



ICINCO 2006

THIRD INTERNATIONAL CONFERENCE ON
INFORMATICS IN CONTROL, AUTOMATION AND ROBOTICS

Proceedings

Robotics and Automation

SETÚBAL, PORTUGAL · AUGUST 1-5, 2006

ORGANIZED BY



SPONSORED BY



TECHNICAL CO-SPONSORSHIP



IN COOPERATION WITH



ICINCO 2006

Proceedings of the
Third International Conference on
Informatics in Control, Automation and Robotics

Robotics and Automation

Setúbal, Portugal

August 1 – 5, 2006

Organized by

**INSTICC – Institute for Systems and Technologies of
Information, Control and Communication**

Sponsored by **Polytechnic Institute of Setúbal**

Technical Co-Sponsorship

**IEEE Robotics and Automation Society
International Federation of Automatic Control**

In Cooperation With

**American Association for Artificial Intelligence
AgentLink**

**ACM Special Interest Group on Artificial Intelligence
Portuguese Association for Automatic Control**

Hosted by **Setúbal College of Business Administration**

Copyright © INSTICC – Institute for Systems and Technologies of
Information, Control and Communication
All rights reserved

Edited by Juan Andrade Cetto, Jean-Louis Ferrier, José Dias Pereira and Joaquim Filipe

Printed in Portugal

ISBN: 972-8865-60-0

ISBN (13 digits): 978-972-8865-60-3

Depósito Legal: 215456/06

<http://www.icinco.org>

secretariat@icinco.org

BRIEF CONTENTS

BRIEF CONTENTS	III
KEYNOTE LECTURES	IV
TUTORIAL	IV
ORGANIZING AND STEERING COMMITTEES	V
PROGRAM COMMITTEE	VII
AUXILIARY REVIEWERS	X
SELECTED PAPERS BOOK	XI
FOREWORD.....	XIII
CONTENTS.....	XV

KEYNOTE LECTURES

Mihaela Ulieru

The University of New Brunswick

Canada

Oleg Gusikhin

Ford Research & Adv. Engineering

U.S.A.

Norihiro Hagita

ATR Intelligent Robotics and Communication Laboratories

Japan

Hojjat Adeli

The Ohio State University

U.S.A.

Mark d'Inverno

University of Westminster

U.K.

William J. O'Connor

University College Dublin

Ireland

Gerard T. McKee

The University of Reading

U.K.

TUTORIAL

Mihaela Ulieru

The University of New Brunswick

Canada

ORGANIZING AND STEERING COMMITTEES

Conference Chair

Joaquim Filipe, INSTICC / Polytechnic Institute of Setúbal Setúbal, Portugal

Honorary Chair

Hojjat Adeli, The Ohio State University, U.S.A.

Program Co-chairs

Juan Andrade Cetto, Universitat Autònoma de Barcelona, Spain

Jean-Louis Ferrier, University of Angers, France

José Dias Pereira, E.S.T. Setúbal, Portugal

Proceedings Production

Paulo Brito, INSTICC, Portugal

Helder Coelhas, INSTICC, Portugal

Bruno Encarnação, INSTICC, Portugal

Vitor Pedrosa, INSTICC, Portugal

Mónica Saramago, INSTICC, Portugal

Secretariat, Webdesigner and Graphics Production

Marina Carvalho, INSTICC, Portugal

PROGRAM COMMITTEE

Eugenio Aguirre, University of Granada, Spain

Frank Allgower, University of Stuttgart, Germany

Fouad Al-Sunni, KFUPM, Saudi Arabia

Yacine Amirat, University Paris 12, France

Luis Antunes, GUESS/Universidade de Lisboa, Portugal

Peter Arato, Budapest University of Technology and Economics, Hungary

Helder Araújo, University of Coimbra, Portugal

Gustavo Arroyo-Figueroa, Instituto de Investigaciones Electricas, Mexico

Marco Antonio Arteaga, Universidad Nacional Autonoma de Mexico, Mexico

Nikos Aspragathos, University of Patras, Greece

Miguel Ayala Botto, Instituto Superior Técnico, Portugal

Robert Babuska, TU Delft, The Netherlands

Mark Balas, University of Wyoming, U.S.A.

Bijnan Bandyopadhyay, IIT Bombay, India

Ruth Bars, Budapest University of Technology and Economics, Hungary

Karsten Berns, University Kaiserslautern, Germany

Patrick Boucher, SUPELEC, France

Guido Bugmann, University of Plymouth, U.K.

Edmund Burke, University of Nottingham, U.K.

Kevin Burn, University of Sunderland, U.K.

Clifford Burrows, Innovative Manufacturing Research Centre, U.K.

Luis M. Camarinha-Matos, New University of Lisbon, Portugal

Marco Campi, University of Brescia, Italy

Jorge Martins de Carvalho, FEUP, Portugal

Alicia Casals, Technical University of Catalonia, Spain

Christos Cassandras, Boston University, U.S.A.

Raja Chatila, LAAS-CNRS, France

Tongwen Chen, University of Alberta, Canada

Albert M. K. Cheng, University of Houston, U.S.A.

Sung-Bae Cho, Yonsei University, Korea

Ryszard S. Choras, University of Technology & Agriculture, Poland

Carlos Coello Coello, CINVESTAV-IPN, Mexico

António Dourado Correia, University of Coimbra, Portugal

Yechiel Crispin, Embry-Riddle University, U.S.A.

Keshav Dahal, University of Bradford, U.K.

Danilo De Rossi, University of Pisa, Italy

Angel P. del Pobil, Universitat Jaume I, Spain

Guilherme DeSouza, University of Missouri, U.S.A.

Rüdiger Dillmann, University of Karlsruhe, Germany

Denis Dochain, Université Catholique de Louvain, Belgium

Alexandre Dolgui, Ecole des Mines de Saint Etienne, France

Marco Dorigo, Université Libre de Bruxelles, Belgium

Wlodzislaw Duch, Nicolaus Copernicus University & NTU, Poland

Heinz-Hermann Erbe, TU Berlin, Germany

Gerardo Espinosa-Perez, Universidad Nacional Autonoma de Mexico, Mexico

Simon Fabri, University of Malta, Malta

Jean-Louis Ferrier, Université d'Angers, France

Florin Gheorghe Filip, The Romanian Academy & The National Institute for R&D in Informatics, Romania

Manel Frigola, Technical University of Catalonia (UPC), Spain

Colin Fyfe, University of Paisley, U.K.

Dragan Gamberger, Rudjer Boskovic Institute, Croatia

Lazea Gheorghe, Technical University of Cluj-Napoca, Romania

Maria Gini, University of Minnesota, U.S.A.

Alessandro Giua, University of Cagliari, Italy

Luis Gomes, Universidade Nova de Lisboa, Portugal

John Gray, University of Salford, U.K.

Dongbing Gu, University of Essex, U.K.

José J. Guerrero, University of Zaragoza, Spain

PROGRAM COMMITTEE (CONT.)

Thomas Gustafsson, Luleå University of Technology, Sweden

Maki K. Habib, Saga university, Japan

Hani Hagras, University of Essex, U.K.

Wolfgang Halang, Fernuniversitaet, Germany

J. Hallam, University of Southern Denmark, Denmark

Riad Hammoud, Delphi Corporation, U.S.A.

Uwe D. Hanebeck, Institute of Computer Science and Engineering, Germany

John Harris, University of Florida, U.S.A.

Dominik Henrich, University of Bayreuth, Germany

Francisco Herrera, University of Granada, Spain

Gábor Horváth, Budapest University of Technology and Economics, Hungary

Weng Ho, National University of Singapore, Singapore

Alamgir Hossain, Bradford University, U.K.

Marc Van Hulle, K. U. Leuven, Belgium

Atsushi Imiya, MIT Chiba University, Japan

Sirkka-Liisa Jämsä-Jounela, Helsinki University of Technology, Finland

Ray Jarvis, Monash University, Australia

Ivan Kalaykov, Örebro University, Sweden

Nicos Karcianas, City University, London, U.K.

Fakhri Karray, University of Waterloo, Canada

Dusko Katic, Mihailo Pupin Institute, Serbia & Montenegro

Kazuhiko Kawamura, Vanderbilt University, U.S.A.

Nicolas Kemper, Universidad Nacional Autónoma de México, Mexico

Graham Kendall, The University of Nottingham, U.K.

Uwe Kiencke, University of Karlsruhe (TH), Germany

Jozef Korbicz, University of Zielona Gora, Poland

Israel Koren, University of Massachusetts, U.S.A.

Bart Kosko, University of Southern California, U.S.A.

Elias Kosmatopoulos, Technical University of Crete, Greece

George L. Kovács, Hungarian Academy of Sciences, Hungary

Krzysztof Kozłowski, Poznan University of Technology, Poland

Gerhard Kraetzschmar, Fraunhofer Institute for Autonomous Intelligent Systems, Germany

Anton Kummert, University of Wuppertal, Germany

Jean-Claude Latombe, Stanford University, U.S.A.

Loo Hay Lee, National University of Singapore, Singapore

Graham Leedham, Nanyang Technological University, Singapore

Kauko Leiviskä, University of Oulu, Finland

Zongli Lin, University of Virginia, U.S.A.

Cheng-Yuan Liou, National Taiwan University, Taiwan

Brian Lovell, The University of Queensland, Australia

Peter Luh, University of Connecticut, U.S.A.

Anthony Maciejewski, Colorado State University, U.S.A.

N. P. Mahalik, Gwangju Institute of Science and Technology, Korea

Frederic Maire, Queensland University of Technology, Australia

Bruno Maione, Politecnico di Bari, Italy

Om Malik, University of Calgary, Canada

Jacek Mandziuk, Warsaw University of Technology, Poland

Philippe Martinet, LASMEA, France

Aleix Martinez, Ohio State University, U.S.A.

Rene V. Mayorga, University of Regina, Canada

Gerard McKee, The University of Reading, U.K.

Seán McLoone, National University of Ireland (NUI) Maynooth, Ireland

Basil Mertzios, Thessaloniki Institute of Technology and Democritus University, Greece

Shin-ichi Minato, Hokkaido University, Japan

José Mireles Jr., Universidad Autonoma de Ciudad Juarez, Mexico

Vladimir Mostyn, VSB - Technical University of Ostrava, Czech Republic

PROGRAM COMMITTEE (CONT.)

- Kenneth Muske**, Villanova University, U.S.A.
- Ould Khessal Nadir**, Okanagan College, Canada
- Fazel Naghdy**, University of Wollongong, Australia
- Sergiu Nedeveschi**, Technical University of Cluj-Napoca, Romania
- Maria Neves**, Instituto Superior de Engenharia do Porto, Portugal
- Hendrik Nijmeijer**, Eindhoven University of Technology, The Netherlands
- Urbano Nunes**, University of Coimbra, Portugal
- José Valente de Oliveira**, Universidade do Algarve, Portugal
- Andrzej Ordys**, University of Strathclyde, U.K.
- Djamila Ouelhadj**, University of Nottingham, ASAP GROUP, U.K.
- Michel Parent**, INRIA, France
- Thomas Parisini**, University of Trieste, Italy
- Gabriella Pasi**, Consiglio Nazionale delle Ricerche, Italy
- Witold Pedrycz**, University of Alberta, Canada
- Carlos Eduardo Pereira**, Federal University of Rio Grande do Sul - UFRGS, Brazil
- Maria Petrou**, Imperial College, U.K.
- J. Norberto Pires**, University of Coimbra, Portugal
- Marios Polycarpou**, University of Cyprus, Cyprus
- Marie-Noëlle Pons**, CNRS, France
- Libor Preucil**, Czech Technical University in Prague, Czech Republic
- Bernardete Ribeiro**, University of Coimbra, Portugal
- M. Isabel Ribeiro**, Instituto Superior Técnico, Portugal
- Robert Richardson**, University of Manchester, U.K.
- John Ringwood**, National University of Ireland (NUI), Maynooth, Ireland
- Juha Röning**, University of Oulu, Finland
- Agostinho Rosa**, Instituto Superior Técnico, Portugal
- Hubert Roth**, University Siegen, Germany
- António Ruano**, CSI, Portugal
- Erol Sahin**, Middle East Technical University, Turkey
- Antonio Sala**, Universidad Politecnica de Valencia, Spain
- Abdel-Badeeh M. Salem**, Ain Shams University, Egypt
- Ricardo Sanz**, Universidad Politécnica de Madrid, Spain
- Medha Sarkar**, Middle Tennessee State University, U.S.A.
- Nilanjan Sarkar**, Vanderbilt University, U.S.A.
- Jurek Sasiadek**, Carleton University, Canada
- Carlos Sagüés**, University of Zaragoza, Spain
- Daniel Sbarbaro**, Universidad de Concepcion, Chile
- Klaus Schilling**, Bayerische Julius-Maximilians Universität Würzburg, Germany
- Chi-Ren Shyu**, University of Missouri-Columbia, U.S.A.
- Bruno Siciliano**, Università di Napoli Federico II, Italy
- João Silva Sequeira**, Instituto Superior Técnico, Portugal
- Mark Spong**, University of Illinois, U.S.A.
- Tarasiewicz Stanislaw**, Université Laval, Canada
- Aleksandar Stankovic**, Northeastern University, U.S.A.
- Gerrit van Straten**, Wageningen University, The Netherlands
- Raúl Suárez**, Universitat Politecnica de Catalunya (UPC), Spain
- Ryszard Tadeusiewicz**, AGH University of Science and Technology, Poland
- Tianhao Tang**, Shanghai Maritime University, China
- Daniel Thalmann**, EPFL, Switzerland
- Gui Yun Tian**, University of Huddersfield, U.K.
- Ivan Tyukin**, RIKEN Brain Science Institute, Japan
- Cees van Leeuwen**, RIKEN BSI, Japan
- Annamaria R. Varkonyi-Koczy**, Budapest University of Technology and Economics, Hungary
- Bernardo Wagner**, University of Hannover, Germany
- Axel Walthelm**, Sepp Med GmbH, Germany
- Jun Wang**, Chinese University of Hong Kong, China
- Lipo Wang**, Nanyang Technological University, Singapore

PROGRAM COMMITTEE (CONT.)

Alfredo Weitzenfeld, ITAM, Mexico

Dirk Wollherr, Technische Universität München, Germany

Sangchul Won, Pohang University of Science and Technology, Korea

Kainam Thomas Wong, University of Waterloo, Canada

Jeremy Wyatt, University of Birmingham, U.K.

Alex Yakovlev, University of Newcastle, U.K.

Hujun Yin, University of Manchester, U.K.

Anibal Zanini, Universidad Nacional de Buenos Aires, Argentina

Yanqing Zhang, Georgia State University, U.S.A.

Dayong Zhou, University of Oklahoma, U.S.A.

Albert Zomaya, The University of Sydney, Australia

Detlef Zuehlke, Technical University Kaiserslautern, Germany

AUXILIARY REVIEWERS

Alejandra Barrera, ITAM, Mexico

Levent Bayindir, Middle East Technical University, Turkey

Domingo Biel, Universitat Politècnica de Catalunya, Spain

Stephan Brummund, University of Karlsruhe, IIT, Germany

F. Wilhelm Bruns, University of Bremen, Germany

Roman Buil, Dept. of Electrical & Computer Engineering, University of Connecticut, U.S.A.

Yang Cao, Department of Computer Science, Beijing Institute of Technology, China

Raquel Cesar, Laseeb-ISR, Portugal

Ying Chen, Dept. of Electrical & Computer Engineering, University of Connecticut, U.S.A.

Paulo Coelho, Instituto Politécnico de Tomar, Portugal

Gert van Dijck, K. U. Leuven, Laboratorium voor Neurofysiologie, Belgium

Liya Ding, The Ohio State University, U.S.A.

Didier Dumur, Supélec, Department of Automatic Control, France

Adriano Fagiolini, Interdepartmental Research Centre "E. Piaggio" – Faculty of Engineering, University of Pisa, Italy

Daniele Fontanelli, Interdepartmental Research Centre "E. Piaggio" – Faculty of Engineering, University of Pisa, Italy

Jeff Fortuna, The Ohio State University, U.S.A.

Istvan Harmati, Department of Control Engineering and Information Technology Budapest University of Technology and Economics, Hungary

Sunghoi Huh, Interdepartmental Research Centre "E. Piaggio" – Faculty of Engineering, University of Pisa, Italy

Feng Jin, Department of Automation, Tsinghua University, China

Abhinaya Joshi, Dept. of Electrical & Computer Engineering, University of Connecticut, U.S.A.

Balint Kiss, Department of Control Engineering and Information Technology Budapest University of Technology and Economics, Hungary

Yan Li, Software Institute, EECS, Peking University, China

Gonzalo Lopez-Nicolas, University of Zaragoza, Spain

Patrick De Mazière, K. U. Leuven, Laboratorium voor Neurofysiologie, Belgium

Rafael Muñoz-Salinas, Department of Computer Science and A. I., University of Granada, Spain

Ana Cristina Murillo, University of Zaragoza, Spain

Ming Ni, Dept. of Electrical & Computer Engineering, University of Connecticut, USA

Soumen Sen, Interdepartmental Research Centre "E. Piaggio" – Faculty of Engineering, University of Pisa, Italy

Razvan Solea, Instituto de Sistemas e Robótica – UC, Portugal

Onur Soysal, Middle East Technical University, Turkey

Wei Tan, Department of Automation, Tsinghua University, China

Giovanni Tonietti, Interdepartmental Research Centre "E. Piaggio" – Faculty of Engineering, University of Pisa, Italy

Ali Emre Turgut, Middle East Technical University, Turkey

Jörg Velten, University of Wuppertal, Faculty of Electrical, Information and Media Engineering Communication Theory, Germany

Anne von Vietinghoff, University of Karlsruhe, IIT, Germany

Youqing Wang, Department of Automation, Tsinghua University, China

Yunhua Wang, University of Oklahoma, U.S.A.

Bo Xiong, Dept. of Electrical & Computer Engineering, University of Connecticut, USA

Bailly Yan, Université Paris 12, France

Feng Zhao, Dept. of Electrical & Computer Engineering, University of Connecticut, U.S.A.

SELECTED PAPERS BOOK

A number of selected papers presented at ICINCO 2006 will be published by Springer, in a book entitled Informatics in Automation, Control and Robotics III. This selection will be done by the conference and program co-chairs, among the papers actually presented at the conference, based on a rigorous review by the ICINCO 2006 program committee members.

FOREWORD

Welcome to the 3rd International Conference on Informatics in Control, Automation and Robotics (ICINCO 2006). This conference series has consolidated as a major forum to debate technical and scientific advances presented by researchers and developers both from academia and industry, working in areas related to Control, Automation and Robotics.

In this year conference program we have included oral presentations (full papers and short papers) as well as posters, organized in three simultaneous tracks: “Intelligent Control Systems and Optimization”, “Robotics and Automation” and “Systems Modeling, Signal Processing and Control”. Furthermore, ICINCO 2006 includes 3 satellite workshops, 7 plenary keynote lectures and 1 tutorial, given by internationally recognized researchers.

The three satellite workshops that are held in conjunction with ICINCO 2006 are: Multi-Agent Robotic Systems (MARS 2006), Biosignal Processing and Classification (BPC 2006) and Artificial Neural Networks and Intelligent Information Processing (ANNIIP 2006).

ICINCO has received 309 paper submissions, not including workshops, from more than 50 countries, in all continents. To evaluate each submission, a double blind paper review was performed by the program committee, whose members are researchers in one of ICINCO main topic areas. Finally, only 157 papers were published in the proceedings and presented at the conference; of these, 113 papers were selected for oral presentation (31 full papers and 82 short papers) and 44 papers were selected for poster presentation. The global acceptance ratio was 51% and the full paper acceptance ratio was 10%. After the conference, some authors will be invited to publish extended versions of their papers in a journal and a short list of about thirty papers will be included in a book that will be published by Springer with the best papers of ICINCO 2006.

In order to promote the development of research and professional networks the conference includes in its social program a Workshops Social Event & Banquet in the evening of August 1 (Tuesday), and a Conference Social Event & Banquet in the evening of August 4 (Friday).

We would like to express our thanks to all participants. First of all to the authors, whose quality work is the essence of this conference. Next, to all the members of the program committee and reviewers, who helped us with their expertise and valuable time. We would also like to deeply thank the invited speakers for their excellent contribution in sharing their knowledge and vision. Finally, a word of appreciation for the hard work of the secretariat; organizing a conference of this level is a task that can only be achieved by the collaborative effort of a dedicated and highly capable team.

Commitment to high quality standards is a major aspect of ICINCO that we will strive to maintain and reinforce next year, including the quality of the keynote lectures, of the workshops, of the papers, of the organization and other aspects of the conference. We look forward to seeing more results of R&D work on Informatics in Control, Automation and Robotics at ICINCO 2007, next May, at the University of Angers, France.

Juan Andrade Cetto

Universitat Autònoma de Barcelona, Spain

Jean-Louis Ferrier

Université d'Angers, France

José Dias Pereira

Escola Superior de Tecnologia de Setúbal, Portugal

Joaquim Filipe

Polytechnic Institute of Setúbal / INSTICC, Portugal

CONTENTS

INVITED SPEAKERS

KEYNOTE LECTURES

HOLONIC STIGMERGY AS A MECHANISM FOR ENGINEERING SELF-ORGANIZING APPLICATIONS <i>Mibaela Ulieru and Stefan Grobbelaar</i>	IS-5
INTELLIGENT VEHICLE SYSTEMS - Applications and New Trends <i>Oleg Gusikhin, Dimitar Filev and Nestor Rychtyckyj</i>	IS-11
SYMBIOSIS OF HUMAN AND COMMUNICATION ROBOTS <i>Noribiro Hagita</i>	IS-19
THEORY AND APPLICATION OF INTELLIGENT AGENT SYSTEMS <i>Mark d'Inverno</i>	IS-25
WAVE-BASED CONTROL OF FLEXIBLE MECHANICAL SYSTEMS <i>William J. O'Connor</i>	IS-27
WHAT IS NETWORKED ROBOTICS? <i>Gerard McKee</i>	IS-23

TUTORIAL

AN APPLICATION OF INDUSTRIAL AGENTS TO CONCRETE BRIDGE MONITORING <i>Mibaela Ulieru and Sajjad Ahmad Madani</i>	IS-43
--	-------

ROBOTICS AND AUTOMATION

FULL PAPERS

VISUAL TOPOLOGICAL MAP BUILDING IN SELF-SIMILAR ENVIRONMENTS <i>Toon Goedemé, Tinne Tuytelaars and Luc Van Gool</i>	3
USING THE TRANSFERABLE BELIEF MODEL TO VEHICLE NAVIGATION SYSTEM <i>Touil Khalid, Zribi Mourad and Benjelloun Mobammed</i>	10
TRACKING MULTIPLE OBJECTS USING THE VITERBI ALGORITHM <i>Andreas Krünßling, Frank E. Schneider and Stephan Sebestedt</i>	18
AUTONOMOUS GAIT PATTERN FOR A DYNAMIC BIPED WALKING <i>Christophe Sabourin, Kurosh Madani and Olivier Bruneau</i>	26
ROBUST POSTURE CONTROL OF A MOBILEWHEELED PENDULUM MOVING ON AN INCLINED PLANE <i>Danielle Sami Nasrallah, Hannab Michalska and Jorge Angeles</i>	34
NEUROLOGICAL AND ENGINEERING APPROACHES TO HUMAN POSTURAL CONTROL <i>Karim Tabboub, Thomas Mergner and Christoph Ament</i>	42
PARTICLE-FILTER APPROACH AND MOTION STRATEGY FOR COOPERATIVE LOCALIZATION <i>Fernando Gomez Bravo, Alberto Vale and Maria Isabel Ribeiro</i>	50
SEMIOTICS AND HUMAN-ROBOT INTERACTION <i>João Silva Sequeira and Maria Isabel Ribeiro</i>	58
INTERACTION CONTROL EXPERIMENTS FOR A ROBOT WITH ONE FLEXIBLE LINK <i>L. F. Baptista, J. M. M. Martins and J. M. G. Sá da Costa</i>	66
TOWARD 3D FREE FORM OBJECT TRACKING USING SKELETON <i>Djamel Merad and Jean-Yves Didier</i>	74
A GAIN-SCHEDULING APPROACH FOR AIRSHIP PATH-TRACKING <i>Alexandra Moutinho and José Raul Azinheira</i>	82
SMOOTH TRAJECTORY PLANNING FOR FULLY AUTOMATED PASSENGERS VEHICLES - Spline and Clothoid based Methods and its Simulation <i>Larissa Labakhua, Urbano Nunes, Rui Rodrigues and Fátima S. Leite</i>	89
IMPROVING TRACKING TRAJECTORIES WITH MOTION ESTIMATION <i>Jorge Pomares, Gabriel J. García and Fernando Torres</i>	97
DIFFERENT CLASSIFIERS FOR THE PROBLEM OF EVALUATING CORK QUALITY IN AN INDUSTRIAL SYSTEM <i>Beatriz Paniagua-Paniagua, Miguel A. Vega-Rodríguez, Juan A. Gómez-Pulido and Juan M. Sánchez-Pérez</i>	104
DEPTH GRADIENT IMAGE BASED ON SILHOUETTE - A Solution for Reconstruction of Scenes in 3D Environments <i>Pilar Merchán, Antonio Adán and Santiago Salamanca</i>	112
LOCALIZATION WITH DYNAMIC MOTION MODELS - Determining Motion Model Parameters Dynamically in Monte Carlo Localization <i>Adam Milstein and Tao Wang</i>	120

REACTIVE SIMULATION FOR REAL-TIME OBSTACLE AVOIDANCE <i>Mariolino De Cecco, Enrico Marcuzzi, Luca Baglivo and Mirco Zaccariotto</i>	128
--	-----

SHORT PAPERS

PATTERN TRACKING AND VISUAL SERVOING FOR INDOOR MOBILE ROBOT ENVIRONMENT MAPPING AND AUTONOMOUS NAVIGATION <i>O. Ait Aider, G. Blanc, Y. Mezouar and P. Martinet</i>	139
--	-----

A NOVEL HAPTIC INTERFACE FOR FREE LOCOMOTION IN EXTENDED RANGE TELEPRESENCE SCENARIOS <i>Patrick Rößler, Timothy Armstrong, Oliver Hessel, Michael Mende and Uwe D. Hanebeck</i>	148
--	-----

THE LAGR PROJECT - Integrating Learning into the 4D/RCS Control Hierarchy <i>James Albus, Roger Bostelman, Tsai Hong, Tommy Chang, Will Shackelford and Michael Shneier</i>	154
--	-----

PDPT FRAMEWORK - Building Information System with Wireless Connected Mobile Devices <i>Ondrej Krejcar</i>	162
--	-----

HUMAN ARM-LIKE MECHANICAL MANIPULATOR - The Design and Development of a Multi -Arm Mobile Robot for Nuclear Decommissioning <i>Mohamed J. Bakari and Derek W. Seward</i>	168
--	-----

MTR: THE MULTI-TASKING ROVER - A New Concept in Rover Design <i>Antonios K. Bouloumbasis, Gerard T. McKee, Paul M. Sharkey and Peter Tolson</i>	176
--	-----

OPTIMAL PLANNING FOR AUTONOMOUS AGENTS UNDER TIME AND RESOURCE UNCERTAINTY <i>Aurélie Beynier, Laurent Jeanpierre and Abdel-Ilbab Mouaddib</i>	182
--	-----

COMBINING REINFORCEMENT LEARNING AND GENETIC ALGORITHMS TO LEARN BEHAVIOURS IN MOBILE ROBOTICS <i>R. Iglesias, M. Rodríguez, C. V. Regueiro, J. Correa and S. Barro</i>	188
---	-----

ROBUST MULTI-ROBOT COOPERATION THROUGH DYNAMIC TASK ALLOCATION AND PRECAUTION ROUTINES <i>Sanem Sariel, Tucker Balch and Nadia Erdogan</i>	196
--	-----

ELECTRONIC SOLUTION BASED ON MICRO-CONTROLLER AT91SAM7S256 FOR PLATOONING MULTI-AGENT SYSTEM IMPLEMENTATION <i>José M. Rodríguez, AbdelBaset M. H. Awawdeh, Felipe Espinosa, Julio Pastor, Fernando Valdés, Miguel A. Ruiz and Antonio Gil</i>	202
--	-----

TWO LAYER CONTROL STRATEGY APPLIED TO BUILDING AUTOMATION <i>João Figueiredo and José Sá da Costa</i>	210
--	-----

HYBRID IMPEDANCE CONTROL FOR MULTI-SEGMENTED INSPECTION ROBOT Kairo-II <i>C. Birkenbofer, S. Studer, J. M. Zöllner and R. Dillmann</i>	217
---	-----

MANAGING CONTROL ARCHITECTURES DESIGN PROCESS - Patterns, Components and Object Petri Nets in Use <i>Robin Passama, David Andreu, Christophe Dony and Thérèse Libourel</i>	223
--	-----

COOPERATIVE MAP BUILDING USING QUALITATIVE REASONING FOR SEVERAL AIBO ROBOTS <i>David A. Graullera, Salvador Moreno and Maria Teresa Escrig</i>	229
---	-----

AUTONOMOUS BEHAVIOR-BASED EXPLORATION OF OFFICE ENVIRONMENTS <i>Daniel Schmidt, Tobias Luksch, Jens Wettach and Karsten Berns</i>	235
--	-----

TOWARDS A SLAM SOLUTION FOR A ROBOTIC AIRSHIP <i>Cesar Castro, Samuel Bueno and Alessandro Victorino</i>	241
MONTE CARLO LOCALIZATION IN HIGHLY SYMMETRIC ENVIRONMENTS <i>Stephan Sebestedt and Frank E. Schneider</i>	249
A NEW SENSORIAL AND DRIVING LOCOMOTION INTERFACE FOR VIRTUAL REALITY <i>Yves Dupuis, Jean-Luc Impagliazzo, Cédric Anthierens and Dominique Millet</i>	255
ONLINE HIERACHICAL CONTROL FOR LEGGED SYSTEMS BASED ON THE INTERACTION FORCES <i>José R. Puga, Filipe M. Silva and Boaventura R. da Cunha</i>	261
A PERFORMANCE METRIC FOR MOBILE ROBOT LOCALIZATION <i>Antonio Ruiz-Mayor, Gracián Triviño and Gonzalo Bailador</i>	269
A STUDY ON ASR/TTS SERVER ARCHITECTURE FOR NETWORK ROBOT SYSTEM <i>In-Ho Choi and Tae-Hoon Kim</i>	277
ROBOT BEHAVIOR ADAPTATION FOR FORMATION MAINTENANCE <i>Maité López-Sánchez</i>	283
HIERARCHICAL MULTI-ROBOT COORDINATION - Aggregation Strategies Using Hybrid Communication <i>Yan Meng, Jeffrey V. Nickerson and Jing Gan</i>	289
PARTIAL STABILIZABILITY OF CASCADED SYSTEMS APPLICATIONS TO PARTIAL ATTITUDE CONTROL <i>Chaker Jammazi and Azgal Abichou</i>	296
SIMULTANEOUS LOCALIZATION AND MAPPING IN UNMODIFIED ENVIRONMENTS USING STEREO VISION <i>A. Gil, O. Reinoso, C. Fernández, M. A. Vicente, A. Rottmann and O. Martínez Mozos</i>	302
MISSION PLANNING, SIMULATION AND SUPERVISION OF UNMANNED AERIAL VEHICLE WITH A GIS-BASED FRAMEWORK <i>Pedro Gutierrez, Antonio Barrientos, Jaime del Cerro and Rodrigo San Martin</i>	310
A SEMANTICALLY RICH POLICY BASED APPROACH TO ROBOT CONTROL <i>Matthew Johnson, Jeffery Bradshaw, Paul Feltovich, Renia Jeffers, Hyuckchul Jung and Andrzej Uszok</i>	318
EYE AND GAZE TRACKING ALGORITHM FOR COLLABORATIVE LEARNING SYSTEM <i>Djamel Merad, Stephanie Metz and Serge Mignet</i>	326
A SOLUTION FOR EVALUATING THE STOPPER QUALITY IN THE CORK INDUSTRY <i>Beatriz Paniagua-Paniagua, Miguel A. Vega-Rodríguez, Juan A. Gómez-Pulido and Juan M. Sánchez-Pérez</i>	334
VISUAL SPEECH RECOGNITION USING WAVELET TRANSFORM AND MOMENT BASED FEATURES <i>Wai C. Yau, Dinesh K. Kumar, Sridhar P. Arjunan and Sanjay Kumar</i>	340
ROBUST AUGMENTED REALITY TRACKING BASED VISUAL POSE ESTIMATION <i>Madjid Maldi, Fakhr-Eddine Ababsa and Malik Mallem</i>	346
STUDIES ON VISUAL PERCEPTION FOR PERCEPTUAL ROBOTICS <i>Özger Ciftcioglu, Michael S. Bittermann and I. Sevil Sariyildiz</i>	352
ESTIMATION OF PERFORMANCE OF HEAVY VEHICLES BY SLIDING MODES OBSERVERS <i>N. K. M'Sirdi, A. Boubezoul, A. Rabbi and L. Fridman</i>	360

RANGE DETERMINATION FOR MOBILE ROBOTS USING ONE OMNIDIRECTIONAL CAMERA <i>Ola Millnert, Toon Goedemé, Tinne Tuytelaars, Luc Van Gool, Alexander Hütemann and Marnix Nuttin</i>	366
ELLIPTIC NET - A PATH PLANNING ALGORITHM FOR DYNAMIC ENVIRONMENTS <i>Martin Saska, Miroslav Kulich and Libor Přeučil</i>	372
AN ENERGY-BASED BACKGROUND MODELLING ALGORITHM FOR MOTION DETECTION <i>Paolo Spagnolo, Marco Leo, Tiziana D'Orazio, Andrea Caroppo and Tommaso Martiriggiano</i>	378
LOGGING, ALERT & EMERGENCY SYSTEM FOR ROAD TRANSPORT VEHICLES - AN EXPERIMENTAL ECALL, BLACK-BOX AND DRIVER ALERTING SYSTEM <i>Javier Fernández, Fernando Cantalapiedra, Mario Mata, Veronica Egido and Sergio Bemposta</i>	384
STATIC FACE DETECTION AND EMOTION RECOGNITION WITH FPGA SUPPORT <i>Paul Santi-Jones and Dongbing Gu</i>	390
MULTIPLE MOBILE ROBOTS MOTION-PLANNING: AN APPROACH WITH SPACE-TIME MCA <i>Fabio M. Marchese</i>	398
NEURO-ADAPTIVE DYNAMIC CONTROL FOR TRAJECTORY TRACKING OF MOBILE ROBOTS <i>Marvin K. Bugeja and Simon G. Fabri</i>	404
TRAJECTORY CONTROL AND MODELLING OF AN OMNI-DIRECTIONAL MOBILE ROBOT <i>André Scolari Conceição, A. Paulo Moreira and Paulo J. Costa</i>	412
REDUCING ACCUMULATED ERRORS IN EGO-MOTION ESTIMATION USING LOCAL BUNDLE ADJUSTMENT <i>Akihiro Sugimoto and Tomobiko Ikeda</i>	418
A SPECIFIC LOCOMOTION INTERFACE FOR VIRTUAL REALITY - Design of a Wheelchair Type Haptic <i>Cédric Anthierens, Jean-Luc Impagliazzo, Yves Dupuis and Eric Richard</i>	426
IMPROVING THE RESULTS OF THE CONTENT-BASED IMAGE QUERY ON MEDICAL IMAGERY <i>Liana Stanescu, Dan Dumitru Burdescu, Anca Ion and Marius Brezovan</i>	432
A PATH PLANNING STRATEGY FOR OBSTACLE AVOIDANCE <i>Guillaume Blanc, Youcef Mezouar and Philippe Martinet</i>	438
A HYBRID FEEDBACK CONTROLLER FOR CAR-LIKE ROBOTS - Combining Reactive Obstacle Avoidance and Global Replanning <i>Matthias Hentschel, Oliver Wulf and Bernardo Wagner</i>	445
POSTERS	
DEVELOPMENT OF HIGH PERFORMANCE SERVO DRIVE/ANTI DRIVE MECHANISM FOR BACKLASH REMOVAL <i>I. Askari, S. A. Hassan, M. Altaf, A. Azim, M. B. Malik and K. Munawar</i>	453
N-ARY TREES CLASSIFIER <i>Duarte Duque, Henrique Santos and Paulo Cortez</i>	457
DESIGN OF A PROTOTYPE ROBOT VACUUM CLEANER - From Virtual Prototyping to Real Development <i>Leire Maruri, Ana Martínez-Esnaola, Joseba Landaluze, Sergio Casas and Marcos Fernandez</i>	461

IMPROVED METHOD FOR HIGHLY ACCURATE INTEGRATION OF TRACK MOTIONS <i>Michael Kleinkes, Werner Neddermeyer and Michael Schnell</i>	469
A NEW METHOD FOR REJECTION OF UNCERTAINTIES IN THE TRACKING PROBLEM FOR ROBOT MANIPULATORS <i>Juan A. Méndez, S. Torres, L. Acosta, E. González and V. M. Becerra</i>	474
PERFORMANCE ANALYSIS OF CSMA/CA PROTOCOL IN IEEE 802.11 NETWORKS USING BACKOFF MECHANISM <i>Amitb M. N.</i>	478
THE VISIBILITY PROBLEM IN VISUAL SERVOING <i>C. Pérez, R. Morales, N. García-Aracil, J. M. Azorín and J. M. Sabater</i>	482
LOCALITY AND GLOBALITY: ESTIMATIONS OF THE ENCRYPTION COLLECTIVITIES <i>Cristian Lăpu, Tudor Niculin and Eduard Franți</i>	486
PERFORMANCE EVALUATION OF A CONTROLLED FLOW-SHOP SYSTEM WITH A TIMED PETRI NET MODEL <i>Loïc Plassart, Philippe Le Parc, Frank Singhoff and Lionel Marcé</i>	494
OPTICAL FLOW NAVIGATION OVER ACROMOVI ARCHITECTURE <i>Patricio Nebot and Enric Cervera</i>	500
STEREO DISPARITY ESTIMATION USING DISCRETE ORTHOGONAL MOMENTS <i>Tomasz Andrysiak and Michał Choraś</i>	504
DISTRIBUTED CONTROL SYSTEM OF AN EXPERIMENTAL ROBOTIC CELL WITH 3D VISION <i>Andrés S. Vázquez, Antonio Adán, Roberto Torres and Carlos Cerrada</i>	508
A TECHNIQUE FOR IMPERCEPTIBLE EMBEDDING OF DATA IN A COLOR IMAGE <i>Kaliappan Gopalan</i>	512
GLOBAL OPTIMIZATION OF PERFORMANCE OF A 2PRR PARALLEL MANIPULATOR FOR COOPERATIVE TASKS <i>Héctor A. Moreno, J. Alfonso Pámanes, Philippe Wenger and Damien Chablat</i>	516
A MULTI-AGENT COLLABORATIVE CONTROL ARCHITECTURE WITH FUZZY ADJUSTMENT FOR A MOBILE ROBOT <i>Bianca Innocenti, Beatriz López and Joaquim Salvi</i>	523
POWER ESTIMATION FOR REGISTER TRANSFER LEVEL BY GENETIC ALGORITHM <i>Yaseer A. Durrani, Teresa Riesgo and Felipe Machado</i>	527
ESTIMATION OF ROAD PROFILE USING SECOND ORDER SLIDING MODE OBSERVER <i>A. Rabbi, N. K. M'Sirdi, M. Ouladsine and L. Fridman</i>	531
ACO BASED METHOD COMPARATION APPLIED TO FLEET MANAGEMENT PROBLEM <i>Miriam Anton-Rodriguez, Daniel Boto-Giralda, Francisco J. Diaz-Pernas and J. Fernando Diez-Higuera</i>	535
MULTIPROCESSOR ROBOT CONTROLLER - An Experimental Robot Controller for Force-Torque Control Tasks <i>István Oláb and Gábor Tevesz</i>	540
ROBOTIC ARCHITECTURE BASED ON ELECTRONIC BUSINESS MODELS - From Physics Components to Smart Services <i>José Vicente Berná-Martínez, Francisco Maciá-Pérez, Virgilio Gilart-Iglesias and Diego Marcos-Jorequera</i>	544

FAULT DETECTION OF THE ACTUATOR BLOCKING - Experimental Results in Robot Control Structures <i>Matei Vinatoru and Eugen Iancu</i>	548
EXTRACTION OF SIGNIFICANT REGIONS IN COLOR IMAGES FOR LANDMARK IDENTIFICATION <i>Jose-Luis Albarral and Enric Celaya</i>	552
A HOLONIC FAULT TOLERANT MANUFACTURING PLATFORM WITH MULTIPLE ROBOTS <i>Theodor Borangiu, Florin Daniel Anton, Silvia Tunaru and Anamaria Dogar</i>	557
A NEW HYBRID SAMPLING STRATEGY FOR PRM PLANNERS - To Address Narrow Passages Problem <i>Sofiane Ahmed Ali, Eric Vasselín and Alain Faure</i>	561
DYNAMIC PARAMETERS IDENTIFICATION OF AN OMNI-DIRECTIONAL MOBILE ROBOT <i>André Scolari Conceição, A. Paulo Moreira and Paulo J. Costa</i>	565
MANAGEMENT OF A MULTICAMERA TRACKING SYSTEM <i>C. Motamed and R. Lherbier</i>	571
AUTHOR INDEX	577

Posters

A MULTI-AGENT COLLABORATIVE CONTROL ARCHITECTURE WITH FUZZY ADJUSTMENT FOR A MOBILE ROBOT

Bianca Innocenti, Beatriz López, Joaquim Salvi
Institute of Informatics and Applications
University of Girona - Spain
Email: {bianca,blopez,qsalvi}@eia.udg.es

Keywords: Robot design, control architecture, mobile robots.

Abstract: One of the current challenges of control research is to make systems capable of showing intelligent responses to changing circumstances. To address this task, more complex systems are being developed. However, it is technologically difficult and potentially dangerous to build complex systems that are controlled in a completely centralized way. One approach to building decentralization systems is using multi-agent technology for building control architectures. But it seems risky to recursively extend using multi-agent systems to develop part of the system, such as a single behaviour. One alternative approach is to use collaborative control to deploy specific (low level) behaviours, so that several controllers are combined in a single agent of the multi-agent architecture in order to achieve the wanted behaviour. This paper presents a collaborative controller applied to the goto behaviour. The experiments were carried out using a Pioneer mobile robot.

1 INTRODUCTION

One of the current challenges of control is to make systems capable of showing highly flexible and intelligent responses to changing circumstances. Artificial Intelligence provides learning and adaptation methods, as well as decision making techniques to achieve these control properties. However, it is technologically difficult and potentially dangerous to build complex systems that are controlled in a completely centralized way (Murray et al., 2003).

In this line, (Rosenblatt, 1997) built an architecture composed of distributed, independent, asynchronous decision-making behaviours that were coordinated by a central arbiter. The overall behaviour of the system is rational, coherent and goal-oriented while preserving real-time responsiveness to its immediate physical environment. In (Bryson, 2001) several architectures are analyzed. The advantages of this architecture are the following: they facilitate their development and lead to the evolutionary creation of robust systems of incrementally greater capabilities. In these architectures, each behaviour is implemented by a module with communication abilities.

Recent advances in Multi-Agent Systems (MAS) have inspired researchers to go one abstract level further in implementing the architectures, in which mo-

dules are replaced by agents.

Nevertheless, behaviours considered in these architectures are not simple. For example, a **goto** behaviour, in a free-obstacle path, should take into account if the target point is close or far away from the current robot position.

In order to tackle the design of each behaviours, two approaches can be followed. On one hand, each behaviour can be implemented as a MAS again, assuming the risk that the robot could not be reactive enough to avoid obstacles when it moves too fast or the obstacles are mobile. And on the other hand, it is possible to take advantage of collaborative control to make up a single behaviour, combining several controllers in a single agent.

Integrating both research lines (the multi-agent approach and collaborative control) we get as a result a MAS architecture with collaborative controllers. Collaborative control is applied to design and develop a single behaviour, while the overall robot architecture is based on a MAS where each agent represents each behaviour. In this paper we give a detailed explanation of how the collaborative control approach based on Fuzzy Logic (Klir and Folger, 1992) is implemented in a single agent. Details on the MAS approach can be found in (Innocenti et al., 2006).

This paper is organized as follows. In Section 2,

the related work is presented. Then, in Section 3 the MAS architecture is described while the collaborative control proposal is given in Section 4. In Section 5 the results are shown. Finally, some conclusions and future work are drawn in Section 6.

2 RELATED WORK

As stated above, our approach concerns MAS and collaborative control. Collaborative control has a general meaning, so, each time an algorithm to control a complex task is defined, the idea of collaboration in control is introduced. Thus, any development of complex systems with MAS can be considered as a collaborative approach.

On one hand, there are several architectures built as multi-agent systems to control a single robot, as for example (Neves and Oliveira, 1997), (Busquets et al., 2003), (Giorgini et al., 2002) or (Ros et al., 2005). Most of them present a centralized behaviour coordination and each behaviour has only one controller to set the desired outputs.

On the other hand, there are some works related to collaborative control in robots ((Goldberg and Chen, 2001), (Figueras et al., 2002), (Gerkey et al., 2002)). In the latter, collaborative control is obtained by relying on the physical dynamics of the robot's actuator. Due to their nature, motors temporally average their inputs, so Gerkey and colleagues propose that a population of non-communicating controllers drive the robot by interleaving commands to them. The resultant robot motion is then achieved as a superposition of the different control signals.

In accordance with (Saffiotti, 1997), our hypothesis is that, instead of superposing measures, higher decision making procedures can be used to coordinate the different controllers. Particularly, we propose using Fuzzy Logic to model the control actions provided by heterogeneous controllers and to decide, according to the robot motion dynamics, which combination of control actions have to be executed at a given time.

In addition, the output of the collaborative controller is the output of a single behaviour, instead of being directly connected to the robot actuators. The output of the single behaviour (agent) is coordinated in a multi-agent architecture to decide the next robot action.

3 MAS ARCHITECTURE

In our MAS architecture, agents can be grouped into perception, behavioural, actuator and deliberative agents. Perception agents obtain information about the environment and about the internal conditions of

the robot; behavioural agents carry out specific actions, such as avoiding obstacles; deliberative agents implement high-level tasks such as planning; and actuator agents are in charge of controlling the linear and angular speed of the robot interacting directly with motors.

The **goto** agent is a behavioural agent which is responsible for driving the robot to the target position at different speeds. Other behavioural agents, are the **avoid** agent, responsible for avoiding obstacles and the **goThrough** agent, that is in charge of driving the robot through narrow places like doors. All the agents coordinate their behaviours by means of a distributed protocol in order to assure that no conflicting actions are sent to the robot motors (see (Innocenti et al., 2006) for a detailed explanation).

4 COLLABORATIVE CONTROL

In this section we present our collaborative control method based on combining multiple controllers using Fuzzy Logic to implement the behaviour of the **goto** agent.

Instead of developing only one quite elaborated controller, we design several controllers to cope with different control aspects separately and join their actions in order to obtain the complex behaviour of the **goto** agent.

Our starting point is the aggregation function proposed in (Gerkey et al., 2002), that we extend by adding weights corresponding to the relevance of each controller according to the current context. Therefore, the desired speed calculation is defined as:

$$\Omega = \frac{\sum_{i=1}^n \eta_i \cdot w_t}{\sum_{t=1}^n w_t} \quad (1)$$

where η_i is the requested wheel speed over time, Ω the final wheel speed, n the number of controllers and w_t the weights that satisfy $\sum_{t=1}^n w_t = 1$. By using weights, it is possible, to give more or less importance to the controllers.

In order to determine the weights, we propose to introduce knowledge about the environment, such as whether the robot is near the destination point or not. Depending on this information, we can combine two position controllers: one that is *fast* and the other that is *accurate*. When the robot is **far** away from the destination point, we can stress the fast controller; when the robot gets **closer** to its destination, we can give more importance to the commands provided by the accurate one.

Fuzzy terms such as **far** or **close** can be modelled by fuzzy sets, in terms of the distance left (d) to the destination point. d is defined as $d = (d_{max} - d_{rec})/d_{max}$ where d_{max} is the distance between the

initial and final coordinates, and d_{rec} , the distance from the initial to the current coordinates. Thus, the fuzzy set **close** is defined as:

$$\mu_c(d) = \left\{ \begin{array}{ll} 1 & d \leq min \\ \frac{(-d+max)}{(max-min)} & min < d < max \\ 0 & d \geq max \end{array} \right\} \quad (2)$$

where min and max parameters have been tuned empirically.

According to this definition and depending on the robot's movement, the distance to the destination point can be nonlinear along time, making the fuzzy set also nonlinear.

On the other hand, the fuzzy set **far** is defined as:

$$\mu_f(d) = 1 - \mu_c(d); \quad (3)$$

Based on the above fuzzy set definition, we can resolve the fuzzy concurrent control adjustment as:

$$\begin{aligned} w_{fast} &= \mu_f(d) \\ w_{slow} &= \mu_c(d) \end{aligned} \quad (4)$$

where w_{fast} corresponds to the weight of the faster controller and w_{slow} to the accurate one.

Note that the way we use the fuzzy values determines, according to equation 1, the relevance of the commands of the different controllers. According to equation 4, both controllers collaborate in an intermediate situation, that is, in the sloping part of the fuzzy sets. Therefore, there is no abrupt change in the control, but progressively one controller has less influence in the final decision while the other one takes control (fuzzy adjustment).

5 RESULTS

We have implemented the MAS architecture in C++ adhoc MAS platform due to communication constraints. The experiment shown in this paper focus on the implementation of goto agent as a collaborative controller, so we assure that they were performed in obstacle-free paths meaning that the goto agent does not need to coordinate its desired actions with the rest of the behavioural agents in the MAS architecture. All the experiments were carried out with our own model (Innocenti et al., 2004) of the commercial robot Pioneer 2DX of ActivMedia Robotics.

In order to design the goto agent, we choose to implement two different controllers and mix both control vectors by means of fuzzy weights. One position controller is very fast but does not arrive exactly to the set-point while the other is accurate and reaches

the desired input. The output of the controllers are the desired linear and angular speeds. The best accurate controller achieved has a settling time of at least twice the time taken by the fast controller.

The control loop of the proposed concurrent control is shown in Fig. 1. The fuzzy concurrent control adjustment block is in charge of mixing the desired speeds of the controllers in order to change progressively from one controller to the other.

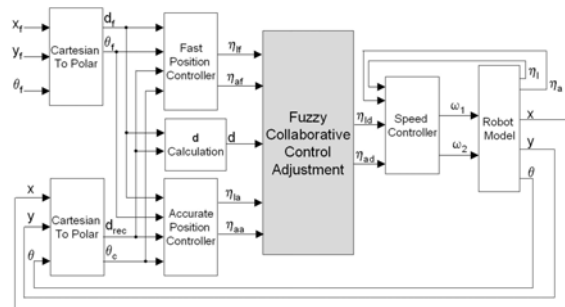


Figure 1: Block diagram of collaborative control loop.

Fig. 2 shows the response of the whole system using the collaborative control (1) for the initial position and heading of $(x_0, y_0, \theta_0) = (0, 0, 0)$ and the desired set-point of $(x_f, y_f, \theta_f) = (-1, 5, 0)$.

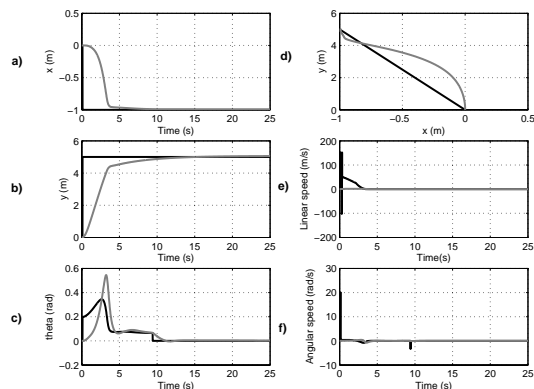


Figure 2: Response of the fuzzy concurrent control.

One interesting feature of this concurrent controller is that it works better than the controllers separately, especially for the unreachable states produced by the non-linear nature of the robot model. This behaviour can be seen in Fig. 3, where the graphics represents the response for the accurate controller, the fast one, and the collaborative approach respectively.

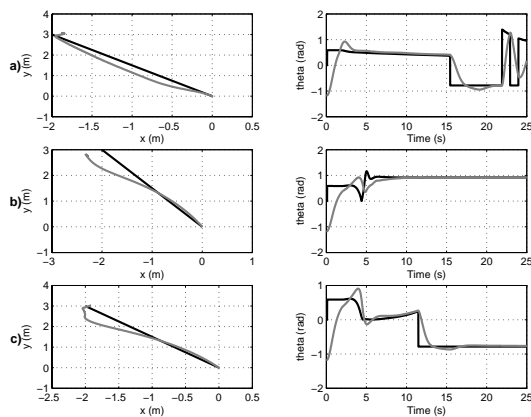


Figure 3: Comparison of the response of the controllers; a) the slow controller, b) the fast controller and c) the concurrent control.

6 CONCLUSIONS

In this paper we present a robot collaborative control architecture based on integrating recent advances in multi-agent systems and collaborative control. In particular, we focus on the design of a single agent, the goto agent, based on a fuzzy adjustment of two position controllers. This approach tries to introduce higher knowledge into the decision making process of the control system. We propose modelling the relevance of the controllers as a fuzzy set, considering the distance travelled by the robot.

To test our method, we have designed the goto agent of the MAS architecture with the proposed collaborative controller. We have performed several experiments to evaluate the responsiveness and efficiency of our architecture. With the fuzzy collaborative control, in which both controllers are combined, the response of the controlled system for several set-points is faster than the response of the accurate controller and more accurate than the response produced by the faster controller. Furthermore, it works for some of the unreachable set-points of the previous experiments (isolated controllers).

As further work, we are planning to extend our approach to n controllers. In addition, we are also exploring the extension of the collaborative control to other agents, such as the goThrough agent, which is responsible for driving the robot through narrow spaces, such as corridors or doors.

ACKNOWLEDGEMENTS

This work has been partially supported by the Spanish MEC Project TIN2004-06354-C02-02 and DURSI-AGAUR 00296SGR.

REFERENCES

- Bryson, J. (2001). *Intelligence by Design: Principles of Modularity and Coordination for Engineering Complex Adaptive Agents*. PhD thesis, Massachusetts Institute of Technology.
- Busquets, D., Sierra, C., and López de Mántaras, R. (2003). A multiagent approach to qualitative landmark-based navigation. *Autonomous Robots*, 15:129 – 154.
- Figueras, A., Colomer, J., and De la Rosa, J. (2002). Supervision of heterogeneous controllers for a mobile robot. In *The XV World Congress IFAC*.
- Gerkey, B., Mataric, M., and Sukhatme, G. (2002). Exploiting physical dynamics for concurrent control of a mobile robot. *Proceedings ICRA '02. IEEE International Conference on Robotics and Automation*, 4:3467 – 3472.
- Giorgini, P., Kolp, M., and Mylopoulos, J. (2002). Socio-intentional architectures for multi-agent systems: The mobile robot control case. *Proceedings of the Fourth International Bi-Conference Workshop on Agent-Oriented Information Systems (AOIS-02) at CAiSE2002, Toronto, Canada*.
- Goldberg, K. and Chen, B. (2001). Collaborative control of robot motion: robustness to error. In *Proceedings of the 2001 IEEE/RSJ International Conference on Intelligent Robots and Systems*, pages 655–660.
- Innocenti, B., López, B., and Salvi, J. (2006). How MAS support distributed robot control. *International Symposium of Robotics (ISR)*.
- Innocenti, B., Ridao, P., Gascons, N., El-Fakdi, A., López, B., and Salvi, J. (2004). Dynamical model parameters identification of a wheeled mobile robot. *5th IFAC/EURON Symposium on Intelligent Autonomous Vehicles (preprints)*.
- Klir, G. J. and Folger, T. A. (1992). *Fuzzy Sets, Uncertainty, and Information*. Prentice Hall.
- Murray, R., Åström, K., Boyd, S., Brockett, R., and Stein, G. (2003). Future directions in control in an information-rich world. *IEEE Control Systems Magazine*, 23, issue 2:20 – 33.
- Neves, M. C. and Oliveira, E. (1997). A multi-agent approach for a mobile robot control system. *Proceedings of Workshop on "Multi-Agent Systems: Theory and Applications" (MASTA'97 - EPPIA'97) - Coimbra -Portugal*, pages 1 – 14.
- Ros, R., de Mántaras, R. L., Sierra, C., and Arcos, J. L. (2005). A cbr system for autonomous robot navigation. *Frontiers in Artificial Intelligence and Applications 131, IOS Press*, pages 299–306.
- Rosenblatt, J. K. (1997). *DAMN: A Distributed Architecture for Mobile Navigation*. PhD thesis, Robotics Institute at Carnegie Mellon University.
- Saffiotti, A. (1997). The uses of fuzzy logic in autonomous robot navigation. *Soft Computing*, 1(4):180 – 197.

AUTHOR INDEX

Ababsa, F.	346	Cantalapiedra, F.	384
Abichou, A.	296	Caroppo, A.	378
Acosta, L.	474	Casas, S.	461
Adán, A.	112, 508	Castro, C.	241
Aider, O.	139	Cecco, M.	128
Albarral, J.	552	Celaya, E.	552
Albus, J.	154	Cerrada, C.	508
Ali, S.	561	Cerro, J.	310
Altaf, M.	453	Cervera, E.	500
Ament, C.	42	Chablat, D.	516
Andreu, D.	223	Chang, T.	154
Andrysiak, T.	504	Choi, I.	277
Angeles, J.	34	Choras, M.	504
Anthierens, C.	255, 426	Ciftcioglu, Ö.	352
Anton, F.	557	Conceição, A.	412, 565
Anton-Rodriguez, M.	535	Correa, J.	188
Arjunan, S.	340	Cortez, P.	457
Armstrong, T.	148	Costa, J.	66, 210
Askari, I.	453	Costa, P.	412, 565
Awawdeh, A.	202	Cunha, B.	261
Azim, A.	453	D’Orazio, T.	378
Azinheira, J.	82	Diaz-Pernas, F.	535
Azorín, J.	482	Didier, J.	74
Baglivo, L.	128	Diez-Higuera, J.	535
Bailador, G.	269	Dillmann, R.	217
Bakari, M.	168	Dogar, A.	557
Balch, T.	196	Dony, C.	223
Baptista, L.	66	Dupuis, Y.	255, 426
Barrientos, A.	310	Duque, D.	457
Barro, S.	188	Durrani, Y.	527
Becerra, V.	474	Egido, V.	384
Bemposta, S.	384	Erdogan, N.	196
Berná-Martínez, J.	544	Escrig, M.	229
Berns, K.	235	Espinosa, F.	202
Beynier, A.	182	Fabri, S.	404
Birkenhofer, C.	217	Faure, A.	561
Bittermann, M.	352	Feltovich, P.	318
Blanc, G.	139, 438	Fernández, C.	302
Borangui, T.	557	Fernández, J.	384
Bostelman, R.	154	Fernandez, M.	461
Boto-Giralda, D.	535	Figueiredo, J.	210
Boubezoul, A.	360	Franți, A.	486
Bouloubasis, A.	176	Fridman, L.	360, 531
Bradshaw, J.	318	Gan, J.	289
Bravo, F.	50	García, G.	97
Brezovan, M.	432	García-Aracil, N.	482
Bruneau, O.	26	Gil, A.	202, 302
Bueno, S.	241	Gilart-Iglesias, V.	544
Bugeja, M.	404	Goedemé, T.	3, 366
Burdescu, D.	432	Gómez-Pulido, J.	104, 334

AUTHOR INDEX (CONT.)

González, E.....	474	Marcuzzi, E.....	128
Gool, L.....	3, 366	Martin, R.	310
Gopalan, K.....	512	Martinet, P.....	139, 438
Graullera, D.	229	Martinez-Esnaola, A.....	461
Gu, D.....	390	Martins, J.....	66
Gutierrez, P.....	310	Martiriggiano, T.	378
Hanebeck, U.....	148	Maruri, L.	461
Hassan, S.....	453	Mata, M.	384
Hentschel, M.....	445	McKee, G.	176
Hessel, O.....	148	Mende, M.	148
Hong, T.....	154	Méndez, J.....	474
Hüntemann, A.....	366	Meng, Y.....	289
Iancu, E.....	548	Merad, D.....	74, 326
Iglesias, R.....	188	Merchán, P.....	112
Ikeda, T.....	418	Mergner, T.....	42
Impagliazzo, J.....	255, 426	Metz, S.....	326
Innocenti, B.....	523	Mezouar, Y.....	139, 438
Ion, A.....	432	Michalska, H.....	34
Jammazi, C.....	296	Miguet, S.	326
Jeanpierre, L.....	182	Millet, D.	255
Jeffers, R.....	318	Millnert, O.....	366
Johnson, M.....	318	Milstein, A.....	120
Jung, H.....	318	Mohammed, B.	10
Khalid, T.....	10	Morales, R.	482
Kim, T.....	277	Moreira, A.....	412, 565
Kleinkes, M.....	469	Moreno, H.	516
Kräußling, A.....	18	Moreno, S.	229
Krejcar, O.....	162	Motamed, C.....	571
Kulich, M.....	372	Mouaddib, A.....	182
Kumar, D.	340	Mourad, Z.	10
Kumar, S.	340	Moutinho, A.	82
Labakhua, L.	89	Mozos, O.	302
Landaluze, J.	461	Munawar, K.....	453
Leite, F.....	89	N., A.	478
Leo, M.....	378	Nasrallah, D.....	34
Lherbier, R.....	571	Nebot, P.....	500
Libourel, T.	223	Neddermeyer, W.....	469
López, B.....	523	Nickerson, J.....	289
López-Sánchez, M.	283	Niculiu, T.....	486
Luksch, T.	235	Nunes, U.....	89
Lupu, C.	486	Nuttin, M.	366
M'Sirdi, N.....	360, 531	Oláh, I.	540
Machado, F.	527	Ouladsine, M.	531
Maciá-Pérez, F.....	544	Pámanes, J.	516
Madani, K.....	26	Paniagua-Paniagua, B.....	104, 334
Maidi, M.	346, 453	Parc, P.....	494
Mallem, M.	346	Passama, R.....	223
Marcé, L.....	494	Pastor, J.	202
Marchese, F.....	398	Pérez, C.	482
Marcos-Jorequera, D.....	544	Plassart, L.	494

AUTHOR INDEX (CONT.)

Pomares, J.	97	Uszok, A.	318
Přeučil, L.	372	Valdés, F.	202
Puga, J.	261	Vale, A.	50
Rabhi, A.	360, 531	Vasselin, E.	561
Regueiro, C.	188	Vázquez, A.	508
Reinoso, O.	302	Vega-Rodríguez, M.	104, 334
Ribeiro, M.	50, 58	Vicente, M.	302
Richard, E.	426	Victorino, A.	241
Riesgo, T.	527	Vinatoru, M.	548
Rodrigues, R.	89	Wagner, B.	445
Rodríguez, J.	202	Wang, T.	120
Rodríguez, M.	188	Wenger, P.	516
Rößler, P.	148	Wettach, J.	235
Rottmann, A.	302	Wulf, O.	445
Ruiz, M.	202	Yau, W.	340
Ruiz-Mayor, A.	269	Zaccariotto, M.	128
Sabater, J.	482	Zöllner, J.	217
Sabourin, C.	26		
Salamanca, S.	112		
Salvi, J.	523		
Sánchez-Pérez, J.	104, 334		
Santi-Jones, P.	390		
Santos, H.	457		
Sariel, S.	196		
Sariyildiz, I.	352		
Saska, M.	372		
Schmidt, D.	235		
Schneider, F.	18, 249		
Schnell, M.	469		
Sehestedt, S.	18, 249		
Sequeira, J.	58		
Seward, D.	168		
Shackleford, W.	154		
Sharkey, P.	176		
Shneier, M.	154		
Silva, F.	261		
Singhoff, F.	494		
Spagnolo, P.	378		
Stanescu, L.	432		
Studer, S.	217		
Sugimoto, A.	418		
Tahboub, K.	42		
Tevesz, G.	540		
Tolson, P.	176		
Torres, F.	97		
Torres, R.	508		
Torres, S.	474		
Triviño, G.	269		
Tunaru, S.	557		
Tuytelaars, T.	3, 366		



Proceedings of ICINCO 2006
Third International Conference on
Informatics in Control, Automation and Robotics
ISBN: 972-8865-60-0
ISBN (13 digits): 978-972-8865-60-3
<http://www.icinco.org>