Preparing Tomorrow's Scientists and Engineers for the Challenges of the 21st Century

Special Panel Session on Education

Organizer/Moderator: Bozenna Pasik-Duncan
(University of Kansas)

Sponsored by the IFAC TC 9.4,
Technical Committee on Control Education

Acknowledgements

Thanks go to:

•President and Program Committee Members of the IFAC World Congress 2011

•Members of the IFAC EDCOM and IFAC TB and IFAC Secretariat

•Control System Society and American Automatic Control Council

•University of Kansas and KU Secretariat

Special thanks to Dr. Sonia Ortega, NSF G-K12 Program Director, for her inspiring talk given at the ACC'2009 in St. Louis, MO. Her talk resulted in several followed up sessions including this one.

Panelists

- Karl Aström (Lund University)
- Siva Banda (Air Force Research Lab, Wright-Patterson AFB)
- Ruth Bars (Budapest University of Technology and Economics)
- Tamer Basar (University of Illinois, Urbana)
- Antonio Bicchi (University of Pisa)
- Christos Cassandras (Boston University)
- Sebastián Dormido (National University of Distance Education)
- Alexander Fradkov (IPME, Russian Academy of Sciences)

Panelists

- Graham Goodwin (University of Newcastle)
- Vladimir Havlena (Czech Technical University)
- Stephen Kahne (Embry-Riddle Aeronautical University)
- Lennart Ljung (Linköpings Universitet)
- Jan Maciejowski (University of Cambridge)
- Iven Mareels (University of Melbourne)
- Roberto Tempo (IEIT-National Research Council, Torino)
- Ljubo Vlacic (Griffith University)

Purpose

- Focus on multiple challenges and opportunities that are presented to young investigators preparing for careers in science and engineering.
- Address important control engineering education issues of balancing math, science and technology.

Address

- How do we integrate research and education?
- What we, scientists and educators, should do about cultivating student interest in science, math and engineering.
- Is it important for control engineering students to know math and science?
- Should control engineering education focus mostly on engineering?
- Should engineering education focus mostly on technology?

Expected Output

- Recommendations to the control community on how to integrate education with research and how to attract science and engineering students to the field of automatic control.

Bozenna Pasik-Duncan

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Bozenna Pasik-Duncan received her Master's degree in Mathematics from Warsaw University in 1970, and her Ph.D. and Habilitation degrees in Mathematics from the Warsaw School of Economics in 1978 and 1986 respectively. She is a Professor of Mathematics and Courtesy Professor of Electrical Engineering and Computer Science at the University of Kansas. Her research interests are primarily in stochastic theory and control and Science, Technology, Engineering and Mathematics (STEM) education. She has held visiting appointments in Poland, Hungary, Czech Republic, France, Italy, Japan and China. Dr. Pasik-Duncan has been actively involved in the IEEE Control Systems Society (CSS) in a number of capacities. Dr. Pasik-Duncan is a recipient of IEEE Third Millennium Medal, an IEEE Fellow and a Distinguished Member of the CSS. She has been the chair of the CSS and American Automatic Control Council (AACC) Technical committees on Control Education. She has been actively involved in the International Federation of Automatic Control (IFAC) in a number of capacities such as chair of the TC 9.4 - Technical Committee on Control Education, chair of the Harold Chestnut Control Engineering Textbook Prize Selection Committee and the editor of Control Resources Publications .

She has been recognized by the University of Kansas and Association for Women in Mathematics for excellence in teaching. Most recently she received the Steeples Service to Kansas Award for her commitment to STEM education reaching thousands of students in grades K-12 in Kansas and throughout the nation. She is a strong advocate for women in STEM. She is a founder and mentor of CSS Women in Control Group, founder and faculty advisor to the KU Association for Women in Mathematics Chapter, CSS liaison to IEEE Women in Engineering, member of KU Women in Science and member of American Association for University Women. She was inducted to the KU Women's Hall of Fame.

Karl Johan Aström

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Karl Johan Åström was educated at the Royal Institute of Technology (KTH) in Stockholm. After working for IBM Research for five years he was appointed Professor of the Chair of Automatic Control at Lund Institute of Technology (LTH)/Lund University where he established a new department. Åström has broad interests in control including, stochastic control, modeling, system identification, adaptive control, computer control and computer-aided control engineering. He has supervised more than 60 PhD students, written seven books and more than 100 papers in archival journals. He is listed in ISAHighlyCited and he has Erdös number 3. A paper on self-tuning control, co-authored with B. Wittenmark, was selected for the IEEE Book Control Theory: Twenty-five seminal papers 1932-81. He has several patents, one of them for automatic tuning of PID controllers, held jointly with T. Hägglund, has led to substantial industrial production. Åström is a member several academies. He is a Fellow of IEEE and IFAC and he has received many honors; among them six honorary doctorates, the 1985 Rufus Oldenburger Medal from ASME, the 1987 Quazza Medal from IFAC, the 1990 IEEE Control Systems Award, the 1993 IEEE Medal of Honor and the 2002 Great Gold Medal of the Royal Swedish Academy of Engineering.

Challenges in Control Education

K. J. Åström

Department of Automatic Control, Lund University

NAE The Engineer 2020

In the past, steady increases in knowledge has spawned new microdisciplines within engineering. However, contemporary challenges – from biomedical devices to complex manufacturing systems to large systems of networked devices – increasingly require a systems perspective.

There will be growth in areas of simulation and modeling around the creation of novel engineering *structures*. Computer based design-build engineering…will become the norm for most product designs, accelerating the creation of complex structures for which multiple subsystems combine to form a final product.

Control Education

- Basic knowledge for all scientists and engineers
- The dilemma of emerging fields
  - Teach all we know
  - Add courses as research develops
  - Research driven specialization
- Consequences
  - Too many courses, too much specialization
  - Difficult to get an overview
- Consolidation
  - Learn from classic fields
  - Sort, evaluate, select and organize
  - Focus on fundamentals, insight and practical relevance
  - Exploit computing
  - Don’t forget back-on-the-envelope calculations

The Magic of Feedback – Useful Everywhere

Feedback has some amazingly good properties (know your friends!)

- Feedback can make good systems from bad components,
- Feedback can make a system insensitive to disturbances and component variations,
- Feedback can stabilize and shape behavior

Feedback has some drawbacks (know your enemies!)

- Feedback can cause instabilities

  Importance of stability theory

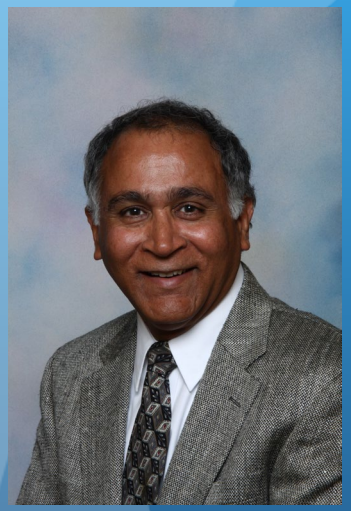
- Feedback feeds sensor noise into the system

What is Control?

- Requirements
- Architecture
  - System structure, sensors, actuators, computers, communication, HMI
- Modeling and Simulation
  - Physics and data
- Control Design
  - Algorithms and logic
  - Simple (PID) and advanced
- Implementation
- Verification and validation
- Commissioning and tuning
- Operation
  - Diagnostics, performance assessment, fault detection
- Reconfiguration and upgrading

Siva S. Banda

Air Vehicles Directorate
Air Force Research Laboratory



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Dr. Siva S. Banda is the Chief Scientist of Air Vehicles Directorate, Air Force Research Laboratory (AFRL), Wright-Patterson Air Force Base, Ohio, USA. Dr. Banda has dedicated his career to ensuring that the aerospace industry possesses the cutting-edge flight control solutions essential to fielding revolutionary air and space platforms for both military and commercial applications. He has been a part of AFRL's scientific professional research staff since 1981.

Dr. Banda's personal professional contributions have been recognized in multiple forums and in multiple ways, most notably through: IEEE Control Systems Technology Award; the Royal Aeronautical Society (RAeS) Silver Medal; IFAC Nathaniel Nichols Medal, the Meritorious Presidential Rank Award; the Distinguished Presidential Rank Award; election as a Fellow of RAeS, AIAA, IEEE, and IFAC; and Membership of the National Academy of Engineering. He serves on Advisory Boards at the University of Southern California, the University of Central Florida, and SIAM. He serves as an Advisor to AFOSR, ONR, ARO, DARPA, NSF, and leads several international technical activities within the NATO Research and Technology Organization and The Technical Cooperation Program. He has served on the Editorial Boards of the IEEE Transactions on Control Systems Technology, the International Journal of Robust & Nonlinear Control, and the AIAA Journal of Guidance, Control & Dynamics. He also has served as thesis adviser and adjunct professor at the Air Force Institute of Technology, Wright State University, and University of Dayton.

Dr. Banda received his B.E. in Electrical Engineering from the Regional Engineering College, Warangal, India; his M.E. in Aeronautical Engineering from the Indian Institute of Science, Bangalore; an M.S. in Systems Engineering from Wright State University; and a PhD in Aerospace Engineering from the University of Dayton in 1974, 1976, 1978 and 1980 respectively. He has authored over 200 technical papers, reports and books, holds two patents, and has delivered more than 120 invited lectures worldwide.


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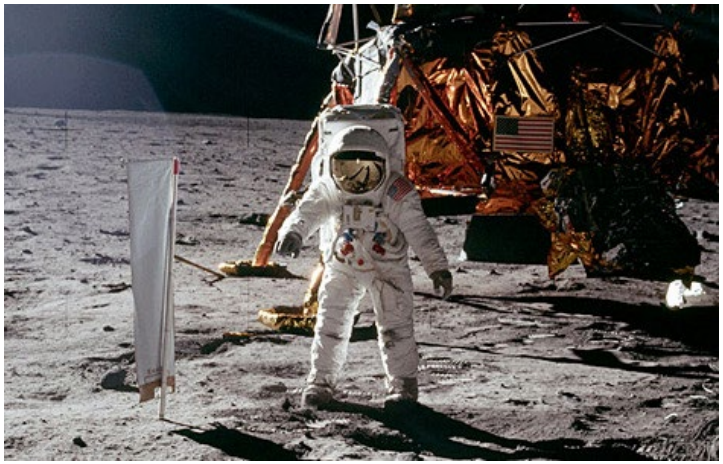
dream big

Cultivate Interest

What we, scientists and educators, should do about cultivating student interest in science, math and engineering?

Go to the moon



Modern Universities Are Working?

- Universities are now businesses
- Tenure track pushes – high volume, high dollar
- Leaves undergraduate students to the side
- Graduate students have less 1-on-1 advisor time
- Is the curriculum current?

Tamer Basar

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Tamar Basar received a B.S.E.E. degree from Robert College, Istanbul, 1969, and M.S., M.Phil, and Ph.D. degrees in engineering and applied science from Yale University, in 1970, 1971 and 1972, respectively. He joined the University of Illinois at Urbana-Champaign in 1981, where he is with the Department of Electrical and Computer Engineering, and holds the positions of Swanlund Endowed Chair, Center for Advanced Study Professor, Research Professor at the Coordinated Science Laboratory, and Research Professor with the Information Trust Institute.

Dr. Basar has authored or co-authored over 200 journal articles and book chapters, and over 300 conference. His forthcoming book Network Security: A Decision and Game Theoretic Approach, Cambridge University Press, 2011 is due out soon. His current research interests include stochastic teams and games; routing, pricing, and congestion control in communication networks; control over wired and wireless networks; mobile and distributed computing; risk-sensitive estimation and control; and game-theoretic approaches to security in computer networks, including intrusion detection and response.

He is a member of the National Academy of Engineering (of the USA), and also carries memberships in several scientific organizations. He is a Fellow of IEEE, and has served its Control Systems Society in various capacities, among which are: Past President (2001), President (2000). He has also been active in IFAC in the organization of several workshops and symposia, and as Editor and Deputy Editor-in-Chief of its flagship journal Automatica from 1992-2003, and since 2004 as Editor-in-Chief and Chair of its editorial board. He is currently the Series Editor of the Annals of ISDG, the Series Editor of Systems & Control: Foundations and Applications, and Honorary Editor of Applied and Computational Mathematics. He is also a subject editor of Wireless Networks and an associate editor of Systems and Control Letters, and is on the editorial and advisory boards of a number of other international journals. Currently, he is also the President of the American Automatic Control Council (2010-2011).

Ruth Bars

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Ruth Bars graduated at the Electrical Engineering Faculty of the Budapest University of Technology, Hungary. She received the doctor of the university degree, and gained the Candidate of Sciences degree of the Hungarian Academy of Sciences, and PhD degree based on research on predictive control algorithms. Currently she is an associate professor at the Department of Automation and Applied Informatics at the Budapest University of Technology and Economics. Her research interests are in predictive control and in developing new ways of control education. She has more than 100 publications. She is teaching different basic and advanced control courses. She has published with co-authors several university lecture notes and textbooks including MATLAB exercises for control education. She was the coauthor of professor Frigyes Csáki writing the first Hungarian textbook entitled Automatika, which had 6 editions. Recently a new textbook has been published with coauthors on the basics of control engineering including also newer conceptions (in Hungarian, but it has been translated to English).

In 1983 she participated in the project of the NSF and the Hungarian Academy of Sciences on computer control of industrial processes at the University of Minnesota, USA. In 1999, 2003 and 2006 she was a visiting lecturer at the Helsinki University of Technology, Finland and in 2002 at the University of Louisiana, Lafayette, USA giving short PhD courses in predictive control. In 2008 she participated in a Marie Curie project at the University of Sevilla related to predictive control.

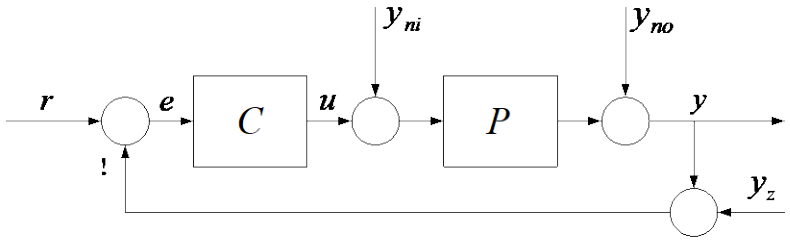
Between 1996 and 2002 she was the head of the IFAC TC on Optimal Control. From 2002 to 2008 she served IFAC as the head of the Coordinating Committee on Design Methods.

She has gained the Frigyes Csáki medal of the Hungarian Scientific Society for Automation, Measurement Technics and Informatics, 1990 and the award for excellent work from the Ministry of Education.

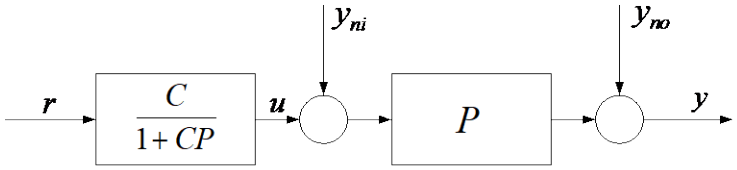
Basic Control Course

It is taught as a basic discipline at the Faculty of Electrical Engineering and Informatics in the 5th semester. It offers fundamental knowledge in analysis and synthesis of continuous and sampled data control systems. The course material has been updated recently introducing newer ideas of controller design (e.g. YOULA parametrization).

Control via negative feedback



Its equivalent for tracking



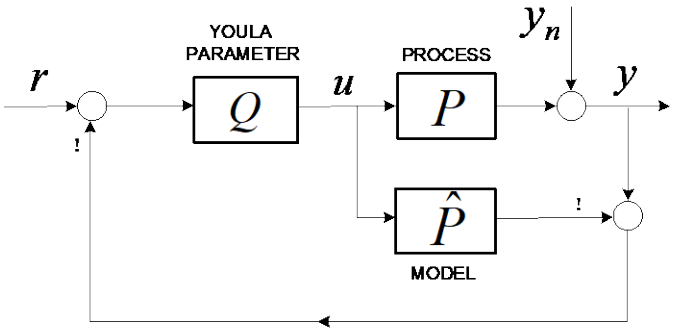
$$\frac{u}{r} = Q = \frac{C}{1+CP}; \qquad C = \frac{Q}{1! \; QP}$$

Q: YOULA parameter

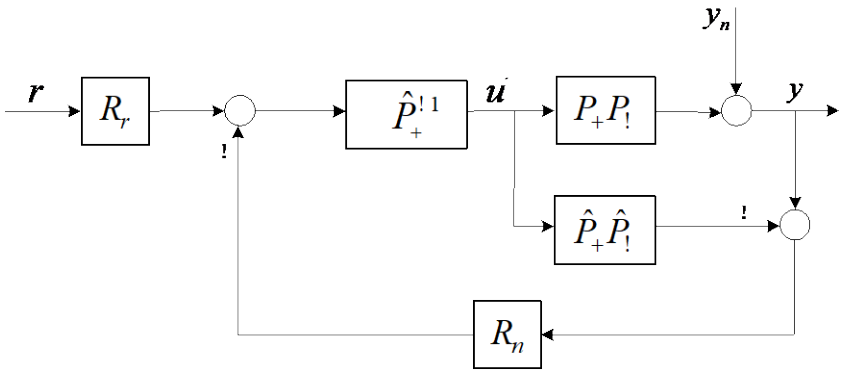
$$u = Qr; \quad y = QPr$$

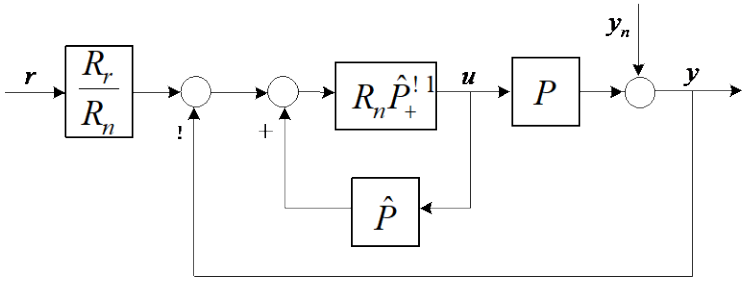
Ideal tracking if Q realizes the inverse of the process.

Disturbance rejection is ensured by IMC.



But P consists of invertible and non-invertible parts: $P = P_+ P_!$. Then $y = P_! r + (1 - P_! y_n)$.
2DF extension with R_r reference and R_n disturbance filters: $y = R_r P_! r + (1 - R_n P_! y_n)$





$$Q = \frac{R_n}{\hat{P}_+}; \qquad C = \frac{R_n \hat{P}_+^{-1}}{1 - R_n \hat{P}_+^{-1} \hat{P}}$$

The filters also have a robustifying effect.

PID controller is a special case of YOULA parametrization, where $Q = \frac{C_{pid}}{1 + C_{pid} P}$

Controller design example

The plant: $P(s) = \frac{1}{(1+5s)(1+10s)} e^{-30s}$; $T_s = 5$; $P(z) = \frac{0.1548(z+0.6065)}{(z-0.3679)(z-0.6065)} z^{-6}$

PID controller designed for $\varphi_m = 60^\circ$: $C(z) = 0.3074 \frac{z-0.6065}{z-1} \frac{z-0.3679}{z}$

The Youla controller with $R_r = R_n = 1$:

Separation of the plant to P_+ and P_-:

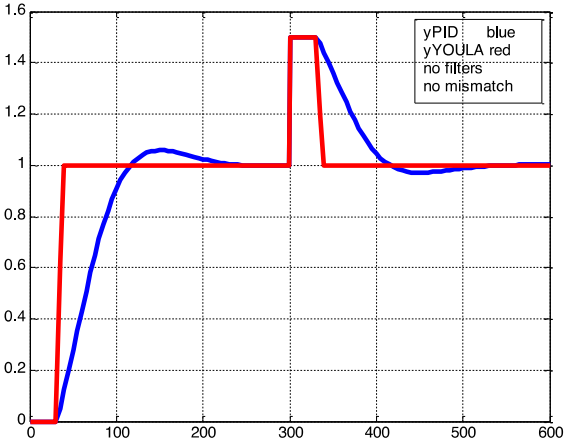
$$P_- = \frac{\left(1+0.6065 z^{-1}\right) z^{-1} \cdot z^{-6}}{1.6065}; \qquad P_+ = \frac{0.1548 \cdot 1.6065}{\left(1-0.3679 z^{-1}\right)\left(1-0.6065 z^{-1}\right)}$$

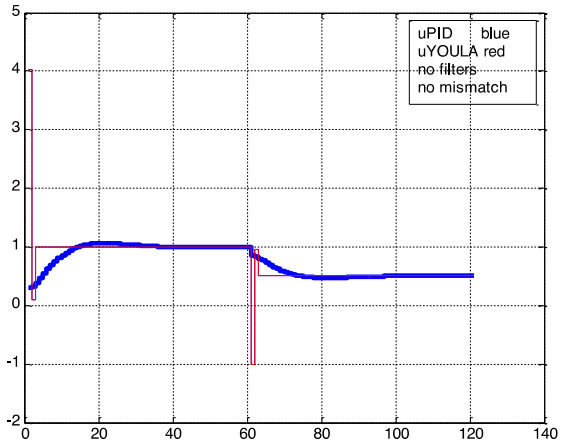
and $$Q = \frac{\left(1-0.3679 z^{-1}\right)\left(1-0.6065 z^{-1}\right)}{0.1548 \cdot 1.6065}$$

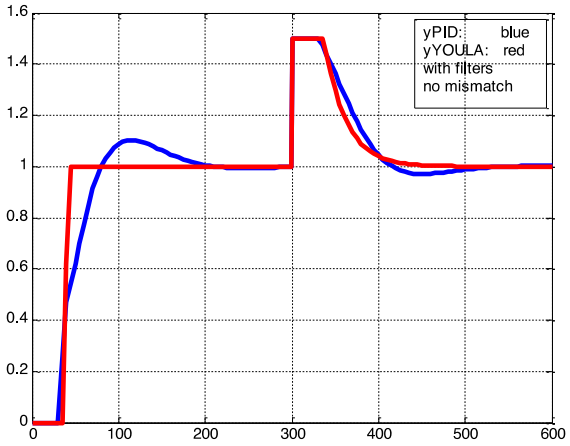
With $R_r = 1/(1+s)^2 \quad 0.9933/(z - 0.006738)$ and $R_n = 1/(1+25s)^2 \quad 0.1813/(z - 0.8187)$

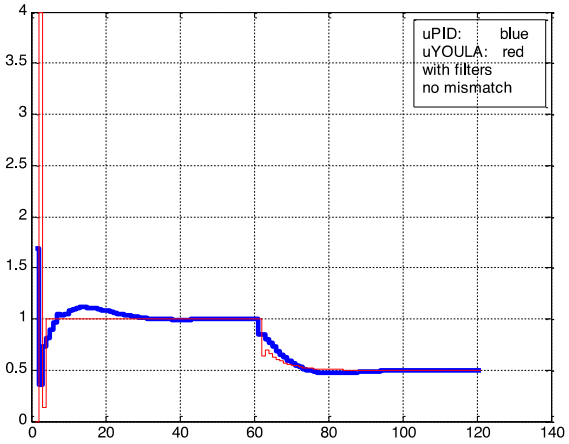
$$Q = \frac{0.729\left(1-0.3679 z^{-1}\right)\left(1-0.6065 z^{-1}\right) z^{-1}}{1-0.8187 z^{-1}}$$

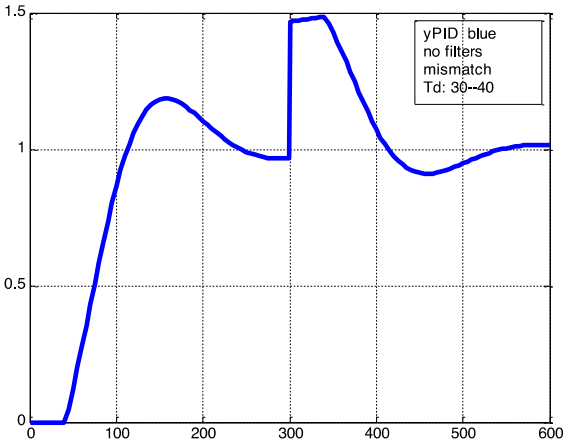
Simulation results (output and control signals: blue: PID, red: Youla)







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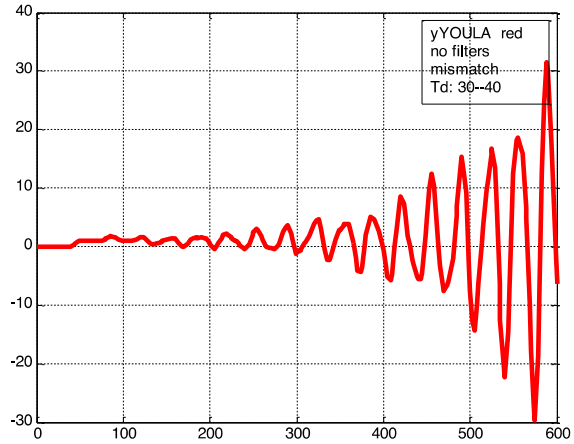
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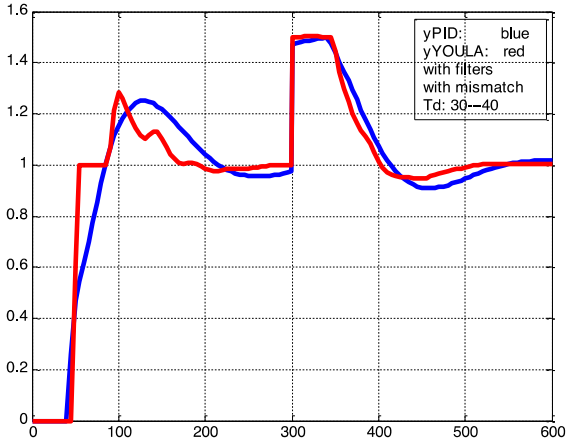
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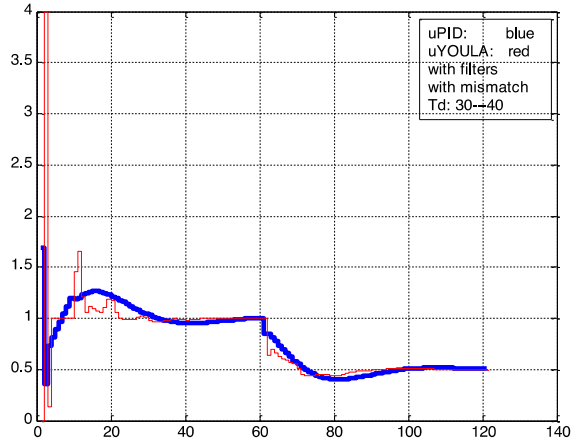
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Antonio Bicchi is Professor of System Theory and Robotics at the University of Pisa. He graduated at the University of Bologna in 1988 and was a postdoc scholar at M.I.T. A.I. Lab in 1988—1990.

His main research interests are in

* Dynamics, kinematics and control of complex mechanichal systems, including robots, autonomous vehicles, and automotive systems;

* Haptics and dextrous manipulation;

* Theory and control of nonlinear systems, in particular hybrid (logic/dynamic, symbol/signal) systems.

He is currently Editor of the Spinger Briefs series on Control, Automation, and Robotics (with T. Basar and M. Krstic) and served (2007-2010) as Editor in Chief for the Conference Editorial Board of IEEE Robotics and Automation Society, as Vice President for Member Activities, as Distinguished Lecturer and Advisory Committee member of IEEE Robotics and Automation Society. He was the founder and General Chair of the First WorldHaptics Conference (with M. Bergamasco), held in Pisa in March 2005, the vice Program Chair for IEEE International Conference on Robotics and Automation in 2001 and 2005, and served in several other capacities. I am an IEEE Fellow since 2005. A list of publications, summing up to more than 300 peer-reviewed papers, and a copy of the CV is available for reference at his web site.

He currently serves as the Director of the Interdepartmental Research Center ``E. Piaggio'' of the University of Pisa, and as Editor in Chief of the Conference Editorial Board for the IEEE Robotics and Automation Society (RAS). Antonio Bicchi is an IEEE Fellow since 2005. He has served as Vice President of IEEE RAS, Distinguished Lecturer, and editor for several scientific journals including Transactions on Robotics and Automation and Int.l J. Robotics Research. He has organized and co-chaired the first WorldHaptics Conference (2005) and Hybrid Systems: Computation and Control (2007).

Integrating Control Teaching at the European Level: The EECI-ICO Experience

European Embedded Control Institute & HYCON2

Main Instruments to Reach the Training Objectives:

- Organization of scientific events;
- Training;
- Grant and Awards Initiatives
- ICO-NEH

International Curriculum Option for Doctoral Studies Studies in Networked, Embedded, and Hybrid Control Systems for Complex, Distributed Heterogeneous Systems;

The International Curriculum Option for Complex, Distributed and Heterogeneous Embedded Systems (ICO)

- ICO is an inter-University convention initiative among 17 universities to provide a common cultural and academic substrate in the field by establishing a network of institutions that impose common supplementary criteria for the participating PhD students

- ICO has been established in 2006 in the framework of the Network of Excellence in Hybrid Control (HYCON), sponsored by the European Commission under grant IST-2004-511368. A permanent result of the project HYCON has been the creation of the European Embedded Control Institute (EECI). Since 2008 it has become an integral part of the activities of EECI.

ICO partners

Technische Universität Eindhoven , Institut National Polytechnique de Lorraine, Kungliga Tekniska Hoegskolan , Ruhr Universität Bochum,Universidad de Sevilla, Università de L'Aquila,Università di Siena, Université de Rennes 1, Université Paris-SUD 11, University of California, Berkeley, Universität Dortmund, University of Patras, University of Twente,Università di Pisa, Università di Cagliari, Universidad de Valladolid, Technische Universität Berlin.

ICO Activities 2006 - 2008

- The first cycle of ICO ended in 2008, with the 1st ICO student meeting in Pisa on October 7 – 9. The program included presentations and a poster session by students, and lectures by distinguished guests.

- During the three years 2006 – 2008 different activities were carried on in teaching and research. Every year, the HYCON-EECI Graduate School in Control was organized for ICO students.

- 30 students from 2006 to 2009. Up to now, 7 students graduated under the curriculum

The New Convention: International Curriculum Option for Doctoral Studies in Networked, Embedded and Hybrid Control Systems (ICO-NEH)

- In 2009, a new Convention was written and sent to all the partners for approval
- New partners were included in the Convention.
- The groups who confirmed to be ready to sign the ICO-NEH convention:

Università di Pisa, Università di Cagliari, University of Patras, Institut National Polytechnique de Lorraine, Université Paris-SUD 11, Ruhr Universität Bochum, Università de L'Aquila, Universidad de Sevilla, Universidad de Valladolid, Université de Rennes 1, Università di Pavia, DISC [including Delft University of Technology, Eindhoven University of Technology, University of Twente, CWI Amsterdam, University of Groningen], Universität Dortmund, University of Lund, Università di Milano, Technische Universität Berlin, Università di Trento.

- Operational from 2011-2012

Christos Cassandras

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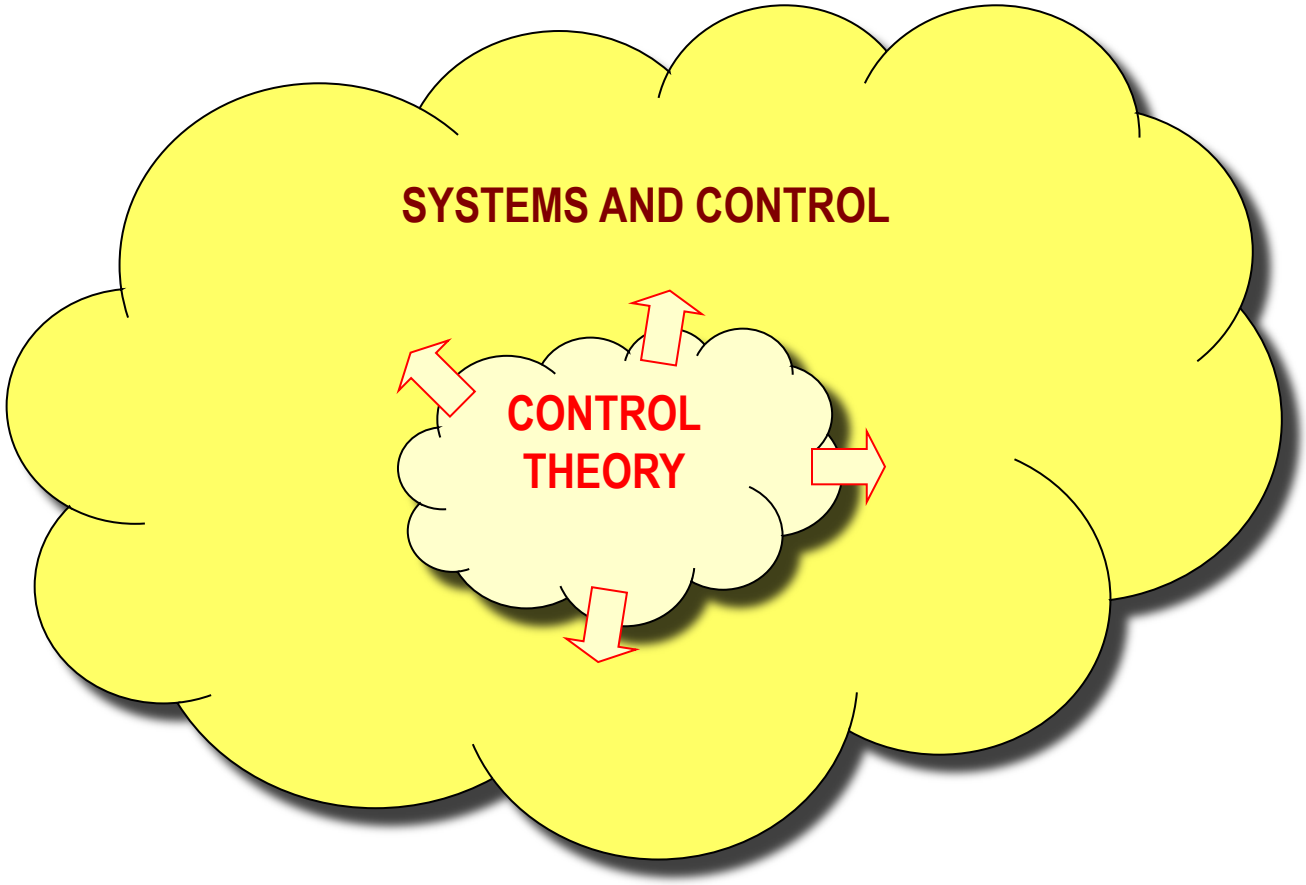
Christos G. Cassandras is Head of the Division of Systems Engineering and Professor of Electrical and Computer Engineering at Boston University. He is also co-founder of Boston University's Center for Information and Systems Engineering. He received degrees from Yale University, Stanford University, and Harvard University. In 1982-84 he was with ITP Boston, Inc. where he worked on the design of automated manufacturing systems. In 1984-1996 he was a faculty member at the Department of Electrical and Computer Engineering, University of Massachusetts/Amherst. He specializes in the areas of discrete event and hybrid systems, stochastic optimization, and computer simulation, with applications to computer and sensor networks, manufacturing systems, and transportation systems. He has published over 300 refereed papers in these areas, and five books. He has guest-edited several technical journal issues and serves on several journal Editorial Boards. He has recently collaborated with The MathWorks, Inc. in the development of the discrete event and hybrid system simulator SimEvents. He taught a course on automated manufacturing systems with hands-on experiments in the Automated Design and Manufacturing Systems Laboratory at Boston University, bringing together various aspects of control and optimization. Dr. Cassandras was Editor-in-Chief of the *IEEE Transactions on Automatic Control* from 1998 through 2009 and has also served as Editor for Technical Notes and Correspondence and Associate Editor. He is the 2011 President-Elect of the IEEE Control Systems Society (CSS) and has served as Vice President for Publications and on the Board of Governors of the CSS. He has chaired the CSS Technical Committee on Control Theory, and served as Chair of several conferences. He has been a plenary speaker at various international conferences and an IEEE Distinguished Lecturer. He is the recipient of several awards, including the Distinguished Member Award of the IEEE Control Systems Society (2006), the 1999 Harold Chestnut Prize (IFAC Best Control Engineering Textbook) for *Discrete Event Systems: Modeling and Performance Analysis*, and a 1991 Lilly Fellowship. He is a member of Phi Beta Kappa and Tau Beta Pi. He is also a Fellow of the IEEE and a Fellow of the IFAC.

BROADEN THE FIELD → SYSTEMS AND CONTROL

Broaden our perspective of CONTROL THEORY to a SYSTEMS AND CONTROL THEORY:

not only control a system, but build systems to be controlled



BROADEN THE FIELD → SYSTEMS AND CONTROL

- Teach and educate a new generation of "system scientists" and "systems engineers" – not just "control engineers"

- Message to students:
  - learn mathematical models for understanding and designing systems
  - control physical and man-made systems
  - measure performance of system, improve it, seek to make it optimal

- We already do this anyway, using a control theorist's unique understanding of concepts such as "dynamics" and "feedback"

- Look at *all* aspects of modern technology as opportunities to design and control increasingly complex dynamic systems

  $\Rightarrow$ design courses and laboratories that reflect this viewpoint

  $\Rightarrow$ teach system modeling beyond

$$\dot{x} = Ax + Bu$$

Sebastián Dormido

School of Engineering
National University of Distance Education

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Sebastián Dormido was born in Jerez de la Frontera, Spain in 1946. He received his BSc and M. S. degree in Physics from the Universidad Complutense de Madrid in 1968 and 1969 and a PhD in Science from the Universidad del Pais Vasco in 1971. From 1968 to 1975 he was successively Assistant and Associate Professor at the Department of Computer Science and Automatic Control of the Universidad Complutense and Universidad del Pais Vasco. Since 1975 he has been Full Professor at the Facultad de Ciencias Físicas of the Universidad Complutense de Madrid (1975-1982) and Escuela Técnica Superior de Ingeniería Informática at Universidad Nacional de Educación a Distancia – UNED- (1982-). In 1982 he was appointed Head of Department of Computer Science and Automatic Control. Further he has served as Vicerrector of Research (1983-1985) in the UNED.

His main fields of interest are: Computer Control Process, Model Based Predictive Control, Robust Control, Modelling and Simulation of Continuous Processes and Control Education with special emphasis on remotes and virtual labs. He has authored and co-authored over 250 technical papers in international journals and conferences and has supervised 35 Ph.D. students.

From 2001-2006 has been President of the Spanish Association of Automatic Control, CEA-IFAC where he promoted the relation between the academic and industrial world. Along his academic career he has been invited to give invited lectures worldwide. He has been a plenary speaker at various international conferences. At the present time 5 of his PhD. students are full professors and 15 are associate professors. He has supervised more than thirty competitive financed research national and international projects and contracts with companies in the area of automatic control in order to make transfer of the technology developed in his research group to the industrial sector. In 2007 received a Doctor Honorary Degree from Universidad de Huelva and in 2008 the National Automatic Control prize from Spanish Automatic Control Committee (CEA).

- *Control systems engineering has a "trademark" problem*
- *Control engineers as "systems integrator" in large and complex engineering projects*
- *The "tradeoff" between theory, applications and computation in control engineering education*
- *"New audience" needs control education*

Alexander Fradkov

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Alexander Fradkov graduated from St.Petersburg State University under supervision of Prof. V.A. Yakubovich. He is an IEEE Fellow, President of the International Physics and Control Society. He is coauthor of more than 500 journals and conference papers, 16 books and textbooks, including the books:

- Cybernetical physics: from control of chaos to quantum control. Springer, 2007.
- Introduction to Control of Oscillations and Chaos. World Scientific, 1998. (with Pogromsky A.Yu)
- Nonlinear and Adaptive Control of Complex Systems. Kluwer, 1999 (with Miroshnik I.V., Nikiforov V.O.).
- Selected Chapters of Automatic Control. Nauka, 1999 (with Andrievsky B.R., in Russian)

Prof. Fradkov has organized and co-chaired many international conferences in St.Petersburg, including 13 International Baltic Student Olympiads on Automatic Control in 1991–2010 (next one will take place on Sept 21-23, 2011), and a number of olympiads on cybernetics for high school students. He is IPC co-chair of the next IFAC Symposium on Control Education in Nizhnii Novgorod, Russia on June 20-22, 2012.

The creator of RUSYCON - Russian Systems and Control Archive –bilingual web resource containing more than 2000 references to useful sources related to systems and control in Russia and worldwide, including links to general references and databases in systems and control, information and educational sites, virtual laboratories and online experiments, sites on nonlinear dynamics, complexity and chaos, etc.

Since 1990 he has been the Head of the "Control of Complex Systems" Lab of the Institute of Problems in Mechanical Engineering of Russian Academy of Sciences. He is also a part-time Professor with the Faculty of Mathematics and Mechanics, Saint Petersburg State University and with National Research University of Information Technologies, Mechanics and Optics.

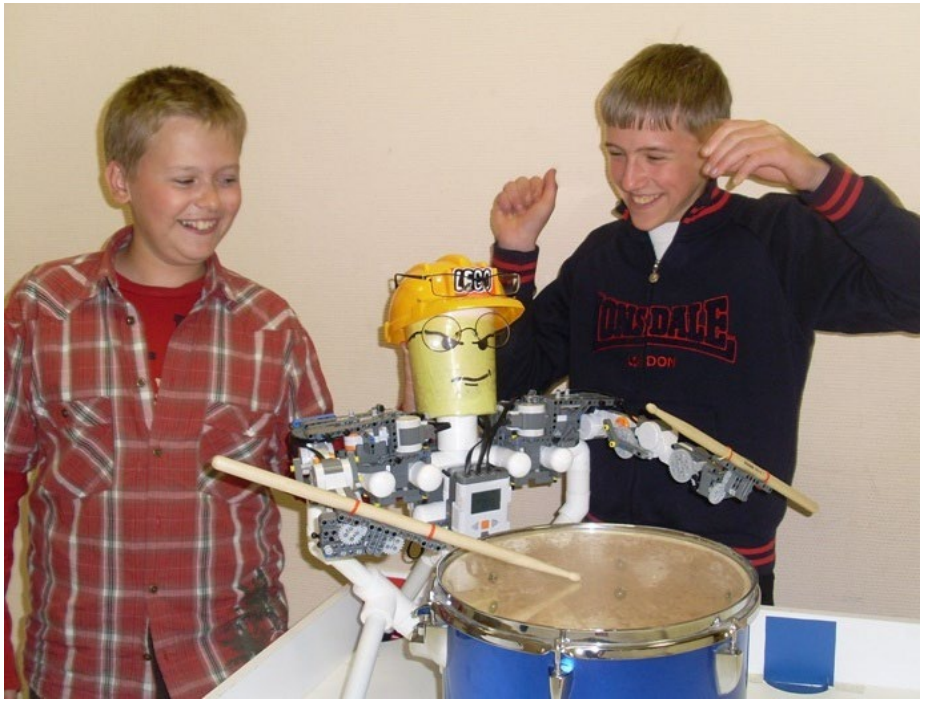
LEGO Robotics joins University and High School, Research and Control Education

LEGO Mindstorms NXT –new generation cybernetic set including:
-Microcomputer NXT-brick enabling communication via USB, Bluetooth with PC, video-camera, mobile phone, other bricks;
- Rich set of sensors: Touch, Sound, Light, Sonar, Gyro, Termo, etc
- Servomotors with encoders;
- Controlled either from a personal computer or autonomously;
- Programmed in C, Java, LabView or MATLAB based environments

Lego-robotics gains tremendous interest among children from 10 to 14 years old

It makes possible:

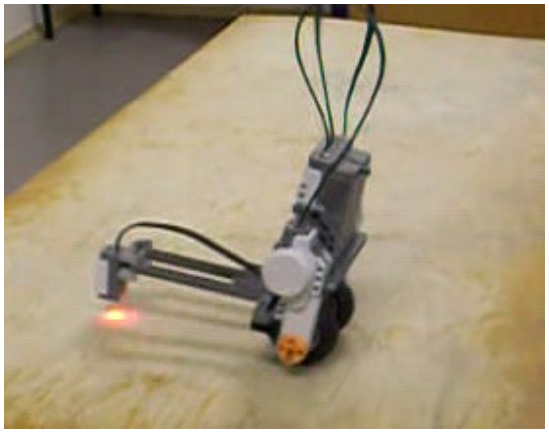
- To motivate students to pursue study of robotics using new knowledge in mathematics, physics, programming
- To enrich the school introductory course of informatics and cybernetics
- To start a continuous learning process «School - University» to enable the training of future professionals



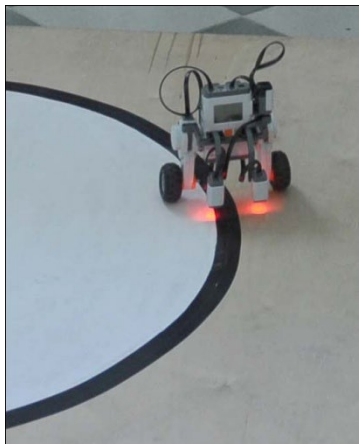
Proposed solution: Joint (IPME-SPbSU-FML#239) university-lyceum laboratory

Cyber-Physical Laboratory: PROJECTS

Cart-pendulum



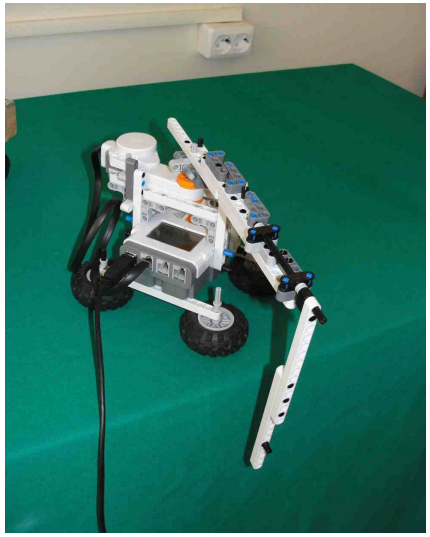
Unstable plant (segway)



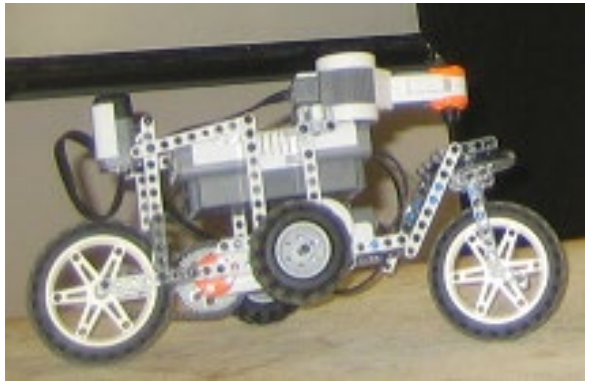
MIMO segways (tuning two PIDs)

Students teach children

Kapitsa pendulum



Furuta pendulum



Adaptive bike (algorithm: Yakubovich, IFAC WC 1972)

OUTCOME

- Increase of interest of school and university students in mechatronics, robotics
- Growth of laboratory base and upgrade
- Introduction of theoretical results into teaching

Demo at IEEE MSC2009 (CSM, Apr. 2010)
(Andrey Pyatygin: lyceum student in 2009, university student in 2011).

Paper Invariance and Trajectory Steering Problem for an Autonomous Wheeled Robot by Yakubovich, Proskurnikov, Luchin, Melnikov accepted at CDC 2011

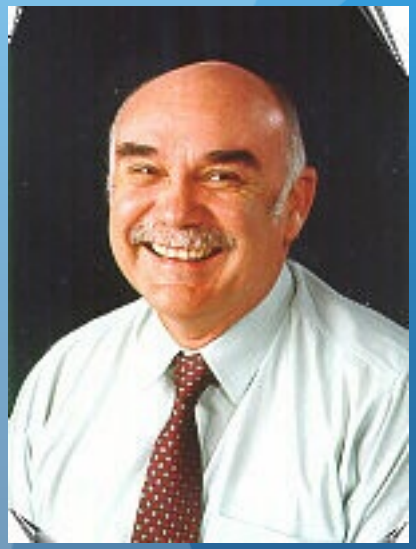
IFAC WC 2011: Invited session "Using LEGO Mindstorms NXT in Control Education "
(Organizers: Marco Casini, U of Siena, Italy; Alexander Fradkov, RAS, Russia)

CHALLENGE:

How to teach control to high school and 1st year students?

Graham Goodwin

Electrical Engineering and
Computer Science
University of Newcastle



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www.eng.newcastle.edu.au/~gcg441/goodwin.html

Graham Goodwin obtained a B.Sc (Physics), B.E (Electrical Engineering), and Ph.D from the University of New South Wales. He is currently Professor Laureate of Electrical Engineering at the University of Newcastle, Australia and is Director of The University of Newcastle Priority Research Centre for Complex Dynamic Systems and Control. He holds Honorary Doctorates from Lund Institute of Technology, Sweden and the Technion Israel. He is the co-author of eight books, four edited books, and many technical papers. Graham is the recipient of Control Systems Society 1999 Hendrik Bode Lecture Prize, a Best Paper award by IEEE Transactions on Automatic Control, a Best Paper award by Asian Journal of Control, and 2 Best Engineering Text Book awards from the International Federation of Automatic Control in 1984 and 2005. In 2008 he received the Quazza Medal from the International Federation of Automatic Control and in 2010 he received the IEEE Control Systems Award. He is a Fellow of IEEE; an Honorary Fellow of Institute of Engineers, Australia; a Fellow of the International Federation of Automatic Control, a Fellow of the Australian Academy of Science; a Fellow of the Australian Academy of Technology, Science and Engineering; a Member of the International Statistical Institute; a Fellow of the Royal Society, London and a Foreign Member of the Royal Swedish Academy of Sciences.

Vladimir Havlena

Honeywell Laboratory Prague
Department of Automatic Control
Czech Technical University

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Professor Vladimir Havlena is a Senior Fellow in Honeywell Prague Laboratory (HPL) and full Professor at the Czech Technical University of Prague.

In HPL, Dr. Havlena is a technical lead of the Process Control and Optimization group. His team developed e.g. a novel advanced process control application for power generation plants or predictive control solution for supercharged diesel engine. This work included theoretical contributions extending the MPC functionality, development of software prototype and engineering tools, and pilot applications. He holds several awards for innovation in the process control area.

At the Czech Technical University, professor Havlena is lecturing ‘Estimation, Filtering and Detection” in MSc course, and supervising several PhD students. He is an author of two textbooks “Modern Control Theory” and “Estimation and Filtering”.

Personal statement (i)

Honeywell

Experience in both academic and industrial research

Professor at the Czech Technical University

- lecturing "Estimation, Filtering and Detection"
- supervising PhD students
- projects funded by the Czech National Science Foundation, Technology Agency of CR and EU

Honeywell Senior Fellow

- technical lead of the Process Control and Optimization group in HPL
- working on APC/RTO since mid 90's
  - 15 years ago, MPC used in chemical industries or refineries
    - typical sampling period several minutes
  - AES solution - application of MPC technology in power industry
    - boilers and turbines requiring reaction within seconds
  - current projects - control of diesel engines for big trucks & exhaust gas after treatment
    - sampling rate of tens of milliseconds

Personal statement (ii)

Honeywell

Gap between theory and practice

- no real conflict there
- practical problems demonstrate the limits of "text book" assumptions
  - motivation to align the assumptions with reality and generalize the theory
  - further rigorous research or ad hoc tinkering ?
    - depends on one's personal preference
    - maybe also on the quality of engineering education ?

Control engineering education

- difficult to maintain the quality
  - mathematics, physics, etc. suppressed within the transformation of 5 year engineering programs into bachelor + master programs (3+2 years)
  - fundamental subjects were significantly reduced within the bachelor study without being adequately replaced within the master study

Interesting and highly innovative industrial projects

- connected with deep understanding of the problem in terms of the underlying first principles
- students interested in real applications should definitely not omit thorough study of the subjects covering these basic principles

Stephen Kahne
Embry-Riddle-Aeronautical University

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Dr. Stephen Kahne is Professor Emeritus of Embry-Riddle Aeronautical University in Arizona where he also served as Chancellor. He was formerly President of IFAC, Vice President of the IEEE, President of the IEEE Control Systems Society, and Editor-in-Chief of the IEEE Transaction on Automatic Control. He has held top leadership positions in several universities and companies in the US and is a Fellow of IFAC, IEEE, and AAAS.

When I think about control engineering education in the 21st century I must consider it based on what I lived through in the last half of the 20th century and the first decade of the 21st century. My PhD was awarded in 1963 and my teaching career extended over the period 1958 to 2009.

In my country, engineers have tended to be viewed as “workers” who are employed for rather specific technical tasks and have found that their tenure in their positions are more determined by the current project work available in the company than by the needs of the company going forward.

I attribute much of this to a failure of engineering students and engineering faculty to appreciate the importance of how to communicate in addition to how to design.

I fear that in the United States we have failed to advance the notion that in addition to being a competent technical designer it is necessary to also understand how to reach audiences of one's work.

In college, faculty members have accepted laboratory reports which may have contained adequate technical analysis but entirely opaque description of the purpose of the exercise and meaning of the results.

Industry recruiters often comment on this weakness as they hire team members for team projects. I am hopeful that more emphasis will be devoted to communication skill development in the future.

Lennart Ljung

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Linköpings Universitet

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Professor Lennart Ljung received his Ph.D. in 1974 in Automatic Control from Lund Institute of Technology. He has been Professor of the chair of Automatic Control in Linköping since 1976. He is also the director of the SSF Strategic Research Center MOVIII.

His research centers mostly around modelling and system identification. He has published ten books including undergraduate textbooks: Automatic Control (Reglerteknik, in Swedish), Signal Processing (Studentlitteratur), Control Theory (Taylor and Francis), Modeling of Dynamic Systems (Prentice-Hall), Exercise books (Studentlitteratur).

He developed courses in Signal Processing, Modeling and Simulation and Control Theory. Participated in the development of a major undergraduate control lab in Linköping. Automatic Control in Linköping received in 2007 one of 5 nation- and university-wide awards as "excellent education environment".

Prof. Ljung has received awards from IEEE Control Systems Society, IFAC, AUTOMATICA, the Royal Swedish Academy of Sciences and The Institute of Engineers, Australia. He has served as editor of several journals and is currently Associate Editor at Large for the European Journal of Control.

Issues in Control Education

- In Linköping, lab/project work is a very essential part of our education
- Our ”Labotek” has about 16000 student hour visits per year (”labotek” = laboratory/library with both scheduled and free work)
- The lab work in important to show the value of Mathematics.
- The Project course, as well as the study profiles have clear links to our major cross-disciplinary research programs.

Jan Maciejowski

Department of Engineering
University of Cambridge

jmm@eng.cam.ac.uk

www-control.eng.cam.ac/Homepage/officialweb.php?id=1

Jan Maciejowski is a Professor of Control Engineering in the Department of Engineering at the University of Cambridge, England. He is Head of the Information Engineering Division, and a member of the Control Group. He is also the President and a Fellow of Pembroke College, Cambridge. He is a member of the IETs Sector Panel for Innovation and Emerging Technologies. He was the President of the European Union Control Association from 2003 to 2005, and was President of the Institute of Measurement and Control for 2002. He is a Chartered Engineer and a Fellow of the Institution of Engineering and Technology (IET), the Institute of Electrical and Electronic Engineers (IEEE), and the Institute of Measurement and Control (InstMC). He was a Distinguished Lecturer of the IEEE Control Systems Society from 2001 to 2007.

Prof. Maciejowski graduated from Sussex University in 1971 with a B.Sc degree in Automatic Control, and from Cambridge University in 1978 with a Ph.D degree in Control Engineering. From 1971 to 1974 he was a Systems Engineer with Marconi Space and Defence Systems Ltd, working mostly on attitude control of spacecraft and high-altitude balloon platforms.

Educating Control Engineers

Jan Maciejowski

Mathematics

- Is it needed? YES!
- Mathematics and abstraction is the essence of the discipline.
- Control PhD's get jobs easily – maybe not as control engineers,

  but as people who can think abstractly.
- Is it all that is needed? NO!

Remember the real problem

- So you can do linear algebra, manipulate block diagrams, prove the KPY Lemma, write beautiful Matlab code, but …
- Why do we use feedback?
- Can you explain it to your Mum?
- Why does noise matter? Where does it come from?

Try the real thing

- School, BSc, MSc, PhD, …

  Are you running on ‘automatic’?

- How about working as a control engineer?

  You might like it! You might be very good at it—but not at research.

- Start your PhD with your own problems and ideas.

Iven Mareels

Biomedical Engineering
University of Melbourne

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www.bme.unimelb.edu.au

Professor Iven Mareels obtained the (ir) Masters of Electromechanical Engineering from Gent University Belgium in 1982 and the PhD in Systems Engineering from the Australian National University, Canberra, Australia in 1987. Since 1996, he is a Professor of Electrical and Electronic Engineering in the Department of Electrical and Electronic Engineering, the University of Melbourne. In June 2007, he became Dean of the Melbourne School of Engineering.

Prof Mareels has received several awards in recognition of his research and teaching. He was a recipient of a 2008 Clunies Ross Award, Academy of Technological Sciences and Engineering for his work on Smart Irrigation Systems. In 2007 he received the inaugural Vice-Chancellor's Knowledge Transfer Excellence award from the University of Melbourne. In 2005, he was named IEEE CSS Distinguished Lecturer, and in 1994 received the Vice-Chancellor's Award for Excellence in Teaching from the Australian National University. He was a co-editor in chief of Systems& Control Letters till December 2007. He has received several awards for his publications. He is Fellow of the Academy of Technological Sciences and Engineering, Australia, a Fellow of the Institute of Electrical and Electronics Engineers (USA), a member of the Society for Industrial and Applied Mathematics, a Fellow of the Institute of Engineers Australia, Vice-Chair and founding member of the Asian Control Association, and a member of the organizing committee for the Asian Control Conference and for the Mathematical Theory in Networks and Systems conference. Over the period Jan 2003-Dec 2005 he was a member of the Board of Governors of the Control Systems Society IEEE. He is Chair of the National Committee for Automation, Control and Instrumentation and is now Chair of the Technical Board of the International Federation of Automatic Control (and ex-officio Vice-President) for the triennium 2008-2011.

Roberto Tempo

IEIT-National Research Council
Politecnico de Torino

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Roberto Tempo graduated in Electrical Engineering at Politecnico di Torino, Italy, in 1980. After a period spent at the Dipartimento di Automatica e Informatica, Politecnico di Torino, he joined the National Research Council of Italy (CNR) at the research institute IEIIT, Torino, where he is a Director of Research of Systems and Computer Engineering since 1991. He has held visiting and research positions at Kyoto University, The University of Tokyo, University of Illinois at Urbana-Champaign, German Aerospace Research Organization in Oberpfaffenhofen and Columbia University in New York.

Dr. Tempo is author or co-author of more than 170 research papers published in international journals, books and conferences. He co-authored the book "Randomized Algorithms for Analysis and Control of Uncertain Systems," Springer-Verlag, London, 2005. He is a recipient of the "Outstanding Paper Prize Award" from the International Federation of Automatic Control (IFAC) for a paper published in Automatica, and of the "Distinguished Member Award" from the IEEE Control Systems Society. He is a Fellow of the IEEE and a Fellow of the IFAC.

He is currently an Editor and Deputy Editor-in-Chief of Automatica, and an Editor-at-Large of the Asian Journal of Control. He has been Editor for Technical Notes and Correspondence of the IEEE Transactions on Automatic Control in 2005-2009. In 2010 he served the IEEE Control Systems Society as President and, during the period 2002-2003, as Vice-President for Conference Activities. He was Program Chair of the first joint IEEE Conference on Decision and Control and European Control Conference, which was held in Seville, Spain, in 2005.

Dr. Tempo's research activities are mainly focused on the study of complex systems with un- certainty. He has been involved in various research projects focused on the design of Unmanned Aerial Vehicles (UAVs) for environmental monitoring, fire detection and prevention, and also natural disaster recognition, see http://staff.polito.it/roberto.tempo/uav.html. He is currently working on the development of tools and algorithms for the computation of PageRank, which is the ranking system used at Google for efficiently listing the search results, see http://staff.polito.it/roberto.tempo/pagerank.htm.

On these topics he has given several invited lectures at various conferences and workshops, including the recent plenary lectures at the Chinese Control and Decision Conference, Mianyang, China and at the 5th International ICST Conference on Performance Evaluation Methodologies and Tools, Paris, France, both held during Spring 2011.

IEIIT-CNR

Control Design of Unmanned Aerial Vehicles (UAVs)

Roberto Tempo

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IEIIT-CNR

UAVs for Fire Prevention and Natural Disaster Recognition

- Activity supported by the Italian Ministry for Research within a National Project
- Objective: Research and educational
- Research groups in *control*, aerospace, communication, computer engineering and government agency for fire surveillance and patrol located in Sicily
- Task: Construct aerial platform for remote piloting and autonomous flight
- Various sensors and two cameras (color and infrared)
- Speed: 10-17 m/s, flight endurance of 40 min

IEIIT-CNR

MH1000 Platform

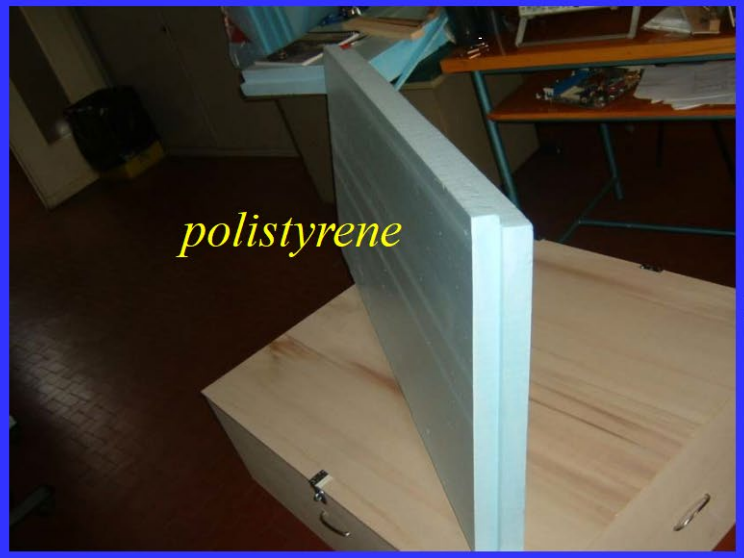
- MH1000
  - Wingspan:1 m; weight: 1.5 Kg
- Ground station
  - Communication protocols/software

Platform based on the MicroHawk configuration developed at Department of Aerospace Engineering, Politecnico di Torino

IEIIT-CNR

Prototype Manufacturing Performed by Students - 1

raw material



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Prototype Manufacturing Performed by Students - 2

working instruments

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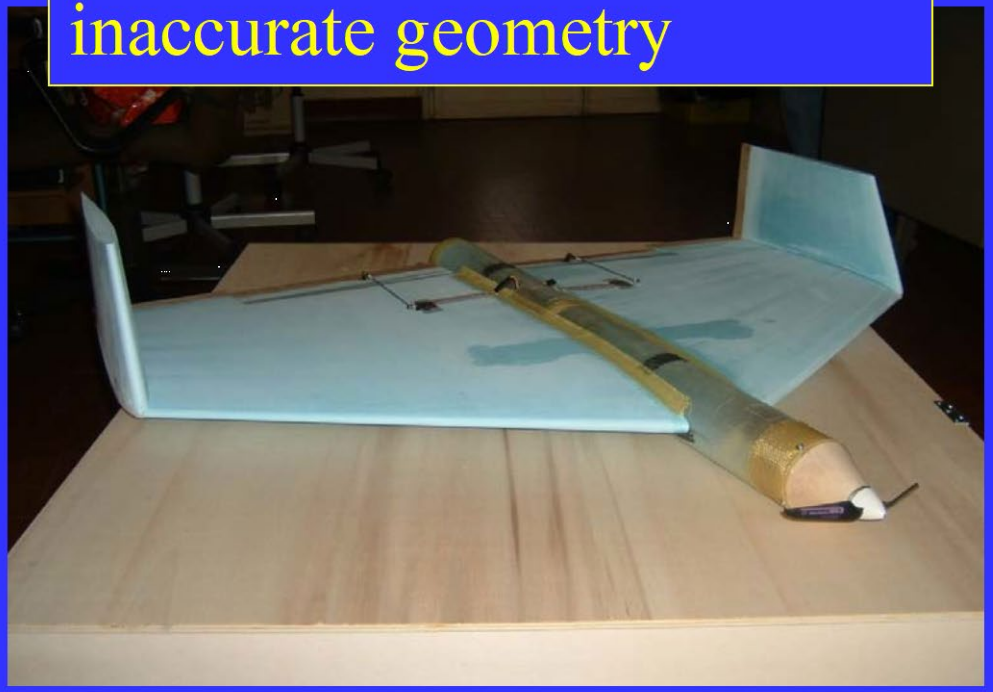
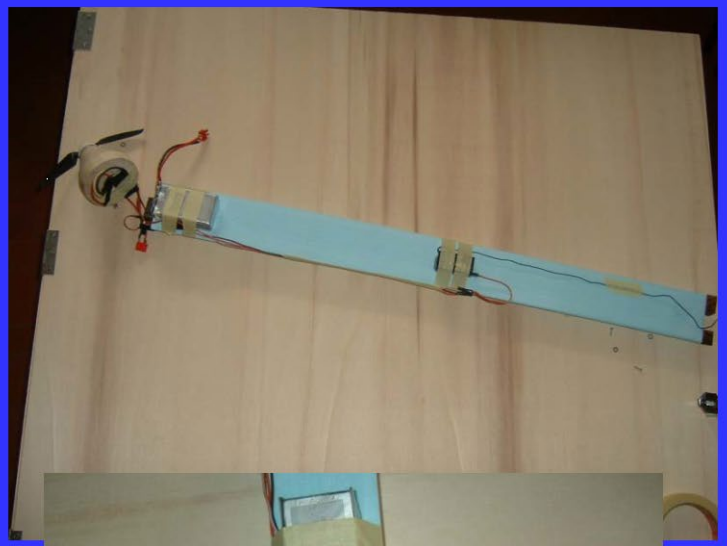
Prototype Manufacturing Performed by Students - 3

easy and cheap construction
rapid manufacturing
bad model reproducibility
inaccurate geometry





IEIIT-CNR

Right Turn and Landing

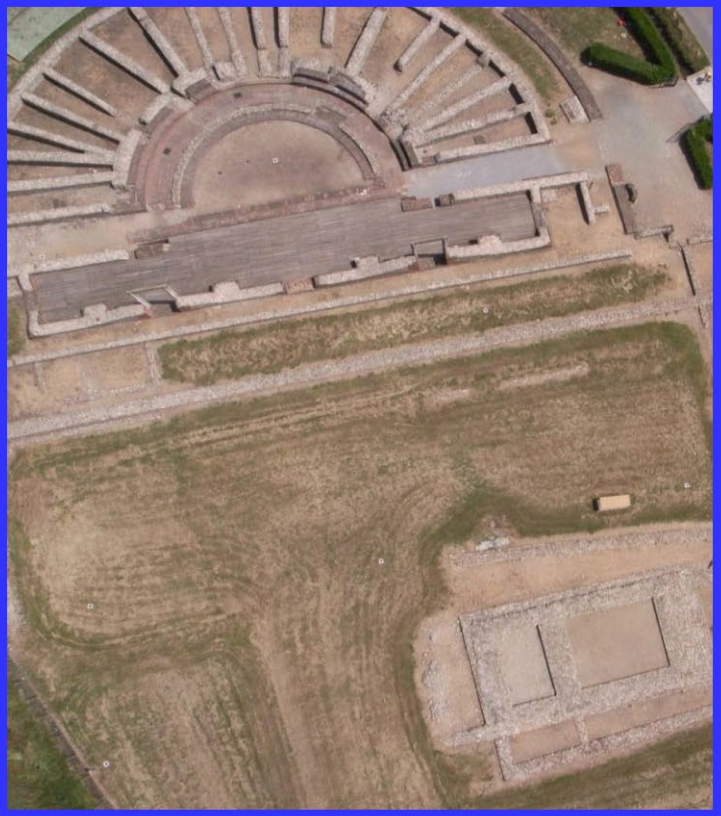
L. Lorefice, B. Pralio and R. Tempo, "Randomization-Based Control Design for Mini-UAVs," Control Engineering Practice, 2009

IEIIT-CNR

MH2000: Monitoring Archaeological Sites

- Archaeological site: Roman city

  Bene Vagienna (*Augusta Bagiennorum*)



IEIIT-CNR

MH2000: Monitoring Archaeological Sites

Archaelogical Site Monitoring, F. Quagliotti and ITHACA (2008)

Ljubo Vlacic

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Griffith University

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Professor Ljubo Vlacic is a member of Griffith University's School of Engineering and Director of its Intelligent Control Systems Laboratory. His career has included a number of positions with both industry and academia. This experience includes the design, development, field-testing and deployment of a variety of sophisticated electronic devices for industrial control applications as well as senior management positions such as, Technical Director, Project Director, Program Director and Head of School.

He is a Fellow of the Institution of Engineers, Australia (FIEAust), a Fellow of the Institution of Engineering and Technology, formerly IEE (FIET), a Senior Member of the Institute of Electrical and Electronic Engineers, U.S.A. (SMIEEE), a Chartered Professional Engineer of Australia (CPEng), a Registered Professional Engineer of Queensland(RPEQ) and a Chartered Engineer, the Engineering Council UK (CEng).

He has been named 2003 Queensland Engineer of the Year in recognition of his work in the development and prototyping of the ICSL Cooperative Autonomous Driving Technology, and the world's first demonstration of intersection traversal and cooperative overtaking maneuvers by autonomous vehicles capable of transporting human passengers.

He established the IEEE-Control Systems/Robotics and Automation Joint Societies Chapter in Queensland in 1999. The Chapter has been awarded the 2004 Chapter of the Year Award by the IEEE-Robotics and Automation Society and the 2004 IEEE - Control Systems Society Outstanding Chapter of the Year Award by IEEE-Control Systems Society.

He graduated from the University of Sarajevo in 1973 (Control) and completed his MPhil and PhD studies in Control in 1976 and 1986 respectively.

Proposition

In an effort to make the discipline of control more attractive to students we often introduce this subject as an enabling technology in the context of embedded electronic systems, intelligent robots, mechatronic systems, advanced communication systems, space technology, etc.

While this approach works well in promoting the field of control and attracting students to the discipline, it however raises numerous questions such as:

Proposition

- are we going to fall into the trap of being technology driven and thus, in the long term, start losing analytical problem solving skills?
- do we need to worry about these changes or, maybe, even strongly support them?
- more and more students want to access innovative courses, on line preferably; do we need an on-line control course too, including on-line tutorials and on-line labs? If so, how should its content be addressed?