the model reference adaptive control problem.

Marino and Tomei [3] extended the available results on the robust adaptive observer to more general cases and establish a robust adaptive observer within a quantifiable error. The result illustrates that the design elucidated in Petros Ioannou and Petar Kokotovic’s seminal book *Adaptive Systems*

with *Reduced Models* is still a very fertile field of research both for linear and nonlinear systems 30 years after.

Bekiaris-Liberis *et al.* [4] solved stabilization problems of LTI systems with unknown parameters and distributed input delay by using backstepping–forwarding transformations of the finite-dimensional state of the plant and of the infinite-dimensional actuator state.

Fidan *et al.* [5] presented the design of an adaptive scheme for localization of a target from distance measurements and motion control of a mobile agent to track and capture this target, and demonstrated the stability of the overall adaptive control scheme with a convergence analysis.

Tao *et al.* [6] addressed the problem of adaptive compensation of unknown multi-input multi-output (multivariable) LTI dynamic systems with actuator nonlinearities. They present a new controller parametrization to deal with bilinear parameters resulted from the multiplication of the actuator nonlinearity parameters and the dynamic system parameters.

Zheng *et al.* [7] proposed two global robust adaptive tracking control schemes for a class of uncertain nonlinear systems that may include nonsmooth actuator nonlinearities. They established guaranteed global uniform boundedness of all signals and asymptotic tracking.

Datta *et al.* [8] explored a new direction of data-based adaptive control design. They suggested a new design approach, wherein a small number of measurements could be used to obtain information about the plant, which could then be used to design a controller guaranteeing stability and performance.

Tsakalis and Dash [9] presented an algorithm for H -infinity adaptation of PID controller parameters, thereby providing a more reliable PID tuning in the case of large mismatch between target and feasible loop shapes.

Happy Birthday from your colleagues and students, Petros! Thank you for giving us the opportunity to celebrate and reflect.

BIOGRAPHY



Petros Ioannou was born on February 3, 1953 in the small village of Tripimeni situated at the foothills of the Pendaktilos peninsula in Cyprus. He left the village at the age of 12 to attend the Technical School of Cyprus in Nicosia, Cyprus. After graduation and completion of his two-year mandatory service with the Cyprus National Guard, he moved to London, England, in 1973, where he worked part time while studying for the university entrance examinations. In 1975, he enrolled at the Department of Mechanical Engineering at the University College of London where he received the BSc degree with First Class Honors in 1978. He continued his studies in the US where he received the MS and PhD degrees from the University of Illinois, Urbana, Illinois, in 1980 and 1982, respectively. During the period 1975–1978, he held a Commonwealth Scholarship from the Association

of Commonwealth Universities, London, England. He was awarded several prizes, including the Goldsmid Prize and the A. P. Head Prize from University College, London.

In 1982, Dr. Ioannou joined the Department of Electrical Engineering-Systems, University of Southern California, Los Angeles, California. He is currently a professor in the same department and the director of the Center of Advanced Transportation Technologies and associate director for Research for the University Transportation Center METRANS. He holds a courtesy appointment with the Department of Aerospace and Mechanical Engineering and with the Department of Industrial Engineering. His research interests are in the areas of adaptive control, neural networks, nonlinear systems, vehicle dynamics and control, intelligent transportation systems, and marine transportation. He was a visiting professor at the University of Newcastle, Australia, and the Australian National University in Canberra during the fall of 1988, the Technical University of Crete in summer of 1992 and fall of 2001, and served as dean of the School of Pure and Applied Science at the University of Cyprus in 1995. As dean, member of the Senate, and member of some vital committees, he pioneered the establishment of the School of Engineering at the University of Cyprus. In 2008/2009, he was a faculty member at the Department of Electrical Engineering and Information Technologies of the Cyprus University of Technology while on sabbatical leave from the University of Southern California.

Dr. Ioannou was the recipient of the Outstanding Transactions Paper Award by the IEEE Control System Society in 1984 and the recipient of a 1985 Presidential Young Investigator Award for his research in adaptive control. In 2009, he received the IEEE ITSS Outstanding ITS Application Award for his work on adaptive cruise control systems. He also received the ‘2009 IET Heaviside Medal for Achievement in Control’ by the Institution of Engineering and Technology (former IEE). In 2012, he received the IEEE ‘ITSS Outstanding Research Award’ for his research contributions in the area of vehicle dynamics and control and intelligent transportation systems. He has served as an associate editor for *IEEE Transactions on Automatic Control*, *International Journal of Control*,

Automatica, and *IEEE Transactions on Intelligent Transportation Systems*. He served as a member of the Control System Society on IEEE ITS Council Committee and his center on advanced transportation technologies was a founding member of IVHS America that was later renamed ITS America. He also served as an associate editor at large of the *IEEE Transactions on Automatic Control* and chairman of the International Federation of Automatic Control (IFAC) Technical Committee on Transportation Systems. He is a member of the Board of Governors of the IEEE Intelligent Transportation Society. He is one of the founders of the Mediterranean Control Association and a member of the Board of Governors. He was one of the founders of the IEEE Mediterranean Control Conference that has been taking place annually since 1992 and one of the founders of the University Transportation Center, METRANS, at the University of Southern California and California State University Long Beach. In 2010, he established a successful Masters program in Financial Engineering at the University of Southern California, which he is currently supervising.

Dr. Ioannou is a Fellow of IEEE, IFAC, and of the Institution of Engineering and Technology (IET). He is the author/coauthor of eight books and over 200 research papers in the area of controls, vehicle dynamics, neural networks, nonlinear dynamical systems, and intelligent transportation systems. As of 2012, he graduated 30 PhD students who went on to pursue very successful careers in Academia and Industry.

Dr. Ioannou has three children, Kira who is finishing her Masters degree in Health Management at the University of Southern California in May 2013, Andreas who is on his second year at the same university studying human biology and working part time as personal trainer and manager of rental properties, and Alexandros who is attending a Montessori school currently learning his ABCs. He is married to Natallia, a CPA finishing her Masters degree in Business Taxation at the Marshal School of Business at the University of Southern California in May 2013.

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Guest Editors

JING SUN

*Naval Architecture and Marine Engineering Department
University of Michigan, Ann Arbor, MI, USA
E-mail: jingsun@umich.edu*

MIROSLAV KRSTIC

*Mechanical and Aerospace Engineering
University of California, San Diego, La Jolla, CA, USA
E-mail: krstic@ucsd.edu*

NIKOLAOS BEKIARIS-LIBERIS

*Mechanical and Aerospace Engineering
University of California, San Diego, La Jolla, CA, USA
E-mail: nikos.bekiaris@gmail.com*