Curriculum Vitae of
ALESSANDRO DE LUCA

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Prof. Alessandro DE LUCA

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ISI-WoK ResearcherID: F-3835-2011

Biosketch

Alessandro De Luca was born in Roma, Italy, on October 11, 1957. He received the *Laurea* degree in Electronic Engineering and the PhD in Systems Engineering from the University of Rome "La Sapienza" in 1982 and 1987, respectively. Since 2000, he is a Full Professor of Robotics, Automation, and Automatic Control at the Sapienza University of Rome. From September 2005 to April 2006, he spent a sabbatical at the Institute for Robotics and Mechatronics at DLR in Oberpfaffenhofen, Germany. Since 2013, he is the Director of the Master of Science in Control Engineering, a new Sapienza program fully taught in English.

His research interests include modeling, motion planning, and control of flexible manipulators, kinematically redundant manipulators, underactuated robots, wheeled mobile robots and mobile manipulators; physical human-robot interaction; hybrid force-velocity control; visual servoing; iterative learning; nonlinear control of nonholonomic mechanical systems; fault detection and isolation; control of locomotion platforms. He has published over 200 journal and conference papers and book chapters, receiving two best conference paper awards (ICRA 1998, BioRob 2012) and one best application paper award (IROS 2008). He is one of the authors of the PROSE-awarded *Springer Handbook of Robotics* (2008, 2016), and Editor of the book *Advances in Control of Articulated and Mobile Robots* (Springer, 2004).

For the *IEEE Transactions on Robotics and Automation*, he served as an Associate Editor (1994–98), an Editor (1998–2003), and the Editor-in-Chief (2003–04). He has been the Editor-in-Chief of the renamed *IEEE Transactions on Robotics* from its birth in 2004 until September 2008. He has been a member of the *IEEE Robotics and Automation Society (RAS)* AdCom (2008–10) and has served as RAS Vice-President for Publication Activities in 2012–13. He was General Chair of the *2007 IEEE International Conference on Robotics and Automation* held in Rome and Program Chair of the *2016 IEEE International Conference on Robotics and Automation* in Stockholm.

He is an *IEEE Fellow* (class of 2007). He received the German *Helmholtz Humboldt Research Award* for foreign scientists in 2005, and the *IEEE-RAS Distinguished Service Award* in 2009.

Between 2006 and 2012, he has been a member of the Search Committee for Physical Sciences (former Technical Sciences) of the *Körber European Science Award*, granted by the Körber Foundation. He was Chair of Panel PE7 (Systems and Communication Engineering) of the *European Research Council* for Advanced Grants evaluation in 2009, 2011, and 2013, and a member of the Scientific Advisory Board of the *Max Planck Institute for Biological Cybernetics* (from 2015 to 2017).

With the DIAG Robotics group, he has been principal investigator in five European research projects (*PROMotion*, *PHRIDOM*, FP6 *CyberWalk*, FP6 *PHRIENDS*, H2020 *SYMPLEXITY*) and in many national projects, and participates to H2020 *COMANOID*). He was national coordinator of the MIUR PRIN project *SICURA* (2008-10) and european coordinator of the FP7 project *SAPHARI* (2011-15).

Education

Jul. 1987 *Research Doctorate* degree in Systems Engineering from the University of Rome "La Sapienza"

Feb. 1984 *Master* degree in Control Systems Engineering from the University of Rome "La Sapienza"

Nov. 1983 *Professional Engineer* certificate

Mar. 1982 *Laurea* degree in Electronic Engineering *magna cum laude* from the University of Rome "La Sapienza"

University Employment

2000–pres. *Full Professor* of Robotics, Automation, and Automatic Control at the School of Information Engineering, Informatics, and Statistics of the Sapienza University of Rome, Department of Computer, Control, and Management Engineering (DIAG, former DIS until 2011); tenured since Nov. 2003

1993–2000 *Associate Professor* of Automatic Control and Industrial Robotics at the Faculty of Engineering of the University of Rome "La Sapienza", Department of Computer and Systems Science; tenured since Nov. 1995

1992–1993 *Associate Professor* of Automatic Control at the Faculty of Sciences of the University of Milano, Department of Information Sciences

1988–1992 *Researcher* in Automatic Control at the Faculty of Engineering of the University of Rome "La Sapienza", Department of Computer and Systems Science; tenured after three years

Visits

Sep. 2005–Apr. 2006 *Visiting Researcher* at the Institute for Robotics and Mechatronics of DLR in Oberpfaffenhofen, Germany, under the support of a *Helmholtz Humboldt Research Award* for foreign scientists

Nov. 1989 *Visiting Researcher* at the CINVESTAV, Mexico City, Mexico

Sep. 1985–May 1986 *Visiting Scholar* at the Robotics and Automation Lab of the Rensselaer Polytechnic Institute, Troy, NY

Academic Committees

Local

2013–pres. Director of the Master Degree in Control Engineering of Sapienza University of Rome

2013–pres. Research Doctorate Committee in Automatic Control, Bioengineering, and Operations Research of Sapienza University of Rome

2010–pres. Scientific responsible for the Exchange Agreement between the School of Information Engineering, Informatics, and Statistics of Sapienza University of Rome and the Graduate School of Engineering of the Tohoku University in Sendai

2010–2012 Member of the panel of experts for the evaluation of the quality of research activities of the University of Rome "La Sapienza" (VQR 2004–2010)

2002–2006 ERASMUS Committee for student mobility within the European Union, School of Engineering, University of Rome "La Sapienza"

1994–2012 Research Doctorate Committee in Systems Engineering, University of Rome "La Sapienza"

1995–1996 Professional Engineering Qualification Committee, University of Rome "La Sapienza"

1990–1991 Executive Committee of the Department of Computer and Systems Science, University of Rome "La Sapienza"

National

Oct. 2016 Committee for Evaluation of Full Professor in Automatic Control, University of Naples Federico II

Nov. 2014 Committee for Evaluation of Full Professor in Automatic Control, Politecnico of Turin

Jun. 2014 Committee for Evaluation of Associate Professor in Automatic Control, University of Bologna

Jun. 2011 Committee for Doctorate Degree in Automation, Robotics, and Bioengineering, University of Pisa

Dec. 2010 Committee for Doctorate Degree in Computer and Systems Engineering, University of Napoli Federico II

Sep. 2010 Committee for Promotion to Associate Professor in Automatic Control, University of Lecce

Oct. 2006 Committee for Promotion to Full Professor in Automatic Control, Politecnico of Milan

Nov. 2004 Committee for Doctorate Degree in Computer Science and Automation, University of Roma Tre

May 2000 Committee for Promotion to Researcher in Automatic Control, University of Roma "Tor Vergata"

Nov. 1999 Committee for Doctorate Degree in Electronic and Computer Engineering, University of Napoli Federico II

Abroad

Feb. 2017 *Doctor of Philosophy, University of British Columbia*, Vancouver, Canada; Joonyoung Kim, "Path-Invariant and Time-Optimal Motion Control for Industrial Robots"

Jan. 2016 *Habilitation à Diriger des Recherches, Lagadic team of IRISA/INRIA Rennes Bretagne Atlantique*, Rennes, France; Paolo Robuffo Giordano

Jun. 2013 *Habilitation à Diriger des Recherches, Laboratoire d'Analyse et d'Architecture des Systèmes du CNRS*, Toulouse, France; Nicolas Mansard

Jul. 2010 *Doktor-Ingenieurs, Karlsruher Institute für Technologie*, Karlsruhe, Germany; Giulio Milighetti, "Multisensorielle diskret-kontinuierliche Überwachung und Regelung humanoider Roboter"

Mar. 2008 *Habilitation à Diriger des Recherches, INRIA*, Sophia Antipolis, France; Ezio Malis

Sep. 2006 *Doktor-Ingenieurs, Technische Universität München*, München, Germany; Michael Thümmel, "Modellbasierte Regelung mit nichtlinearen inversen Systemen und Beobachtern zur Optimierung der Dynamik von Robotern mit elastischen Gelenken"

Jan. 2006 *Habilitation à Diriger des Recherches, Laboratoire d'Analyse et d'Architecture des Systèmes du CNRS*, Toulouse, France; Thierry Siméon

Nov. 2005 *Doktor der Ingenieurwissenschaften, Universität des Saarlandes*, Saarbrücken, Germany; Christian Ott, "Cartesian Impedance Control of Flexible Joint Manipulators"

Oct. 2004 *Habilitation à Diriger des Recherches, Université de Nice–Sophia Antipolis*, Valbonne, France; Pascal Morin

Sep. 2004 *Thèse de Doctorat, Institut National Polytechnic de Grenoble*, Grenoble, France; Cédric Pradalier, "Navigation Intentionnelle d'un Robot Mobile"

Dec. 2003 *Thèse de Doctorat, Institut National Polytechnic de Toulouse*, Toulouse, France; David Bonnafous, "Exécution Réactive de Trajectoires pour Robots Mobile Non-Holonomes"

Nov. 2002 *Habilitation à Diriger des Recherches, Université d'Evry Val d'Essonne*, Evry, France; Tarek Hamel

Feb. 2002 *Thèse de Doctorat, École Centrale de Nantes*, Nantes, France; Mouhacine Benosman, "Commande de Bras Manipulateurs Souples et Extensions aux Systémes à Non Minimum de Phase"

Feb. 2001 *Habilitation à Diriger des Recherches, Laboratoire d'Analyse et d'Architecture des Systèmes du CNRS*, Toulouse, France; Philippe Souères

Dec. 1999 *Thèse de Doctorat, Université Paul Sabatier de Toulouse*, Toulouse, France; Viviane Cadenat, "Commande Référencée Multi-capteurs pour la Navigation d'un Robot Mobile"

Jul. 1999 *Habilitation à Diriger des Recherches, Laboratoire d'Analyse et d'Architecture des Systèmes du CNRS*, Toulouse, France; Thierry Siméon

Oct. 1998 *European Doctor Thesis, Universitat Politècnica de Catalunya*, Barcelona, Spain; Albert Castellet, "Solving Inverse Kinematics Problems Using an Interval Method"

Teaching Activities

Academic Courses

(ordered by last year offered)

2003–pres. *Robotics I*, 6 ECTS, Master in Artificial Intelligence and Robotics and Master in Control Engineering (both taught in English) & previously 1st level 'Laurea' in Computer and Control Engineering, Electronic Engineering; University of Roma "La Sapienza" (85 students/year)

2004–pres. *Robotics II*, 6 ECTS, Master in Control Engineering and Master in Artificial Intelligence and Robotics (both taught in English) & 2nd Level 'Laurea' in Computer Engineering, Control Engineering, Electronic Engineering; University of Roma "La Sapienza" (85 students/year)

2013–pres. *Automation*, 9 ECTS, 1st level 'Laurea' in Computer and Control Engineering; University of Roma "La Sapienza" (50 students/year)

2010–pres. *Elective in Robotics*, 3 ECTS, Master in Artificial Intelligence and Robotics (taught in English); University of Roma "La Sapienza" (20 students/year)

2000–pres. *Modeling and Control of Flexible Structures*, PhD course in "Systems Engineering"; University of Roma "La Sapienza" (10 students/year, course taught in selected years)

2015–2016 *Automatic Control*, 3 ECTS, 1st level 'Laurea' in Electrical Engineering; University of Roma "La Sapienza" (30 students/year)

2014–2015 *Automatic Control*, 3 ECTS, 1st level 'Laurea' in Communication Engineering; University of Roma "La Sapienza" (20 students/year)

2009–2010 *Digital Control Systems*, 6 ECTS, 1st level 'Laurea' in Computer Engineering, Control Engineering, Electronic Engineering; University of Roma "La Sapienza" (15 students/year)

1992–2004 *Industrial Robotics*, 'Laurea' in Computer Engineering, Electrical Engineering, Electronic Engineering, Mechanical Engineering; University of Roma "La Sapienza" (35 students/year)

2002–2003 *Automatic Control II*, 2nd Level 'Laurea' in Computer Engineering; University of Roma Tre (30 students/year)

2001–2003 *Automatic Control*, 1st level 'Laurea' in Computer Engineering, Electronic Engineering; University of Roma "La Sapienza" – Site of Latina (15 students/year)

1993–2001 *Automatic Control*, 'Laurea' in Computer Engineering; University of Roma "La Sapienza" (200 students/year)

1994–1998 *Control Systems I*, Master in "Theory and Methods for Systems Analysis and Control"; University of Roma "La Sapienza" (10 students/year)

1993–1994 *Operation Research*, 'Laurea' in Information Science; University of Milano (150 students/year)

1992–1994 *Control of Industrial Processes*, 'Laurea' in Information Sciences; University of Milano (30 students/year)

1989–1992 *Adaptive Control*, Master in "Theory and Methods for Systems Analysis and Control"; University of Roma "La Sapienza" (10 students/year)

1988–1989 *Systems Theory*, Master in "Theory and Methods for Systems Analysis and Control"; University of Roma "La Sapienza" (10 students/year)

External Courses

Jul. 2015 Coordinator of the Summer School on “Robot Control” *SIDRA National Doctorate School*, Bertinoro, Italy

Feb. 2015 Two lectures on “’Control of Soft Robots: Regulation, Feedback Linearization, Collision Detection”, *SAPHARI NMMI Winter School on Soft Robotics*, Roma, Italy

Jun. 2014 Lectures on “Safe Control of Physical Human-Robot Interaction”, *Great Ideas in ICT 2014, DIAG Doctorate Schools*, Roma, Italy

Jul. 2010 Lectures on “Modeling and Control of Robots with Elastic Joints” and “Safe Physical Human-Robot Interaction”, *CIRA National Doctorate School on Robotics*, Bertinoro, Italy

Jan. 2010 Lecture on “Detection and Isolation of Faults and Collisions in Robot Arms”, *Doctorate School in Information Science and Engineering*, Bologna, Italy

Apr. 2007 ICRA’07 Tutorial on “Nonlinear Control of Flexible Joint Robots”, *2007 IEEE Int. Conf. on Robotics and Automation*, Roma, Italy

Jul. 2003 Lectures on “Robots with Elastic Joints: Modeling and Control” and “Robots with Flexible Links: Modeling and Control”, *CIRA National Doctorate School on Control of Robotic Systems*, Bertinoro, Italy

Feb. 2000 Lecture on “Kinematics and Motion Generation for Wheeled Mobile Robots”, *International School RoboCup 2000 Camp*, Padova, Italy

Jun. 1996 Lectures on “Decoupling and Feedback Linearization of Robots with Mixed Rigid/Elastic Joints” and “Nonholonomic Behavior in Redundant Robot Arms”, *DISC Summer School on Applications of Modern Nonlinear Control Theory*, Zeist, Netherlands

Jul. 1994 Lectures on “Control of Nonholonomic Mechanical Systems”, *Advanced Professional School on Kinematics and Dynamics of Multi-Body Mechanical Systems*, International Center for Mechanical Sciences (CISM), Udine, Italy (see [BC-3] in the list of publications)

Sep. 1992 Lectures on “Control of Rigid Robots: Robots in Contact with the Environment” and “Control of Flexible Robots: Modelling of Robots with Flexible Links”, *Summer School on Theory of Robot Control*, École Nationale Supérieure d’Ingénieurs Electriciens de Grenoble, Laboratoire d’Automatique de Grenoble (LAG-ENSIEG), Saint Martin d’Hères, France (this course was the basis for the 12-author Springer book on “Theory of Robot Control”, see [BC-5] and [BC-6] in the list of publications).

Jun. 1992 Lectures on "Fundamentals of Automatic Control and Robotics", *Tecnopolis*, Valenzano, Bari, Italy

Mar. 1990 Lectures on "Nonlinear Control" (second edition), *Carl-Cranz Gesellschaft*, Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt (DFVLR), Oberpfaffenhofen, Germany

Nov. 1989 Course on "Nonlinear Control Techniques for Robot Manipulators and Induction Motors", *IX School of the Mexican Association of Automatic Control*, Centro de Investigacion y de Estudios Avanzados (CINVESTAV), Instituto Politecnico National, Mexico City, Mexico

Aug. 1987 Lectures on "Nonlinear Control", *Carl-Cranz Gesellschaft*, Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt (DFVLR), Oberpfaffenhofen, Germany

Feb. 1987 Tutorial on "Robot Manipulators: An Application of Nonlinear Control Methods" for the course "Nonlinear Control Theory", *2nd Workshop on Mathematics in Industry*, Centro Internazionale di Fisica Teorica, Trieste, Italy

Supervision of Students

1993–pres. Advisor of 13 PhD theses in Systems and Control Engineering; Sapienza University of Rome

- **2016–pres.** Maram Khatib (on-going)
- **2015–pres.** Khaled Al Khudir (on-going)
- **2014–pres.** Gabriele Buondonno (on-going)
- **2014–pres.** Federico Patota (on-going)
- **2012–2015** Claudio Gaz, "On Dynamic Identification and Control Issues for the KUKA LWR Robot"
- **2012–2015** Emanuele Magrini, "Estimation of Contact Forces and Interaction Control in Human-Robot Collaboration Tasks"
- **2011–2014** Antonio Paolillo, "Vision-based Control of Humanoids Interacting with the Real World"
- **2008–2011** Fabrizio Flacco, "Modeling and Control of Robots with Compliant Actuation"
- **2004–2007** Paolo Robuffo Giordano, "Visual Estimation and Control of Robot Manipulating Systems"
- **2002–2005** Riccardo Farina, "Trade-off between Precision and Operative Safety in Robots with Intrinsic Compliance"

1997–2001 Fabio Maria Antoniali, "A Novel Bayesian Approach to Mobile Robot Localization"

1998–2001 Alessandro Bettini, "Task and Joint Control of Human-Robot Collaborative Systems"

1998–2001 Stefano Iannitti, "Motion Planning and Control of a Class of Underactuated Robots"

1993–1996 Raffaella Mattone, "Una Metodologia Generale per la Modellazione Orientata al Compito ed il Controllo di Sistemi Robotici Cooperanti" (in Italian)

1992–pres. Supervisor of more than 100 2nd Level 'Laurea' (5-year Engineering curriculum) or Master theses in Computer Engineering, Electronic Engineering, Mechanical Engineering, Systems Engineering, Robotics; University of Roma "La Sapienza"

1992–1994 Supervisor of 7 'Laurea' thesis in Information Sciences; University of Milano

The above students have performed their final work in the Robotics Laboratory of our DIAG (former DIS) Department, in industries in Italy (ABB, Oerlikon Contraves, SIR), or in international institutions (e.g., Fraunhofer IPA Stuttgart, Fraunhofer IITB/IOSB Karlsruhe, Örebro University, Tohoku University).

Scientific Activities

Principal Investigator in Research Groups

(if not stated otherwise)

European

2015–2018 H2020 IA Project FoF-637080 "Symbiotic Human-Robot Solutions for Complex Surface Finishing Operations (SYMPLEXITY)" supported by the *European Commission*

2015–2018 (Participant) H2020 RIA Project ICT-645097 "Multi-Contact Collaborative Humanoids in Aircraft Manufacturing (COMANOID)" supported by the *European Commission*

2011–2015 (Coordinator) FP7 IP Project "Safe and Autonomous Physical Human-Aware Robot Interaction (SAPHARI)" supported by the *European Commission*

2006–2009 FP6 STREP Project "Physical Human-Robot Interaction: Safety and Dependability (PHRIENDS)" supported by the *European Commission*

2006 Perspective Research Project "Physical Human-Robot Interaction in Anthropic Domains (PHRIDOM)" supported by the *European Commission* within the EURON network

2005–2008 6th FP STREP Project "The CyberCarpet – Enabling Omni-directional Walking in Virtual Worlds (CyberWalk)" supported by the *European Commission*

2002–2004 (Participant) IP EU-IST-2001 "Intelligent Fault Tolerant Control in Integrated System (IFATIS)" supported by the *European Commission*

2000–2003 European Robotics Research Network (EURON) supported by the *European Commission*

1994–1996 European Robotics Network (ERNET) of the Human Capital and Mobility Programme supported by the *European Commission*

1992–1995 ESPRIT III Basic Research Action "Planning Robot Motion (PROMotion)" supported by the *European Commission*

National

2012–2015 Research Project "I-Mule", within the *Industry 2015 (Made in Italy)* program supported by the *Ministry of Economic Development*

2008–2010 (Coordinator) National Research Project "SICURA: Safe Physical Interaction between Robots and Humans" supported by the *Ministry of Education University and Research*

2003–2004 National Research Project "MATRICS: Methodologies Applications and Technologies for Robot Interaction Cooperation and Supervision" supported by the *Ministry of Education University and Research*

2001–2003 Research Line "FAI ROBOT: Internet-based Continuous Learning for Industrial Robotic Systems Control" of the Project "Web Learning for Human Resources Quality" supported by the *National Research Council*

2001–2002 National Research Project "MISTRAL: Methodologies and Integration of Subsystems and Technologies for Anthropic Robotics and Locomotion supported by the *Ministry of Education University and Research*

1999–2000 National Research Project "RAMSETE: Articulated and Mobile Robotics for SErvice and TEchnology supported by the *Ministry of University, Scientific Research and Technology*

1998–1999 Fundamental Research Project "Development of an Integrated Mobile Manipulator for Planetary Exploration Tasks" supported by the *Italian Space Agency*

1997–1998 Special Research Project "Advanced Control for Robots with Flexible Elements: Theory and Experimentation" supported by the *National Research Council*

1995–1996 Research Project "Motion Planning and Control of Mobile Robots" supported by the *Ministry of University, Scientific Research and Technology*

1993–1994 Research Project "Control of Robots with Nonholonomic Constraints" supported by the *Ministry of University, Scientific Research and Technology*

1989–1992 (Participant) Research Line "Algorithms, Software, and Devices for Dynamic and Hybrid Control of Industrial Robots" of the Subproject "Robot Control" of the National Robotics Project supported by the *National Research Council*

Society Service

since 2015 Member of the Steering Committee of the *IEEE Robotics and Automation Letters*

2016–2017 Awards Committee member and Chair of the Awards Evaluation Panel of the *IEEE Robotics and Automation Society (RAS)*

2015–2017 Member of the Scientific Advisory Board of the *Max Planck Institute for Biological Cybernetics*

2012–2013 Vice-President for Publication Activities of the *IEEE Robotics and Automation Society (RAS)*

2010–2011 Associate Vice-President for Publication Activities of the *IEEE Robotics and Automation Society (RAS)*

2010 Chair of the Awards Evaluation Panel of the *IEEE Robotics and Automation Society (RAS)*

2009–2013 Chair of Panel PE-7 (Systems and Communication Engineering) of the *European Research Council (ERC)* for the Advanced Grant evaluation

2008–2010 AdCom Member of the *IEEE Robotics and Automation Society (RAS)*

since 2007 Fellow of the *IEEE (The Institute of Electrical and Electronics Engineers)* (previously: Senior Member (2005), Member (1986), Student Member (1982))

2006–2012 Member of the Search Committee for Physical Sciences (Technical Sciences until 2010) of the *Körber European Science Award*, granted by the Körber Foundation

2001–2003 AdCom Member of the *European Robotics Research Network (EURON)*

1998–1999 Member of SIRI (Società Italiana di Robotica Industriale)

1991–1995 Chair of the *Technical Committee on Flexible Manipulators* in the *IEEE Robotics and Automation Society*

Editorial Service

Journals

2004–2008 *Editor-in-Chief* of the *IEEE Transactions on Robotics*

2003–2004 *Editor-in-Chief* of the *IEEE Transactions on Robotics and Automation*

1998–2003 *Editor* of the *IEEE Transactions on Robotics and Automation* (first Editor not from USA)

1994–1998 *Associate Editor* of the *IEEE Transactions on Robotics and Automation*

1984–pres. Reviewer for main archival journals in the areas of Robotics and Automatic Control, including *ASME Journal of Dynamic Systems, Measurements, and Control; Automatica; IEEE Transactions on Automatic Control; IEEE Transactions on Control Systems Technology; IEEE Transactions on Robotics; IEEE Transactions on Systems, Man, and Cybernetics; International Journal of Robotics Research; Journal of Robotics Systems*

Handbook

2016 Author and video contributor to the 2nd Edition of the *Springer Handbook of Robotics*, with the revised chapter on "Robots with Flexible Elements" co-authored with W. Book, see [BC-15] in the list of publications.

2008 One of the 165 selected authors of the *Springer Handbook of Robotics*, with a chapter on "Robots with Flexible Elements" co-authored with W. Book, see [BC-12].

Main Conferences

May 2016 Program Chair (with A. Bicchi) of *2016 IEEE International Conference on Robotics and Automation*, Stockholm, Sweden

May 2013 Vice Co-Chair of *2013 IEEE International Conference on Robotics and Automation*, Karlsruhe, Germany

Dec. 2012 Member of the International Advisory Committee of *12th International Conference on Control, Automation, Robotics and Vision*, Guangzhou, China

Sep. 2011 CEB Editor of *2011 IEEE/RSJ International Conference on Intelligent Robots and Systems*, San Francisco, CA

Sep. 2011 Publication Chair of *2011 IEEE/RSJ International Conference on Intelligent Robots and Systems*, San Francisco, CA

Sep. 2011 Program Chair of *AUTOMATICA.IT 2011*, Pisa, Italy

May 2011 RAS CEB Associate Editor of *2011 IEEE International Conference on Robotics and Automation*, Shanghai, PRC

Dec. 2010 Member of the International Advisory Committee of *11th International Conference on Control, Automation, Robotics and Vision*, Singapore

Oct. 2010 PC Member of *2010 IEEE/RSJ International Conference on Intelligent Robots and Systems*, Taipei, Taiwan

May 2010 Member of the Senior Program Committee (SPC) of *2010 IEEE International Conference on Robotics and Automation*, Anchorage, AK

Oct. 2009 PC Member of *2009 IEEE/RSJ International Conference on Intelligent Robots and Systems*, St. Louis, MO

Dec. 2008 Member of the International Advisory Committee of *10th International Conference on Control, Automation, Robotics and Vision*, Hanoi, Vietnam

Sep. 2008 European PC Member of *2008 IEEE/RSJ International Conference on Intelligent Robots and Systems*, Nice, France

Apr. 2007 General Chair of *2007 IEEE International Conference on Robotics and Automation*, Roma, Italy

Dec. 2006 Member of the International Advisory Committee of *9th International Conference on Control, Automation, Robotics and Vision*, Singapore

Oct. 2006 European PC Member of *2006 IEEE/RSJ International Conference on Intelligent Robots and Systems*, Beijing, China

Sep. 2006 PC Member of *8th IFAC Symposium on Robot Control*, Bologna, Italy

May 2006 IPC Member of *2006 IEEE International Conference on Robotics and Automation*, Orlando, FL

Aug. 2005 European PC Member of *2005 IEEE/RSJ International Conference on Intelligent Robots and Systems*, Edmonton, Canada

Sep. 2004 European PC Member of *2004 IEEE/RSJ International Conference on Intelligent Robots and Systems*, Sendai, Japan

Apr. 2004 IPC Member of *2004 IEEE International Conference on Robotics and Automation*, New Orleans, LA

Oct. 2003 European PC Member of *2003 IEEE/RSJ International Conference on Intelligent Robots and Systems*, Las Vegas, NV

Sep. 2003 IPC Member of *2003 IEEE International Conference on Robotics and Automation*, Taipei, Taiwan

Sep. 2002 European PC Member of *2002 IEEE/RSJ International Conference on Intelligent Robots and Systems*, Lausanne, Switzerland

May 2002 IPC Member of *2002 IEEE International Conference on Robotics and Automation*, Washington, DC

May 2001 IPC Member of *2001 IEEE International Conference on Robotics and Automation*, Seoul, Korea

Apr. 2000 IPC Member of *2000 IEEE International Conference on Robotics and Automation*, San Francisco, CA

May 1999 IPC Member of *1999 IEEE International Conference on Robotics and Automation*, Detroit, MI

May 1998 IPC Member of *1998 IEEE International Conference on Robotics and Automation*, Leuven, Belgium

Sep. 1995 Organizing Committee of *3rd European Control Conference*, Roma, Italy

Dec. 1994 IPC Member of *33rd IEEE Conference on Decision and Control*, Lake Buenavista, FL

Sep. 1994 Organizing Committee of *4th IFAC Symposium on Robot Control*, Capri, Italy

Jun. 1989 Organizing Committee of *1st IFAC Symposium on Nonlinear Control Systems Design*, Capri, Italy

Awards

May 2015 (Finalist) *Best Conference Paper Award* at the *2015 IEEE International Conference on Robotics and Automation*, Seattle, WA (see [C-132] in the list of publications)

Nov. 2014 (Finalist) Best Video Award at the *2014 IEEE/RSJ International Conference on Intelligent Robots and Systems*, Tokyo, Japan (see [V-1] in the list of publications)

Jun. 2012 *Best Paper Award* at the *4th IEEE RAS-EMBS International Conference on Biomedical Robotics and Biomechatronics*, Rome, Italy (see [C-121] in the list of publications)

Apr. 2009 *IEEE-RAS Distinguished Service Award* for outstanding leadership and contributions as Editor-in-Chief of the IEEE Transactions on Robotics, and for service as the ICRA 2007 General Chair

Mar. 2009 Supervisor of Paolo Robuffo Giordano, whose Ph.D. thesis received the *Premio Maffezzoni* for the best Italian thesis in the area of Systems and Control (Automatica) in 2008

Feb. 2009 Chapter author of the *Springer Handbook of Robotics* that received the two *PROSE Awards* for Excellence in Physical Sciences & Mathematics and for Engineering & Technology, The American Publishers Awards for Professional and Scholarly Excellence

Sep. 2008 *Best Application Paper Award* at the *2008 IEEE/RSJ International Conference on Intelligent Robots and Systems*, Nice, France (see [C-105] in the list of publications)

from 2007 Fellow of the *IEEE (The Institute of Electrical and Electronics Engineers)* for contributions to modeling and control of robotic systems

Apr. 2005 Recipient of the German *Helmholtz Humboldt Research Award* for foreign scientists

Dec. 2003 Advisor of Giulio Milighetti, whose Laurea thesis received the *UCIMU National Award* for the best thesis in the section "Machines, Tools, and Components: Design and Applications", Milano, Italy

May 1998 *Best Conference Paper Award* at the *1998 IEEE International Conference on Robotics and Automation*, Leuven, Belgium (see [C-59] in the list of publications)

Jun. 1991 Coauthor with Costanzo Manes of the paper that received the *Best Student Paper Award* at the *5th International Conference on Advanced Robotics*, Pisa, Italy (see [C-33] in the list of publications)

Jun. 1987 Technological innovation and transfer to the productive system award of the *Consorzio Roma Ricerche*

Feb. 1984 University award for the best Master thesis "A new method for the optimization of interconnected systems" (see also [J-1] in the list of publications)

Keynote Lectures

May 2015 "A Control Architecture for Human-Robot Collaboration", *2015 IEEE International Conference on Robotics and Automation*, Seattle, USA

Sep. 2013 "Progress on Human-Robot Coexistence and Collaboration in SAPHARI", *6th International Workshop on Human-Friendly Robotics*, Roma, Italy

Jul. 2012 "Recent Advances in Physical Human-Robot Interaction", *9th International Conference on Informatics in Control, Automation and Robotics*, Roma, Italy

Main Invited Seminars

Oct. 2015 "Physical Human-Robot Collaboration: Sensing, Monitoring, and Control Issues", *Workshop on Safety for Human-Robot Interaction in Industrial Settings*, 2015 IEEE/RSJ International Conference on Intelligent Robots and Systems, Hamburg, Germany

Sep. 2014 "Advances on Human-Robot Collaboration within the SAPHARI project", *Workshop on Human-robot collaboration in standardization and R&D activities*, 2014 IEEE/RSJ International Conference on Intelligent Robots and Systems, Chicago, MI

Jun. 2014 "Control of Compliant Robots for Physical Collaboration with Humans", *1st International Symposium on 'Soft Robotics' in Germany*, Stuttgart, Germany

Oct. 2013 'Physical Human-Robot Interaction: Safe Collision Handling, Coexistence, and Collaboration", *Workshop Robotique LAAS-CNRS*, Toulouse, France

Jun. 2011 "Robots Collision Detection and Safe Reaction", *Centro "E. Piaggio"*, Pisa, Italy

Jan. 2011 "Control Issues for Safety and Performance in Robots with Flexible Transmissions", *Italian Institute of Technology*, Genova, Italy

May 2010 "Dynamic Gravity Cancellation in Robots with Flexible Transmissions: Constant, Nonlinear, and Variable Stiffness", *Workshop on New Variable Impedance Actuators for the Next Generation of Robots*, 2010 IEEE International Conference on Robotics and Automation, Anchorage, Alaska

Feb. 2006 "A Physically-Based Fault Detection and Isolation Method and Its Uses in Robot Manipulators", *38. VDI/VDE Sitzung des FA 4.13 Steuerung und Regelung von Robotern*, Ladenburg, Germany

Jun. 2004 "On the Control of Robots with Visco-Elastic Joints", *Workshop on Applications of Advanced Control Theory to Robotics and Automation* (in honor of Proff. P. Kokotovic and S. Nicosia 70th Birthdays), Villa Mondragone, Roma, Italy

Nov. 1999 "The Role of Advanced Control Systems in Service Robotics", *1st EU-JPN Symposium on Human Friendly Robotics*, Tokyo, Japan

Jul. 1999 "Research Activities on Mobile Robotics at DIS", *LAAS–CNRS*, Toulouse, France

May 1998 "Research Activities at DIS Robotics Laboratory", *Fraunhofer IPA*, Stuttgart, Germany

Apr. 1998 "The Future of Robotics", *FAST Workshop on Automation Beyond Year 2000*, Milano, Italy

Dec. 1997 "Trajectory Control of Flexible Manipulators", *IEEE CSS/RAS Workshop on Control Problems in Robotics and Automation: Future Directions*, San Diego, CA

Jun. 1994 "Nonholonomic Behaviour in Redundant Robot Arms", *MAP Project on Geometry and Robotics*, Department of Mathematics, University of Pisa, Italy

Dec. 1993 "An Iterative Learning Scheme for Regulation in Robot Arms", *École Polytechnique Fédéral de Lausanne*, Institut d'Automatique, Lausanne, Switzerland

May 1992 "Control of Robots with Elastic Joints and Flexible Links", *Workshop on Control Issues to Promote Robotic Machine Intelligence*, 1992 IEEE International Conference on Robotics and Automation, Nice, France

Significant Research Contributions

References are to papers in the separate list of publications (J = Journal paper, C = Conference paper, BC = Book chapter).

Nonlinear Control

Theoretical contributions were provided for the problem of exact linearization of nonlinear systems via dynamic state feedback (see [C-6]) and the associated zero dynamics interpretation ([C-30]). Applications to different nonlinear electromechanical systems have been successfully considered, including induction motors ([J-5, C-13, C-18]), robots with various (joint, link) flexible components ([J-22, C-59, C-71, C-99, C-109]), nonholonomic wheeled mobile robots ([J-26, C-66]), and manipulators with passive joints ([J-25, J-28]).

Flexible Manipulators

A survey on the state-of-the-art on modeling and control of robots with elastic joints and with flexible links is given in a chapter of the *Springer Handbook of Robotics* and, in a more compact form, in another chapter of the *Encyclopedia of Systems and Control*. See [BC-12], [BC-13], and [BC-15].

Joint flexibility— For robots with rigid links but flexible transmissions (harmonic drives, long shafts, or transmission belts), a complete and efficient exact linearization and decoupling algorithm by dynamic feedback has been developed. This result mimics the 'computed torque' approach of the rigid robot case and is useful for accurate trajectory tracking problems. It has been extended also to the case of a mixed rigid/elastic joint setting. Global results have been proven for the regulation of a desired configuration (or of a cartesian pose), based only on linear feedback of motor measurements and on-line gravity compensation (and the use of kinematic mappings for the cartesian case). Exact cancellation of the gravity acting on the robot links can be achieved for robots with linear, nonlinear or variable (actuated) stiffness, so that global regulation by a PD-type law follows without any lower bound on the control gains nor on the device stiffness. The case of visco-elastic joints has been considered, comparing the behavior of static versus dynamic feedback laws for input-output linearization. A simple method has been developed for the feasible dynamic scaling of trajectories under maximum torque constraints. A full state observer based on link acceleration and motor position measurements has been also proposed, and its use for control purposes validated on a KUKA robot with non-negligible joint elasticity. A novel (motor) friction observer and compensation has been introduced and tested on a 7R medical robot. A special effort has been devoted to the modeling, dynamic identification and control of the KUKA LWR4 lightweight robot displaying joint elasticity, and including also the additional estimation of a payload. The case of variable stiffness actuation (VSA) has been also considered. Simultaneous decoupled control of link motion and joint stiffness can be obtained by feedback linearization methods. The problem of estimating on-line the time-varying nonlinear stiffness of VSA-based robots has been approached using a residual-based observer for the flexibility torques and an RLS scheme for obtaining the stiffness characteristics in real time, as well as in combination with pure signal-based methods. Both antagonistic and serial configurations of VSA have been covered, with experimental validation of the approach on the AwAS device of the IIT. An efficient Newton-Euler based numerical method has been developed for inverse dynamics and feedback linearization control computations. The design of compliant actuators for humanoids has been pursued using optimal control techniques. For reference, see, e.g., [J-22, J-30, J-31, J-41, J-46, C-11, C-59, C-64, C-73, C-79, C-84, C-86, C-93, C-96, C-106, C-109, C-112, C-113, C-114, C-116, C-118, C-126, C-127, C-135, C-140, C-142].

Link flexibility— A finite-dimensional closed-form dynamic modeling of open kinematic chain manipulators with flexible links has been proposed. Global regulation by PD control with constant or on-line gravity compensation has been shown for the first time in the flexible case. An iterative update of the feedforward term can be used to make this controller fully independent of any dynamic parameter and also to achieve exact positioning of the deflected arm tip. Stable inversion control has been proposed for the accurate tracking of trajectories defined at special points along the links (in particular, at the link base, i.e., at the joint level). To cope with non-minimum phase limitations, nonlinear regulation is a viable solution to the problem of asymptotic tracking of end-effector trajectories, without the need to resort to non-causal torque commands. The problem of planning rest-to-rest motions in given time (without final oscillations) has been considered for a one-link and a two-link flexible arm. For reference, see, e.g., [J-3, J-4, J-8, J-11, J-12, J-15, J-17, J-29, BC-8, BC-10, C-12, C-26, C-60, C-70, C-71, C-80, C-97, C-103].

Kinematic Redundancy

Algorithms were proposed for the optimal use of kinematic redundancy, in order to maximize criteria like manipulability or joint range while moving the end-effector along a prescribed trajectory. The novel use of the compact and efficient Reduced Gradient (RG) method, the correct definition of second-order (acceleration) schemes, and the characterization and control of cyclic behaviors were the main contributions. The presence of hard constraints at the configuration level (on joint range, velocity, and acceleration/torque) has been efficiently handled with a method named Saturation in the Null Space (SNS), which also embeds a minimum task scaling when the task is unfeasible. For multiple prioritized tasks, the SNS realizes a preemptive strategy which uses at best the capabilities of the redundant robot while preserving task priorities. A novel method has also been proposed for the efficient handling of stack of tasks where priorities may swap, and tasks disappear or be activated. It consists in processing information in a reverse order with a suitable projector (RP = Reverse Priority) so as to enforce validity of the original stack. The case of mobile manipulators with a nonholonomic wheeled base (NMM) that are redundant with respect to the task has been also considered, in particular for visual tasks. Notably, for the special case of NMM with steering wheels in the base, task-oriented kinematic control laws involve the use of dynamic feedback. We have developed a method for implementing a second-order (acceleration or torque) redundancy resolution control law using a suitable version of a velocity-level scheme. Redundancy has been exploited also for a better Cartesian task preservation during the safe robot reaction to on-line detected collisions and for a more natural gaze control of a humanoid head. For reference, see, e.g., [J-7, J-10, J-18, J-20, J-34, J-43, J-44, C-24, C-40, C-65, C-90, C-104, C-110, C-117, C-119, C-122, C-123, C-128, C-130, C-133].

Iterative Learning

When the robotic task is repetitive, one can use the previous trials for improving performance in the subsequent ones, without the need of an accurate dynamic model. The frequency-based design of an iterative learning controller for trajectory tracking tasks has been originally proposed, pointing out the trade-off between convergence of the learning process and asymptotic zeroing of the tracking error. The method has been applied to rigid, joint-elastic, as well as link-flexible robots. Learning can be used also for exploiting redundancy. For reference, see, e.g., [J-9, J-13, C-32, C-39].

Hybrid Force/Velocity Control

We have proposed one of the first implementations of model-based hybrid force/velocity control. The correct complementarity of force and velocity vectors in the task space has been defined in energetic (thus, invariant) terms and extended also to the case of interaction with dynamic environments. In this latter case, three subsets of generalized directions appear: those where only force can be controlled, those were only motion can be controlled, and those were either force or motion can be controlled, dynamically inducing the behavior of the other. Such hybrid force/velocity control framework naturally applies also to the case of multiple dynamically cooperating robots and to human-robot physical interaction. For reference, see, e.g., [J-16, BC-4, C-15, C-20, C-33, C-36, C-47, C-50, C-55, C-56, C-138].

Wheeled Mobile Robots

For the parking and trajectory tracking problems of wheeled mobile robots subject to nonholonomic constraints due to wheel rolling, full comparison of different advanced control laws has been performed in simulation and experimentally (time-varying nonlinear stabilization, non-smooth control, Lyapunov design in polar coordinates, dynamic feedback linearization). Both proprioceptive feedback (from odometry) and visual feedback (from an external camera) implementations were tested. Visual feedback has been used also for planning and execution of collision-free maneuvers among obstacles, keeping already into account the nonholonomic constraints. Adaptations to nonholonomic kinematics of artificial potential and vortex field methods have been also considered for sensor-based navigation of mobile robots. For reference, see, e.g., [J-14, J-26, BC-7, BC-9, C-45, C-53, C-62, C-75, C-76].

Underactuated Robots

Underactuated robots have less control commands than generalized coordinates and display very difficult dynamic stabilization issues. Structural nonlinear controllability properties have been studied. For special classes of planar robots with one or more passive joints, a rest-to-rest motion planning technique and a trajectory tracking controller have been proposed using the flatness of the system (equivalently, its dynamic feedback linearizability). For the regulation to an equilibrium configuration (with or without gravity), a novel control method called iterative steering has been introduced. It consists in the sequential application of open-loop finite time commands leading to contraction of the state error. The open-loop command is evaluated at the state reached at the previous iteration, typically based on an approximate robot model (a polynomial nilpotent approximation which preserves the original system controllability and allows closed-form computations). Exponential convergence and robustness can be guaranteed under suitable hypotheses. This 'maneuvering' approach is valid also for minimalistic systems of robotic manipulation (plate-ball). For reference, see, e.g., [J-19, J-21, J-23, J-24, J-25, J-27, J-28, BC-11, C-61, C-68, C-74].

Mobile Platforms

Within the project *CyberWalk*, an actuated ball-array platform has been built in order to allow unconstrained walking capabilities to a user immersed in a virtual reality. The platform has two actuators, one for a linear treadmill and one for the turntable supporting it and its kinematic model is subject to a nonholonomic constraint. The motion control problem of this platform has been tackled, assuming to measure only the walker position with an overhead camera. The objective is to keep the walking user close to the platform center, using smooth (in terms of physiological perception constraints) control laws. The same control problem has been tackled for a 1D linear and a 2D omnidirectional treadmill, keeping into account the perceptual constraints of the walking user and integrating the system into a virtual reality visualizer. For the 2D omnidirectional treadmill, a more comfortable behavior is guaranteed by designing the two motion controllers in a reference frame attached to and rotated with the user. More recently, a large test campaign on users' behavior and possible changes in their locomotion on this large 2D platform has been performed. Another type of platforms where the presence of nonholonomic constraints is relevant are mobile manipulators mounted on a wheeled base. A task-oriented kinematic modeling allows to define a suitable Jacobian for these systems, to be used for kinematic control. The special case of visual tasks with an eye-in-hand camera has been considered. For reference, see, e.g., [J-34, J-37, J-38, J-40, C-90, C-91, C-92, C-94, C-108].

Visual Servoing

Novel image-based control laws have been designed and tested on different experimental platform. They are based on a nonlinear observer for the depths of point features or for other geometric quantities associated to image moments, so as to realize a pure image-based visual servoing scheme. The same approach allows also an on-line estimation of the camera focal length. As applications, the kinematic control of mobile manipulators using on-board vision and the gazing control of the humanoid head of the ARMAR-III have been considered. For reference, see, e.g., [J-34, J-36, J-39, C-95, C-98, C-101, C-117].

Fault Detection and Isolation

Theoretical and experimental results have been obtained on the problem of fault detection and isolation (FDI) in nonlinear dynamical systems. The proposed methods are based on a differential-geometric approach (for FDI of set of faults, when each single fault cannot be exactly isolated) and on the use of some inherent physical properties of the system (like conservation of momentum in Euler-Lagrange mechanical systems). The design of residual signals detecting and isolating actuator and/or sensor faults has been performed and tested in robotic systems as well as in hydraulic systems, in the face of modeling errors and measurement disturbances. For reference, see, e.g., [J-32, J-33, C-78, C-81, C-82, C-87, C-88, C-89].

Physical Human-Robot Interaction

Within the project *PHRIENDS*, physical issues in human-robot interaction were studied. A robot collision detection scheme that does not use any external sensors beyond the proprioceptive ones (joint encoders, and joint torque sensors if available) has been developed for rigid manipulators and for those having transmission elasticities, viewing the collision as a system fault. The associated residual can be computed efficiently, using also a modified Newton-Euler recursive algorithm. Experimental results have been obtained on the DLR-III, KUKA LWR4, and Universal Robots UR10 lightweight arms, including also different safe reaction modes to impacts with humans at any point of the robot structure and task-preserving strategies accommodating reaction in the null space of redundant manipulators. Tests have been conducted also for collision detection and reaction with sharp tools on biological tissues. For increasing robot safety while preserving motion accuracy, variable compliance joints/actuation has been considered. For this class of robots, we have shown the possibility of simultaneous and decoupled control of link motion and joint elasticity. Furthermore, collisions can be detected also without the knowledge of the actual joint stiffness. The pHRI subject has been further explored in the *SAPHARI* project, where in particular an integrated approach to collision avoidance, detection, and reaction is pursued that integrates multiple exteroceptive and proprioceptive sensors, as well as dynamic model-based techniques. Results have been obtained for collision avoidance using one or more Kinect sensors and computing efficiently distances in the depth space. Contactless human-robot collaboration was obtained also by visual-based coordinated motion between a human carrying a Kinect and the robot pointing at it. Another issue addressed is the discrimination of undesired vs. intentional contacts and the safe control of continuous force exchange tasks in the latter case (human-robot safe coexistence and collaboration). A method that combines external sensing for contact localization and the internal model-based residual has been realized that acts as a virtual force sensor at any location along the robot structure. More information on contact forces/moments can be extracted from virtual sensing and the use of a force/torque sensor at the robot base. Using the estimated contact force, we proposed proposed generalization to the contact space of classical interaction control methods such admittance, impedance or hybrid force-velocity control. This allows more flexibility in human-robot collaboration. Some collision detection and collaboration results were obtained also using only motor current measurements in control architectures for industrial robots that are otherwise closed for the user. Model Predictive Control (MPC) and admittance control have been used in the interaction between a human and ballroom dancing robot. Port-based energy methods allow to regulate exchanged forces in shared control. More recently, we have considered also haptic control problems for finger wearable devices in Augmented Reality applications. For reference, see, e.g., [J-35, J-42, J-45, J-47, J-48, J-49, C-85, C-93, C-99, C-102, C-104, C-105, C-107, C-109, C-115, C-120, C-121, C-124, C-129, C-131, C-132, C-136, C-137, C-138, C-139, C-141].