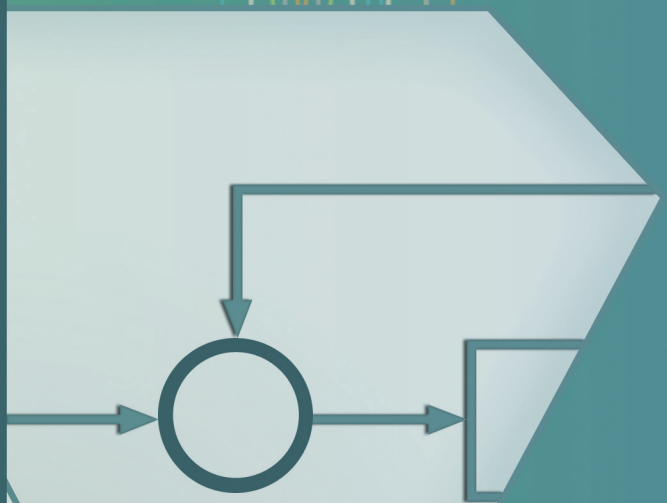
ICINCO 2012

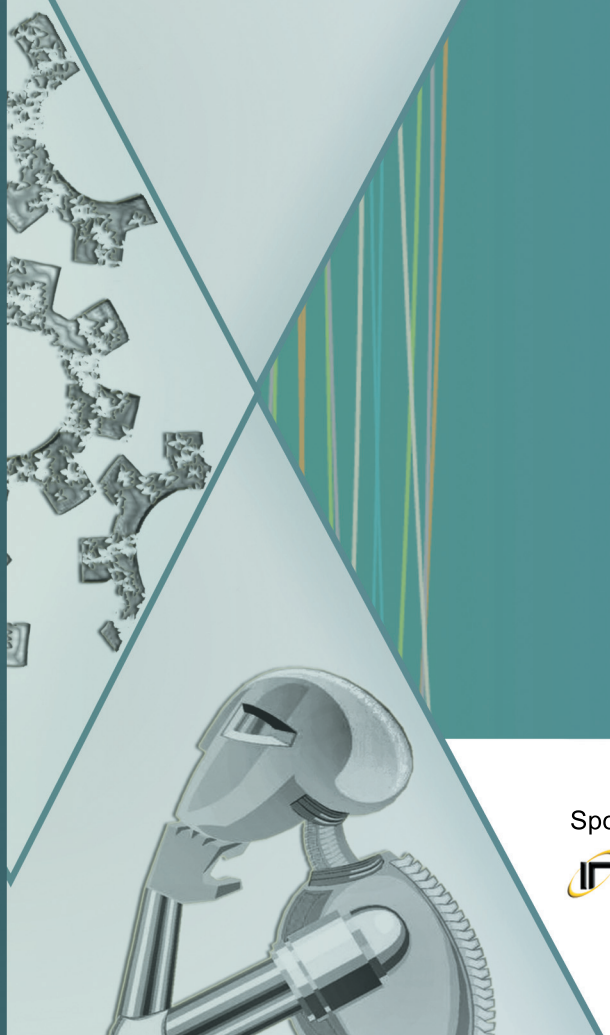
9th International Conference on
Informatics in Control, Automation and Robotics



Proceedings

Volume 2

Rome, Italy
28 - 31 July, 2012



Sponsored by: INSTICC

Co-Sponsored by: IFAC

In Cooperation with: AAAI, acm In-Cooperation, SIGART

ICINCO 2012

Proceedings of the
9th International Conference on
Informatics in Control, Automation and Robotics

Volume 2

Rome, Italy

28 - 31 July, 2012

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

Co-Sponsored by
IFAC – International Federation of Automatic Control

In Cooperation with
AAAI – Association for the Advancement of Artificial Intelligence
EUROMICRO
ACM – Association for Computing Machinery
ACM SIGART – ACM / Special Interest Group on Artificial Intelligence

Copyright © 2012 SciTePress – Science and Technology Publications
All rights reserved

Edited by Jean-Louis Ferrier, Alain Bernard, Oleg Gusikhin and Kurosh Madani

Printed in Portugal
ISBN: 978-989-8565-22-8
Depósito Legal: 344501/12

http://www.icinco.org/
icinco.secretariat@insticc.org

BRIEF CONTENTS

INVITED SPEAKERS IV

SPECIAL SESSIONS CHAIRS IV

ORGANIZING AND STEERING COMMITTEES V

PROGRAM COMMITTEE VI

AUXILIARY REVIEWERS XI

SPECIAL SESSIONS PROGRAM COMMITTEE XII

SELECTED PAPERS BOOK XII

FOREWORD XIII

CONTENTS XV

INVITED SPEAKERS

Alessandro De Luca

Università di Roma "La Sapienza"

Italy

Munther A. Dahleh

MIT

U.S.A.

Alexandre Dolgui

Ecole des Mines de Saint-Etienne

France

Jurek Sasiadek

Carleton University

Canada

SPECIAL SESSIONS CHAIRS

SPECIAL SESSION ON INTELLIGENT VEHICLE CONTROLS & INTELLIGENT TRANSPORTATION SYSTEMS

Oleg Gusikhin, Ford Research & Adv. Engineering, U.S.A.

SPECIAL SESSION ON OPERATIONS MANAGEMENT AND DECISION MAKING IN TODAY'S COMPETITIVE ENVIRONMENT

Amy Lee, Chung Hua University, Taiwan

ORGANIZING AND STEERING COMMITTEES

CONFERENCE CHAIR

Jean-Louis Ferrier, University of Angers, France

PROGRAM CO-CHAIRS

Alain Bernard, Ecole Centrale de Nantes, France

Oleg Gusikhin, Ford Research & Adv. Engineering, U.S.A.

Kurosh Madani, University of Paris-EST Créteil (UPEC), France

PROCEEDINGS PRODUCTION

Helder Coelhas, INSTICC, Portugal

Andreia Costa, INSTICC, Portugal

Patrícia Duarte, INSTICC, Portugal

Bruno Encarnação, INSTICC, Portugal

Liliana Medina, INSTICC, Portugal

Carla Mota, INSTICC, Portugal

Raquel Pedrosa, INSTICC, Portugal

Vitor Pedrosa, INSTICC, Portugal

Cláudia Pinto, INSTICC, Portugal

José Varela, INSTICC, Portugal

CD-ROM PRODUCTION

Pedro Varela, INSTICC, Portugal

GRAPHICS PRODUCTION AND WEBDESIGNER

Daniel Pereira, INSTICC, Portugal

SECRETARIAT

Marina Carvalho, INSTICC, Portugal

WEBMASTER

Susana Ribeiro, INSTICC, Portugal

PROGRAM COMMITTEE

Arvin Agah, The University of Kansas, U.S.A.

El-Houssaine Aghezzaf, Ghent University, Faculty of Engineering and Architecture, Belgium

Arturo Hernandez Aguirre, Centre for Research in Mathematics, Mexico

Eugenio Aguirre, University of Granada, Spain

Hyo-Sung Ahn, Gwangju Institute of Science and Technology (GIST), Korea, Republic of

Adel Al-Jumaily, University of Technology, Sydney, Australia

Frank Allgower, University of Stuttgart, Germany

Yacine Amirat, University Paris Est Créteil (UPEC), France

Stefan Andrei, Lamar University, U.S.A.

Peter Arato, Budapest University of Technology and Economics, Hungary

Rui Araujo, University of Coimbra, Portugal

Helder Araújo, University of Coimbra, Portugal

Carles Batlle Arnau, Universitat Politècnica de Catalunya, Spain

Tomas Arredondo, Universidad Tecnica Federico Santa Maria, Chile

Ronald Askin, Arizona State University, U.S.A.

T. Asokan, Indian Institute of Technology Madras, India

Wudhichai Assawinchaichote, King Mongkut's University of Technology Thonburi, Thailand

Ali Bab-Hadiashar, RMIT University, Australia

Jacky Baltes, University of Manitoba, Canada

Ruth Bars, Budapest University of Technology and Economics, Hungary

Laxmidhar Behera, Indian Institute of Technology, Kanpur, India

Karsten Berns, University of Kaiserslautern, Germany

Arijit Bhattacharya, Dublin City University, Ireland

Robert Bicker, Newcastle University, U.K.

Mauro Birattari, IRIDIA-CoDE, Université Libre de Bruxelles, Belgium

Christian Blum, Universitat Politècnica de Catalunya, Spain

Jean-louis Boimond, ISTIA - LISA, France

Magnus Boman, The Royal Institute of Technology, Sweden

Alan Bowling, University of Texas at Arlington, U.S.A.

Thomas Braunl, The University of Western Australia, Australia

Mietek Brdys, University of Birmingham, U.K.

Kevin Burn, University of Sunderland, U.K.

Amaury Caballero, Florida International University, U.S.A.

Javier Fernandez de Canete, University of Malaga, Spain

Giuseppe Carbone, LARM - Laboratorio di Robotica e Meccatronica, Italy

Alessandro Casavola, University of Calabria, Italy

Riccardo Cassinis, University of Brescia, Italy

Ratchatin Chanchareon, Chulalongkorn University, Thailand

Siam Charoenseang, Institute of Field Robotics, Thailand

Antonio Chella, Università di Palermo, Italy

Peter C. Y. Chen, National University of Singapore, Singapore

Wen-Hua Chen, Loughborough University, U.K.

Yuh-Min Chen, National Cheng Kung University, Taiwan

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

Graziano Chesi, University of Hong Kong, China

PROGRAM COMMITTEE (CONT.)

Tsung-Che Chiang, National Taiwan Normal University, Taiwan

Sung-Bae Cho, Yonsei University, Korea, Republic of

Ryszard S. Choras, University of Technology & Life Sciences, Poland

Chengbin Chu, Ecole Centrale Paris, France

Carlos Coello Coello, CINVESTAV-IPN, Mexico

James M. Conrad, University of North Carolina Charlotte, U.S.A.

Yechiel Crispin, Embry-riddle Aeronautical University, U.S.A.

José Boaventura Cunha, University of Trás-os-montes and Alto Douro, Portugal

Prithviraj (Raj) Dasgupta, University of Nebraska, U.S.A.

Michael A. Demetriou, Worcester Polytechnic Institute, U.S.A.

Mingcong Deng, Tokyo University of Agriculture and Technology, Japan

Rüdiger Dillmann, University of Karlsruhe, Germany

Dimos Dimarogonas, KTH, Sweden

Tony Dodd, The University of Sheffield, U.K.

Alexandre Dolgui, Ecole des Mines de Saint-Etienne, France

António Dourado, University of Coimbra, Portugal

Venky Dubey, Bournemouth University, U.K.

Marc Ebner, Ernst-Moritz-Arndt-Universität Greifswald, Germany

Petr Ekel, Pontifical Catholic University of Minas Gerais, Brazil

Mohammed El-Abd, American University of Kuwait, Kuwait

Atilla Elci, Suleyman Demirel University, Turkey

Simon G. Fabri, University of Malta, Malta

Paolo Falcone, Chalmers University of Technology, Sweden

David Fernández-Llorca, University of Alcalá, Spain

Paolo Fiorini, University of Verona, Italy

Juan J. Flores, University of Michoacan, Mexico

Heinz Frank, Heilbronn University Campus Kuenzelsau, Germany

Georg Frey, Saarland University, Germany

Ponnambalam S. G., Monash University Sunway Campus, Malaysia

Dragan Gamberger, Rudjer Boskovic Institute, Croatia

Nicholas Gans, University of Texas at Dallas, U.S.A.

Maria I. Garcia-Planas, Universitat Politecnica de Catalunya, Spain

Ryszard Gessing, Silesian University of Technology, Poland

Lazea Gheorghe, Technical University of Cluj-Napoca, Romania

Paulo Gil, Universidade Nova de Lisboa, Portugal

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

Alessandro Giua, University of Cagliari, Italy

Luis Gomes, Universidade Nova de Lisboa, Portugal

Bhaskaran Gopalakrishnan, West Virginia University, U.S.A.

Frans C. A Groen, University of Amsterdam, The Netherlands

Jason Gu, Dalhousie University, Canada

Kevin Guelton, University of Reims Champagne-Ardenne, France

José J. Guerrero, Universidad de Zaragoza, Spain

Eugenio Guglielmelli, Università Campus Bio-Medico, Italy

Lei Guo, Chinese Academy of Sciences (CAS), China

Thomas Gustafsson, Luleå University of Technology, Sweden

PROGRAM COMMITTEE (CONT.)

Maki K. Habib, The American University in Cairo, Egypt

Wolfgang Halang, Fernuniversitaet, Germany

John Hallam, University of Southern Denmark, Denmark

Jennifer Harding, Loughborough University, U.K.

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

Inman Harvey, University of Sussex, U.K.

Dominik Henrich, University of Bayreuth, Germany

Suranga Hettiarachchi, Indiana University Southeast, U.S.A.

Victor Hinostroza, University of Ciudad Juarez, Mexico

Kaoru Hirota, Tokyo Institute of Technology, Japan

Wladyslaw Homenda, Warsaw University of Technology, Poland

Fumiya Iida, Institute of Robotics and Intelligent Systems, ETH Zurich, Switzerland

Mirjana Ivanovic, Faculty of Sciences, University of Novi Sad, Serbia

Sarangapani Jagannathan, Missouri University of Science and Technology, U.S.A.

Masoud Jamei, Simcyp Limited, U.K.

Ray Jarvis, Monash University, Australia

Thira Jearsiripongkul, Thammasat University, Thailand

Myong K. Jeong, Rutgers University, U.S.A.

Ping Jiang, The University of Bradford, U.K.

Ivan Kalaykov, Örebro University, Sweden

Michail Kalogiannakis, University of Crete, Greece

Mansour Karkoub, Texas A&M University, Qatar

Dusko Katic, Mihailo Pupin Institute, Serbia

Behrokh Khoshnevis, University of Southern California, U.S.A.

DaeEun Kim, Yonsei University, Korea, Republic of

Jonghwa Kim, University of Augsburg, Germany

Diego Klabjan, Northwestern University, U.S.A.

Ashok K. Kochhar, Aston University, U.K.

Lingxue Kong, Deakin University, Australia

Waree Kongprawechnon, Thammasat University, Thailand

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

George L. Kovács, Hungarian Academy of Sciences, Hungary

Krzysztof Kozlowski, Poznan University of Technology, Poland

Mianowski Krzysztof, Politechnika Warszawska, Poland

Masao Kubo, Narional Defense Academy of Japan, Japan

Kin Keung Lai, City University of Hong Kong, Hong Kong

Kathryn J. De Laurentis, University of South Florida, U.S.A.

Soo-Young Lee, KAIST, Korea, Republic of

Graham Leedham, University of New England, Australia

Kauko Leiviskä, University of Oulu, Finland

Kang Li, Queen's University Belfast, U.K.

Tsai-Yen Li, National Chengchi University, Taiwan

Yangmin Li, University of Macau, China

Gordon Lightbody, University College Cork, Ireland

Huei-Yung Lin, National Chung Cheng University, Taiwan

Józef Lisowski, Gdynia Maritime University, Poland

Changchun Liu, The MathWorks, Inc., U.S.A.

Guoping Liu, University of Glamorgan, U.K.

Honghai Liu, University of Portsmouth, U.K.

Savvas Loizou, Cyprus University of Technology, Cyprus

PROGRAM COMMITTEE (CONT.)

Luís Seabra Lopes, University of Aveiro, Portugal

Gonzalo Lopez-Nicolas, Universidad de Zaragoza, Spain

Iuan-Yuan Lu, National Sun Yat-sen University, Taiwan

Edwin Lughofer, Johannes Kepler University, Austria

Martin Lukac, Tohoku University, Japan

José Tenreiro Machado, Institute of Engineering of Porto, Portugal

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

Nitaigour Mahalik, California State University - Fresno, U.S.A.

Bruno Maione, Politecnico Di Bari, Italy

Frederic Maire, Queensland University of Technology, Australia

Om Malik, University of Calgary, Canada

Jacek Mandziuk, Warsaw University of Technology, Poland

Philippe Martinet, Ecole Centrale de Nantes, France

Sonia Martínez, Mechanical and Aerospace Engineering department, UC San Diego, U.S.A.

Aníbal Matos, Faculdade de Engenharia da Universidade do Porto (FEUP), Portugal

Ross McAree, University of Queensland, Australia

Ken Mcgarry, University of Sunderland, U.K.

Carlo Menon, Simon Fraser University, Canada

Patrick Millot, University of Valenciennes, France

Sara Moein, Multimedia University, Malaysia

António Paulo Moreira, INESC Porto / FEUP, Portugal

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

Zoltan Nagy, Loughborough University, U.K.

Saeid Nahavandi, Deakin University, Australia

Andreas Nearchou, University of Patras, Greece

Luciana Nedel, Universidade Federal do Rio Grande do Sul (UFRGS), Brazil

Sergiu Nedevschi, Technical University of Cluj-Napoca, Romania

Maria Neves, Instituto Superior de Engenharia do Porto, Portugal

Juan A. Nolazco-Flores, ITESM, Campus Monterrey, Mexico

Andrzej Obuchowicz, University of Zielona Góra, Poland

José Valente de Oliveira, Universidade do Algarve, Portugal

Christos Panayiotou, University of Cyprus, Cyprus

Igor Paromtchik, INRIA, France

Bozenna Pasik-Duncan, University of Kansas, U.S.A.

Pierre Payeur, University of Ottawa, Canada

Fernando Lobo Pereira, University of Porto, Portugal

Marco Antonio Arteaga Perez, Universidad Nacional Autonoma de Mexico, Mexico

Jeff Pieper, University of Calgary, Canada

Selwyn Piramuthu, University of Florida, U.S.A.

Angel P. Del Pobil, Universitat Jaume I, Spain

Marie-Noëlle Pons, CNRS, France

Raul Marin Prades, Jaume I University, Spain

Robert Richardson, University of Leeds, U.K.

Julio Elias Normey Rico, Universidade Federal de Santa Catarina, Brazil

Juha Röning, University of Oulu, Finland

Mehdi Roopaei, University of Texas at San Antonio, U.S.A.

Danilo De Rossi, University of Pisa, Italy

Carlos Sagüés, University of Zaragoza, Spain

Mehmet Sahinkaya, University of Bath, U.K.

Antonio Sala, Universidad Politecnica de Valencia, Spain

PROGRAM COMMITTEE (CONT.)

Abdel-Badeeh Mohamed Salem, Ain Shams University, Egypt

Marcello Sanguineti, University of Genoa, Italy

Elena De Santis, University of L'Aquila, Italy

Srikanth Saripalli, Arizona State University, U.S.A.

Medha Sarkar, Middle Tennessee State University, U.S.A.

Nilanjan Sarkar, Vanderbilt University, U.S.A.

Jurek Sasiadek, Carleton University, Canada

Hideyuki Sawada, Kagawa University, Japan

Daniel Sbarbaro, Universidad de Concepcion, Chile

Klaus Schilling, University Würzburg, Germany

Carla Seatzu, University of Cagliari, Italy

Ali Selamat, Universiti Teknologi Malaysia, Malaysia

João Sequeira, Instituto Superior Técnico / Institute for Systems and Robotics, Portugal

Michael Short, Teesside University, U.K.

Dan Simon, Cleveland State University, U.S.A.

Olivier Simonin, INRIA - LORIA, France

Joaquin Sitte, Queensland University of Technology, New Zealand

Adam Slowik, Koszalin University of Technology, Poland

Andrzej Sluzek, Khalifa University of Science Technology and Research, U.A.E.

Qing Song, Nanyang Technological University, Singapore

Stefano Squartini, Università Politecnica delle Marche, Italy

Burkhard Stadlmann, Upper Austria University of Applied Sciences, Wels, Austria

Sergiu Stan, Technical University of Cluj-Napoca, Romania

Tarasiewicz Stanislaw, Université Laval, Canada

A. Frank Van Der Stappen, Utrecht University, The Netherlands

J. D. Stigter, Wageningen University, The Netherlands

Olaf Stursberg, University of Kassel, Germany

Kazuya Takeda, Nagoya University, Japan

Tianhao Tang, Shanghai Maritime University, China

József K. Tar, Óbuda University, Hungary

Abdelhamid Tayebi, Lakehead University, Canada

Daniel Thalmann, Nanyang Technological University, Singapore

Haydn A. Thompson, University of Sheffield, U.K.

Gui Yun Tian, Newcastle University, U.K.

N. G. Tsagarakis, Istituto Italiano di Tecnologia, Italy

Avgoustos Tsinakos, University of Kavala Institute of Technology / Athabasca University of Canada, Greece

Antonios Tsourdos, Cranfield University (Cranfield Defence and Security), U.K.

Ali Emre Turgut, Universite Libre de Bruxelle, Belgium

Angel Valera, Universidad Politécnica de Valencia, Spain

Bram Vanderborght, Vrije Universiteit Brussel, Belgium

Eloisa Vargiu, Barcelona Digital, Spain

Ramiro Velazquez, Universidad Panamericana, Mexico

Damir Vrancic, Jožef Stefan Institute, Slovenia

Bernardo Wagner, Leibniz Universität Hannover, Germany

James Whidborne, Cranfield University, U.K.

Sangchul Won, Pohang University of Science and Technology, Korea, Republic of

Peter Xu, The University of Auckland, New Zealand

Xun W. Xu, University of Auckland, New Zealand

Marek Zaremba, Université du Québec (UQO), Canada

PROGRAM COMMITTEE (CONT.)

Janan Zaytoon, University of Reims Champagne Ardennes, France

Du Zhang, California State University, U.S.A.

Primo Zingaretti, Università Politecnica delle Marche, Italy

Loredana Zollo, Università Campus Bio-Medico, Italy

Argyrios Zolotas, Loughborough University, U.K.

AUXILIARY REVIEWERS

Francesca Cordella, University of Naples Federico II, Italy

Ayan Dutta, University of Nebraska at Omaha, U.S.A.

Daniel Gutierrez Gomez, Universidad de Zaragoza, Spain

K. R. Guruprasad, University of Nebraska, U.S.A.

Chin-Tien Huang, NCKU, Taiwan

Janyl Jumadinova, University of Nebraska at Omaha, U.S.A.

Aravindhan Krishnan, ASU, U.S.A.

Paolo Lino, Politecnico Di Bari, Italy

Angelica Muñoz-Meléndez, INAOE, Mexico

Gulherme Raffo, Federal University of Santa Catarina, Brazil

Daniele Rosa, Università degli Studi di Cagliari, Italy

Jinglin Shen, University of Texas at Dallas, U.S.A.

Merhan Zareh, University of Cagliari, Italy

SPECIAL SESSIONS PROGRAM COMMITTEE

SPECIAL SESSION ON INTELLIGENT VEHICLE CONTROLS & INTELLIGENT TRANSPORTATION SYSTEMS

Vishi Gupta, Ford Motor Company, U.S.A.

Oleg Gusikhin, Ford Research & Adv. Engineering, U.S.A.

Ilya Kolmanovsky, University of Michigan, U.S.A.

Anatoli Koulinitch, Meritor, Inc., U.S.A.

Perry MacNeille, Ford Motor Company, U.S.A.

Danil Prokhorov, Toyota Tech Center, U.S.A.

SPECIAL SESSION ON OPERATIONS MANAGEMENT AND DECISION MAKING IN TODAY'S COMPETITIVE ENVIRONMENT

Ying Chung Chang, Ching Yun University, Taiwan

Cheng-Che Chen, Far East University, Taiwan

Hsing Hung Chen, Macau University of Science and Technology, Macau

Mou-Yuan Liao, Yuanpei University, Taiwan

Yu-Hsin Lin, Minghsin University of Science and Technology, Taiwan

SELECTED PAPERS BOOK

A number of selected papers presented at ICINCO 2012 will be published by Springer-Verlag in a LNEE Series book. This selection will be done by the Conference Chair and Program Co-chairs, among the papers actually presented at the conference, based on a rigorous review by the ICINCO 2012 Program Committee members.

FOREWORD

This book contains the proceedings of the 9th International Conference on Informatics in Control, Automation and Robotics (ICINCO 2012) which was sponsored by the Institute for Systems and Technologies of Information, Control and Communication (INSTICC) and held in Rome, Italy. ICINCO 2012 was co-sponsored by the International Federation of Automatic Control (IFAC) and held in cooperation with the Association for the Advancement of Artificial Intelligence (AAAI), Euromicro and the ACM Special Interest Group on Artificial Intelligence (ACM SIGART).

The ICINCO Conference Series has now 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 that benefit from Information Technology.

In the Conference Program we have included oral presentations (full papers and short papers) and posters, organized in four simultaneous tracks: "Intelligent Control Systems and Optimization", "Robotics and Automation", "Signal Processing, Sensors, Systems Modelling and Control" and "Industrial Engineering, Production and Management". We have included in the program three plenary keynote lectures, given by internationally recognized researchers, namely – Alessandro De Luca (Università di Roma "La Sapienza", Italy), Munther A. Dahleh (MIT, United States), Alexandre Dolgui (Ecole des Mines de Saint-Etienne, France) and Jurek Sasiadek (Carleton University, Canada).

The meeting is complemented with three special sessions: Special Session on Artificial Neural Networks and Intelligent Information Processing (ANNIIP), Special Session on Intelligent Vehicle Controls & Intelligent Transportation Systems (IVC&ITS) and Special Session on Operations Management and Decision Making in Today's Competitive Environment (OMDM).

ICINCO received 360 paper submissions, including special sessions, from 58 countries, in all continents. To evaluate each submission, a double blind paper review was performed by the Program Committee. Finally, only 197 papers are published in these proceedings and presented at the conference. Of these, 144 papers were selected for oral presentation (40 full papers and 104 short papers) and 53 papers were selected for poster presentation. The full paper acceptance ratio was 11%, and the oral acceptance ratio (including full papers and short papers) was 40%. As in previous editions of the Conference, based on the reviewer's evaluations and the presentations, a short list of authors will be invited to submit extended versions of their papers for a book that will be published by Springer with the best papers of ICINCO 2012.

Conferences are also meeting places where collaboration projects can emerge from social contacts amongst the participants. Therefore, in order to promote the development of research and professional networks the Conference includes in its social program a Conference

Social Event & Banquet in the evening of July 30 (Monday).

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 auxiliary 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 INSTICC team; 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 in Informatics, Control, Automation and Robotics at ICINCO 2013.

Jean-Louis Ferrier
University of Angers, France

Alain Bernard
Ecole Centrale de Nantes, France

Oleg Gusikhin
Ford Research & Adv. Engineering, U.S.A.

Kurosh Madani
University of Paris-EST Créteil (UPEC), France

CONTENTS

INVITED SPEAKERS

KEYNOTE SPEAKERS

Recent Advances in Physical Human-Robot Interaction IS-5
Alessandro De Luca

Resilience of Dynamical Transportation Networks IS-7
Munther A. Dahleh

Optimization in Design of Automated Machining Systems IS-9
Alexandre Dolgui

Space Robotics - Guidance, Navigation and Control Challenges IS-11
Jurek Sasiadek

ROBOTICS AND AUTOMATION

FULL PAPERS

On the Multiple-view Triangulation Problem with Perspective and Non-perspective Cameras - A Virtual Reprojection-based Approach 5
Graziano Chesi

Hierarchical Planning of Modular Behaviour Networks for Office Delivery Robot 14
Jong-Won Yoon and Sung-Bae Cho

Development of a Piezo-actuated Robot for Cell Injection 21
D. Chakarov, K. Kostadinov, A. Shulev and T. Tiankov

Design and Analysis of an Automated Heavy Vehicle Platoon 31
Gábor Rödönyi, Péter Gaspár, József Bokor and László Palkovics

Trajectory Tracking Control by LMI-based Approach for Car-like Robots 38
Nicoleta Minoiu Enache

View-based SLAM using Omnidirectional Images 48
D. Valiente, A. Gil, L. Fernández and O. Reinoso

Autonomously Traversing Obstacles - Metrics for Path Planning of Reconfigurable Robots on Rough Terrain 58
Michael Brunner, Bernd Brüeggemann and Dirk Schulz

Development of Parallel Two-wheel Vehicle with Lower Gravity Center of Vehicle Body 70
Yoshiyuki Noda, Yukinori Sago, Kazuhiko Terashima, Kiyoaki Kakihara and Hirotoshi Kawamura

Design and Control of a Novel Unmanned Ground Vehicle 77
M. Osinuga and A. Lanzon

Link Quality Estimator for a Mobile Robot 87
Narek Pezeshkian, Joseph D. Neff and Abraham Hart

Trajectory Tracking Control of Nonholonomic Wheeled Mobile Robots - Combined Direct and Indirect Adaptive Control using Multiple Models Approach 95
Altan Onat and Metin Ozkan

Global Visual Features based on Random Process - Application to Visual Servoing 105
Laroussi Hammouda, Khaled Kaaniche, Hassen Mekki and Mohamed Chtourou

Compensation of Tool Deflection in Robotic-based Milling 113
Alexandr Klimchik, Dmitry Bondarenko, Anatol Pashkevich, Sebastien Briot and Benôit Furet

A Bug-based Path Planner Guided with Homotopy Classes 123
Emili Hernández, Marc Carreras and Pere Ridao

LGMD based Neural Network for Automatic Collision Detection 132
Ana Silva, Jorge Silva and Cristina Santos

Vision based Real-time Modeling of Dynamic Unstructured Environments in Driving Scenarios 141
Andrei Vatavu and Sergiu Nedevschi

From Robot Commands to Real-time Robot Control - Transforming High-level Robot Commands into Real-time Dataflow Graphs 150
Andreas Schierl, Andreas Angerer, Alwin Hoffmann, Michael Vistein and Wolfgang Reif

SHORT PAPERS

Particle Filtering for Position based 6DOF Visual Servoing in Industrial Environments 161
Aitor Ibarguren, José María Martínez-Otzeta and Iñaki Maurtua

An Autonomous Biped - Concept and Design 167
Peter Jakubik

A Generative Traversability Model for Monocular Robot Self-guidance 177
Michael Sapienza and Kenneth Camilleri

How to Use an Adaptive High-gain Observer in Diagnosis Problems 185
Frédéric Lafont, Jean-François Balmat, Nathalie Pessel and Jean-Paul Gauthier

Semi-static Object Detection using Polygonal Maps for Safe Navigation of Industrial Robots 191
Dario Lodi Rizzini, Gionata Boccalini and Stefano Caselli

Modelling of a Grasping and Manipulation Controller 199
Pavel Dzitac and Abdul Md Mazid

3D Dense Reconstruction from Two-Frame Stereo Correspondences 205
Costantino Scozzafava and Giuseppe Zuffanti

An Integrated Approach for Efficient Mobile Robot Trajectory Tracking and Obstacle Avoidance 211
Aleksandar Cosic, Marko Susic and Dusko Katic

Dynamic Model of a 7-DOF Whole Arm Manipulator and Validation from Experimental Data 217
Zaira Pineda Rico, Andrea Lecchini-Visintini and Rodrigo Quian Quiroga

Object Recognition based on a Simplified PCNN 223
Yuli Chen, Yide Ma, Dong Hwan Kim and Sung-Kee Park

Evaluation of a Joint Hysteresis Model in a Robot Actuated by Pneumatic Muscles 230
Michael Kastner, Hubert Gattringer and Ronald Naderer

Semantic Place Recognition based on Deep Belief Networks and Tiny Images 236
Ahmad Hasasneh, Emmanuelle Frenoux and Philippe Tarroux

Two-view Epipole-based Guidance Control for Autonomous Unmanned Aerial Vehicles 242
W. Achicanoy, C. Sagüés, G. López-Nicolás and C. Rodríguez

Motorbike Modeling and Control 249
João Sequeira and Marco di Vittori

Motion Detection and Velocity Estimation for Obstacle Avoidance using 3D Point Clouds 255
Sobers L. X. Francis, Sreenatha G. Anavatti and Matthew Garratt

Robot Phase Entrainment on Quadruped CPG Controller 260
Vitor Matos and Cristina P. Santos

Integral Sliding Mode and Second Order Sliding Mode Attitude and Altitude Tracking of a Quadrotor System - Theory and Experiment 266
Mouloud Bouchoucha, Abdessamed Boudane, Kamel Ali and Sofiane Seghour

False Positive Outliers Rejection for Improving Image Registration Accuracy - Application to Road Traffic Aerial Sequences 274
Ines Hadj Mtir, Khaled Kaâniche, Pascal Vasseur and Mohamed Chtourou

Kinematic Analysis of Lower Mobility Cooperative Arms by Screw Theory 280
Philip Long, Wisama Khalil and Stéphane Caro

Construction and Modeling of a Variable Collective Pitch Coaxial UAV 286
Jinqiang Cui, Fei Wang, Zhengyin Qian, Ben M. Chen and Tong H. Lee

Mobile Robots Pose Tracking - A Set-membership Approach using a Visibility Information 292
Rémy Guyonneau, Sébastien Lagrange and Laurent Hardouin

A Mobile Service Robot for Industrial Applications 298
Luca Lattanzi, Giacomo Angione, Cristina Cristalli, Florian Weisshardt, Georg Arbeiter and Birgit Graf

The Modular Behavioral Environment for Humanoids and other Robots (MoBeE) 304
Mikhail Frank, Jürgen Leitner, Marijn Stollenga, Simon Harding, Alexander Förster and Jürgen Schmidhuber

Integrating Kinect Depth Data with a Stochastic Object Classification Framework for Forestry Robots 314
Mostafa Pordel, Thomas Hellström and Ahmad Ostovar

Virtual Mechanism Approach for Dual-arm Manipulation 321
Nejc Likar, Bojan Nemec and Leon Žlajpah

Two-arm Robot Teleoperation using a Multi-touch Tangible User Interface 327
Andreas Angerer, Andreas Bareth, Alwin Hoffmann, Andreas Schierl, Michael Vistein and Wolfgang Reif

Low-speed Modeling and Simulation of Torpedo-shaped AUVs 333
Bjarni Helgason, Leifur Leifsson, Indridi Rikhardsson, Helgi Thorgilsson and Slawomir Koziel

Modeling and Visualizing Individual and Global Trends of a Multi-agent System 339
Vinicius Nonnenmacher, Marta Becker Villamil and Luiz Paulo Luna de Oliveira

Cooperative Autonomous Driving for Vehicular Networks 345
Lamia Iftekhar and Reza Olfati-Saber

Flocking for Networks of Mobile Robots with Nonlinear Dynamics 353
Reza Olfati-Saber and Lamia Iftekhar

Discrete Asymptotic Reachability via Expansions in Non-integer Bases 360
Anna Chiara Lai and Paola Loreti

Robot-Dog – Human Interaction in Urban Search and Rescue Scenarios - Improving the Efficiency of Rescue Teams in Hazardous Environments 366
Anna Bosch, Xavier Cufi, Josep Ll. De la Rosa and Albert Figueras

Force Control of a Duct Cleaning Robot Brush using a Compliance Device 372
Wootae Jeong, Seung-Woo Jeon, Duckshin Park and Soon-Bark Kwon

Towards the Integrated Simulation and Programming of Palletizing Lines 377
Antonello Calò, Davide Buratti, Dario Lodi Rizzini and Stefano Caselli

Task-based Method for Designing Underactuated Elastic Mechanisms 383
Shoichiro Kamada, Youngwoo Kim and Goro Obinata

A Joint Segmentation and Classification of Object Shapes with Feedback for 3D Point Clouds 388
Frauke Wübbold and Bernardo Wagner

Supporting Mobile Robot's Tasks through Qualitative Spatial Reasoning 394
Pascal Rost, Lothar Hotz and Stephanie von Riegen

POSTERS

Predictive Control of Unmanned Formations 403
Martin Saska and Libor Přeučil

Solving the Indoor SLAM Problem for a Low-Cost Robot using Sensor Data Fusion and Autonomous Feature-based Exploration 407
Luciano Buonocore, Cairo Lúcio Nascimento Júnior and Areolino de Almeida Neto

Modeling and Simulation of Humanoid Robot Spine Vertebra 415
M. Souissi, V. Hugel and P. Blazevic

From a Multi-robot Global Plan to Single-robot Actions 419
Bernd Brüeggemann, Elmar Langetepe, Andreas Lenerz and Dirk Schulz

On the Problem of Task Planning in Multi-robot Systems 423
Zhi Yan, Nicolas Jouandeau and Arab Ali Cherif

Improvement of Extraction Method for Inter-turn Fault Detection in IPMSM under Transient Conditions 427
Gyu Tae Choi, Je Won Lee, Minho Choi and Sang Woo Kim

Timed Trajectory Generation for a Vision-based Autonomous Mobile Robot in Cluttered Environments 431
Jorge B. Silva, Cristina P. Santos and João Sequeira

Disassembly Planning using Visual Servoing 435
S. T. Puente, J. Pomares and F. Torres

Monte Carlo Localization using the Global Appearance of Omnidirectional Images - Algorithm Optimization to Large Indoor Environments 439
Lorenzo Fernández, Luis Payá, David Valiente, Arturo Gil and Oscar Reinoso

Design of a Rectangular-type Finger Rehabilitation Robot 443
Gab-Soon Kim, Hyeon-Min Kim, Young-Guk Kim, Hee-Suk Shin and Jungwon Yoon

Facial Expression Recognition based on Facial Feature and Multi Library Wavelet Neural Network 447
Nawel Oussaifi, Wajdi Bellil and Chokri Ben Amar

Simultaneous Control of Translational and Rotational Motion for Autonomous Omnidirectional Mobile Robot - 2nd Report: Robot Model Considering Moving Parts and Evaluation of Movable Area by Heights 451
Ayanori Yorozu, Takafumi Suzuki, Matsumura Tetsuya and Masaki Takahashi

Total Intelligent Life-Saving System against Earthquake and "Tsunami" - Disaster Medical Engineering from Protection to Care in Catastrophe 455
Ichiro Fukumoto, Taku Sahashi and Akira Sahashi

A Novel Approach to Measure under Water Vehicle Disturbance Force for Station Keeping Control 460
J. Manecius Selvakumar and T. Asokan

Hardware in the Loop Module to Calculate Production Indicators 464
Mildred J. Puerto, Josu Larrañaga, Ulrich Doll and Damien Sallé

Programming of a Mobile Robotic Manipulator through Demonstration 468
Lorenzo Peppoloni and Alessandro Di Fava

Improved Leader Follower Formation Control of Autonomous Underwater Vehicles using State Estimation 472
Umesh Neettiyath and Asokan Thondiyath

Improving Stereo Vision Odometry for Mobile Robots in Outdoor Dynamic Environments 476
Dan Pojar and Sergiu Nedevschi

Robust Control of Excavation Mobile Robot with Dynamic Triangulation Vision 481
Alexander Gurko, Wilmar Hernandez, Oleg Sergiyenko, Vera Tyrsa, Juan Ivan Nieto Hipólito, Daniel Hernandez Balbuena and Paolo Mercorelli

Autonomous Navigation of an Outdoor Mobile Robot in a Cluttered Environment 485
Amir Monjazeb, Jurek Z. Sasiadek and Dan Necsulescu

Development of a Wheelchair with a Lifting Function 489
Yoshikazu Mori, Norikatsu Sakai and Kaoru Katsumura

INDUSTRIAL ENGINEERING, PRODUCTION AND MANAGEMENT

SHORT PAPERS

Control of Variable Parametric Actuator in Building Temperature Regulation 497
Todor Ionkov

Assessing the Efficacy of Improvements in User Satisfaction for Mobile Applications - User Feedback from the Review Data 503
Bomi Song, Woori Han and Yongtae Park

Sloshing Suppression Control by using Physical Boundary Element Model and Predictive Control in Liquid Container Transfer System 507
Hisashi Okatsuka, Ryota Shibuya, Kazuhiko Terashima, Yoshiyuki Noda and Yoshiki Matsuo

Process-oriented Approach to Verification in Engineering 513
Ekaterina Auer, Roger Cuypers and Wolfram Luther

Productivity Improvement through Layout Redesign - A Lean Approach Case Study 519
Wa-Muzemba Anselm Tshibangu and Steve Berlinski

The Optimal Gasoline Blending into Romanian Refinery - Case Study 527
Cristian Patrascioiu and Nicolae Nicoleta

POSTERS

Business Process Development for Industrial Cluster 535
Taivo Kangilaski

An Application of Goal Programming Technique for Reconfiguration of Transfer Lines 539
Fatme Makssoud, Olga Battaïa and Alexandre Dolgui

A Control Strategy for Reducing Fuel Consumption in a Hybrid Electric Vehicle 543
Babici Leandru Corneliu Cezar and Alexandru Onea

Observability of Transportation Systems - A Methodology for Reliability Analysis in Logistics and Manufacturing 548
Jan Pinkowski and Axel Hahn

Towards Manufacturing Execution Systems for the Food and Beverage Packaging Industry 552
Stefano Caselli, Michele Pattera and Massimo Ricci

SPECIAL SESSION ON INTELLIGENT VEHICLE CONTROLS & INTELLIGENT TRANSPORTATION SYSTEMS

FULL PAPERS

A Warping Window Approach to Real-time Vision-based Pedestrian Detection in a Truck's Blind Spot Zone 561
Kristof Van Beeck, Toon Goedemé and Tinne Tuytelaars

Road Safety at Intersections Controlled by Traffic Lights - IVC and Risk Indexes 569
Bruno Dalla Chiara, Francesco Paolo Deflorio and Serena Cuzzola

POSTER

Stereo Vision based On-road Vehicle Detection under Illumination Changing Conditions using Self Quotient Image 581
Jonghwan Kim, Chung-Hee Lee and Young-Chul Lim

SPECIAL SESSION ON OPERATIONS MANAGEMENT AND DECISION MAKING IN TODAY'S COMPETITIVE ENVIRONMENT

SHORT PAPERS

Developing A New Variables Sampling Scheme for Product Acceptance Determination 589
Chien-Wei Wu and James C. Chen

Supplier Selection based on Process Yield for LED Manufacturing Processes 594
Y. T. Tai and Chien-Wei Wu

Production Planning and Control Model of Technology Migration for DRAM Industry 599
Ying-Mei Tu

An Evaluation Model for Green and Low-Carbon Suppliers 604
Amy H. I. Lee, He-Yau Kang, Chun Yu Lin and Hsin Wei Wu

An Integrated Model to Evaluate the Performance of Solar PV Firms 609
Chun Yu Lin, Amy H. I. Lee, He-Yau Kang and Wen Hsin Lee

An Integrated Replemishment Model under Dynamic Demand Conditions 614
He-Yau Kang, Amy H. I. Lee and Chun-Mei Lai

A Study on a Decision Support Model for Strategic Alliance in Express Courier Service 620
Friska Natalia Ferdinand, Ki Ho Chung, Hyun Jeung Ko and Chang Seong Ko

AUTHOR INDEX 627

AUTHOR INDEX

Achicanoy, W. 242
Ali, K. 266
Amar, C. 447
Anavatti, S. 255
Angerer, A. 150, 327
Angione, G. 298
Arbeiter, G. 298
Asokan, T. 460, 472
Auer, E. 513
Balbuena, D. 481
Balmat, J. 185
Bareth, A. 327
Battaïa, O. 539
Beeck, K. 561
Bellil, W. 447
Berlinski, S. 519
Blazevic, P. 415
Boccalini, G. 191
Bokor, J. 31
Bondarenko, D. 113
Bosch, A. 366
Bouchoucha, M. 266
Boudane, A. 266
Briot, S. 113
Brüeggemann, B. 58, 419
Brunner, M. 58
Buonocore, L. 407
Buratti, D. 377
Calò, A. 377
Camilleri, K. 177
Caro, S. 280
Carreras, M. 123
Caselli, S. 191, 377, 552
Cezar, B. 543
Chakarov, D. 21
Chen, B. 286
Chen, J. 589
Chen, Y. 223
Cherif, A. 423
Chesi, G. 5
Chiara, B. 569
Cho, S. 14
Choi, G. 427
Choi, M. 427
Chtourou, M. 105, 274
Chung, K. 620
Cosic, A. 211, 211
Cristalli, C. 298
Cufi, X. 366
Cui, J. 286
Cuypers, R. 513
Cuzzola, S. 569
Deflorio, F. 569
Dolgui, A. 539
Doll, U. 464
Dzitac, P. 199
Enache, N. 38
Fava, A. 468
Ferdinand, F. 620
Fernández, L. 48, 439
Figueras, A. 366
Förster, A. 304
Francis, S. 255
Frank, M. 304
Frenoux, E. 236
Fukumoto, I. 455
Furet, B. 113
Garratt, M. 255
Gaspár, P. 31
Gattringer, H. 230
Gauthier, J. 185
Gil, A. 48, 439
Goedemé, T. 561
Graf, B. 298
Gurko, A. 481
Guyonneau, R. 292
Hahn, A. 548
Hammouda, L. 105
Han, W. 503
Harding, S. 304
Hardouin, L. 292
Hart, A. 87
Hasasneh, A. 236
Helgason, B. 333
Hellström, T. 314
Hernandez, W. 481
Hernández, E. 123
Hipólito, J. 481
Hoffmann, A. 150, 327
Hotz, L. 394

AUTHOR INDEX (CONT.)

Hugel, V. 415
Ibarguren, A. 161
Iftekhar, L. 345, 353
Ionkov, T. 497
Jakubik, P. 167
Jeon, S. 372
Jeong, W. 372
Jouandeau, N. 423
Júnior, C. 407
Kaaniche, K. 105, 274
Kakihara, K. 70
Kamada, S. 383
Kang, H. 604, 609, 614
Kangilaski, T. 535
Kastner, M. 230
Katic, D. 211, 211
Katsumura, K. 489
Kawamura, H. 70
Khalil, W. 280
Kim, D. 223
Kim, G. 443
Kim, H. 443
Kim, J. 581
Kim, S. 427
Kim, Y. 383, 443
Klimchik, A. 113
Ko, C. 620
Ko, H. 620
Kostadinov, K. 21
Koziel, S. 333
Kwon, S. 372
Lafont, F. 185
Lagrange, S. 292
Lai, A. 360
Lai, C. 614
Langetepe, E. 419
Lanzon, A. 77
Larrañaga, J. 464
Lattanzi, L. 298
Lecchini-Visintini, A. 217
Lee, A. 604, 609, 614
Lee, C. 581
Lee, J. 427
Lee, T. 286
Lee, W. 609
Leifsson, L. 333
Leitner, J. 304
Lenerz, A. 419
Likar, N. 321
Lim, Y. 581
Lin, C. 604, 609
Long, P. 280
López-Nicolás, G. 242
Loreti, P. 360
Luther, W. 513
Ma, Y. 223
Makssoud, F. 539
Martínez-Otzeta, J. 161
Matos, V. 260
Matsuo, Y. 507
Maurtua, I. 161
Mazid, A. 199
Mekki, H. 105
Mercorelli, P. 481
Monjazeb, A. 485
Mori, Y. 489
Mtir, I. 274
Naderer, R. 230
Necsulescu, D. 485
Nedevschi, S. 141, 476
Neettiyath, U. 472
Neff, J. 87
Nemec, B. 321
Neto, A. 407
Nicoleta, N. 527
Noda, Y. 70, 507
Nonnenmacher, V. 339
Obinata, G. 383
Okatsuka, H. 507
Olfati-Saber, R. 345, 353
Oliveira, L. 339
Onat, A. 95
Onea, A. 543
Osinuga, M. 77
Ostovar, A. 314
Oussaifi, N. 447
Ozkan, M. 95
Palkovics, L. 31
Park, D. 372
Park, S. 223

AUTHOR INDEX (CONT.)

Park, Y. 503
Pashkevich, A. 113
Patrascioiu, C. 527
Pattera, M. 552
Payá, L. 439
Peppoloni, L. 468
Pessel, N. 185
Pezeshkian, N. 87
Pinkowski, J. 548
Pojar, D. 476
Pomares, J. 435
Pordel, M. 314
Přeučil, L. 403
Puente, S. 435
Puerto, M. 464
Qian, Z. 286
Quiroga, R. 217
Reif, W. 150, 327
Reinoso, O. 48, 439
Ricci, M. 552
Rico, Z. 217
Ridao, P. 123
Riegen, S. 394
Rikhardsson, I. 333
Rizzini, D. 191, 377
Rödönyi, G. 31
Rodríguez, C. 242
Rosa, J. 366
Rost, P. 394
Sago, Y. 70
Sagüés, C. 242
Sahashi, A. 455
Sahashi, T. 455
Sakai, N. 489
Sallé, D. 464
Santos, C. 132, 260, 431
Sapienza, M. 177
Sasiadek, J. 485
Saska, M. 403
Schierl, A. 150, 327
Schmidhuber, J. 304
Schulz, D. 58, 419
Scozzafava, C. 205
Seghour, S. 266
Selvakumar, J. 460
Sequeira, J. 249, 431
Sergiyenko, O. 481
Shibuya, R. 507
Shin, H. 443
Shulev, A. 21
Silva, A. 132
Silva, J. 132, 431
Song, B. 503
Souissi, M. 415
Stollenga, M. 304
Susic, M. 211
Suzuki, T. 451
Tai, Y. 594
Takahashi, M. 451
Tarroux, P. 236
Terashima, K. 70, 507
Tetsuya, M. 451
Thondiyath, A. 460, 472
Thorgilsson, H. 333
Tiankov, T. 21
Torres, F. 435
Tshibangu, W. 519
Tu, Y. 599
Tuytelaars, T. 561
Tyrsa, V. 481
Valiente, D. 48, 439
Vasseur, P. 274
Vatavu, A. 141
Villamil, M. 339
Vistein, M. 150, 327
Vittori, M. 249
Wagner, B. 388
Wang, F. 286
Weisshardt, F. 298
Wu, C. 589, 594
Wu, H. 604
Wübbold, F. 388
Yan, Z. 423
Yoon, J. 14, 443
Yorozu, A. 451
Žlajpah, L. 321
Zuffanti, G. 205

Monte Carlo Localization using the Global Appearance of Omnidirectional Images

Algorithm Optimization to Large Indoor Environments

Lorenzo Fernández, Luis Payá, David Valiente, Arturo Gil and Oscar Reinoso

Departamento de Ingeniería de Sistemas y Automática
Miguel Hernández University, Avda. de la Universidad s/n, Elche (Alicante), Spain
l.fernandez@umh.es, lpaya@umh.es, arturo.gil@umh.es, o.reinoso@umh.es

Keywords: Autonomous Robot, Global Appearance, Panoramic Images, Fourier Signature, Monte-Carlo Localization.

Abstract: In this paper we deal with the problem of robot localization using the visual information provided by a single omnidirectional camera mounted on the robot, using techniques based on the global appearance of panoramic images. Our main objective consists in showing the feasibility of the appearance-based approaches in a localization task in a relatively large and real environment. First, we study the approaches that permit us to describe globally the visual information so that it represents with accuracy locations in the environment. Then, we present the probabilistic approach we have used to compute the most probable pose of the robot when it performs a trajectory within the map. At the end, we describe the kind of environments and maps we have used to test our localization algorithms and the final results. The experimental results we show have been obtained using real indoor omnidirectional images, captured in an office building under real conditions.

1 INTRODUCTION

When a mobile robot has to carry out a task autonomously in an environment, it has to face the problem of computing its location within a given map with enough precision so that it can plan the route to follow to go to the target points during the development of the task. During the last years, omnidirectional cameras have become a popular tool to carry out these localization tasks. In this work, we use the information captured by a single camera that is installed on the robot. With this system, we capture omnidirectional images from the environment and we transform these images into a panoramic format to represent locations in the environment.

When the appearance-based approach is used, each scene is represented by a single descriptor which is computed working with the scene as a whole. For example, (Menegatti et al., 2004a; Menegatti et al., 2004b) use a signature based on the Discrete Fourier Transform of panoramic images to build a visual map and to perform a probabilistic localization within this map. (Kröse et al., 2004) use Principal Components Analysis (PCA) (Kirby, 2001) of panoramic images for environment modeling and localization. On the other hand, as no relevant information is extracted, it is necessary to find a descriptor of the global appearance which optimizes the computational cost of the localization process. Also, it must work well in large environments where visual aliasing could be a usual event.

The main goal of this work consists in evaluating the feasibility of the appearance-based approaches in a localization task in a relatively large and real indoor environment and studying how the computational cost and the accuracy of the results depend on the main parameters of the descriptor. With this aim, we make use of the Monte Carlo (MC) Algorithm (Thrun et al., 2000), which has proved to be robust and efficient in localization tasks in the field of mobile robotics. We have decided to describe each omnidirectional image by a single Fourier descriptor. However, the methods described here are in fact independent of the descriptor used to represent the images.

2 MONTE-CARLO LOCALIZATION

In mobile robot localization we are interested in the estimation of the robot's pose (location and orientation, typically, the state $x_t = (x, y, \theta)$) at time t using a set of measurements $z_{1:t} = \{z_1, z_2, \ldots, z_t\}$ from the en-

vironment and the movements $u_{1:t} = \{u_1, u_2, \ldots, u_t\}$ of the robot (Fox et al., 1999). In *Monte Carlo Localization (MCL)* (Thrun et al., 2000), the probability density function $p(x_t|z_{1:t}, u_{1:t})$ is represented by a set of M random samples $\chi_t = \{x_t^i, i = 1 \ldots M\}$ extracted from it, named particles. Each particle can be understood as a hypothesis of the true state of the robot $x_t^i = (\mathrm{x}^i,\ \mathrm{y}^i,\ \theta^i)$. The weight of each sample (particle) determines the importance of the particle. The set of samples defines a discrete probability function that approximates the continuous belief. The *Monte Carlo Localization algorithm* is described briefly in the next lines, and consists of two phases:

Prediction Phase. At time t a set of particles $\overline{\chi_t}$ is generated based on the set of particles χ_{t-1} and a control signal u_t. This step uses the motion model $p(x_t|x_{t-1}, u_t)$. In order to represent this probability function, the movement u_t is applied to each particle while adding a pre-defined quantity of noise. As a result, the new set of particles $\overline{\chi_t}$ represents the density $p(x_t|z_{1:t-1}, u_{1:t})$.

Update Phase. In this second phase, for each particle in the set $\overline{\chi_t}$, the observation z_t obtained by the robot is used to compute a weight ω_t^i. This weight represents the observation model $p(z_t|x_t)$ and is computed as $\omega_t^i = p(z_t|x_t^i)$. The weights are normalized so that $\sum \omega_t^i = 1$. As a result, a set of particles accompanied by a weight $\overline{\chi}_t = \{x_t^i, \omega_t^i\}$ are obtained.

The resulting set χ_t is calculated by resampling with replacement from the set $\overline{\chi}_t$, where the probability of resampling each particle is proportional to its importance weight ω_t^i, in accordance with the literature on the SIR algorithm (Sampling Importance Resampling) (Smith and Gelfand, 1992; Rubin, 1988). Finally, the distribution $p(x_t|z_{1:t}, u_{1:t})$ is represented by the set χ_t.

By means of computing a weight w^i for each particle the Monte Carlo algorithm introduces the current observation z_t of the robot. In this case we consider that our map is composed of a set of N bidimensional landmarks $L = \{l_1, l_2, \ldots, l_N\}$ and the position of these marks on the environment is known. Each landmark l_j is represented by an omnidirectional image I_j associated and a Fourier Signature descriptor d_j that describes the global appearance of the omnidirectional image (Fernandez et al., 2011), thus $l_j = \{(l_{j,\mathrm{x}}, l_{j,\mathrm{y}}), d_j, I_j\}$. d_j is constructed from the bidimensional Fourier signature with all the elements arranged in a vector. Using this Fourier descriptor we compare the descriptor d_t with the rest of descriptors $d_j,\ j = 1 \ldots N$ and find the B landmarks in the map that are closest in appearance with the current image I_t. In this sense, we allow the correspondence of the current observation to several landmarks in the map.

In this work, we propose to compute the weight of each particle $\omega_t^i = p(z_t|x_t^i)$ through a sum of gaussian functions centered on each landmark position and considering the difference in the descriptors of the landmarks (images).

$$\omega_t^i = \sum_{j=1}^{B} \exp\{-v_j \Sigma_l^{-1} v_j^T\} \exp\{-h_j \Sigma_d^{-1} h_j^T\} \qquad (1)$$

where, $v_j = (l_{j,\mathrm{x}}, l_{j,\mathrm{y}}) - (\mathrm{x}^i, \mathrm{y}^i)$ is the difference between the position of the landmark l_j and the position $(\mathrm{x}^i, \mathrm{y}^i)$ of the particle i. The matrix Σ_l is a diagonal matrix $\Sigma_l = diag(\sigma_l^2, \sigma_l^2)$. The variance σ_l^2 is chosen experimentally in order to minimize the error in the localization. $h_j = |d_j - d_t|$ defines the difference between the module of the Fourier descriptor associated to the current image observed and the module of the descriptor associated to the landmark l_j. The matrix $\Sigma_d = diag(\sigma_d^2)$ is a $k \times k$ matrix, being k the length of the Fourier descriptor.

3 EXPERIMENTAL RESULTS

In order to acquire the necessary data for the experiments we have used a Pioneer P3-AT mobile robot, equipped with an omnidirectional camera, and a fixed platform equipped with an omnidirectional camera and a laptop. The map was built by carefully obtaining omnidirectional images at different positions on a regular grid in an office-like environment using the fixed platform. Next, the robot performed some trajectories within this environment, capturing a new omnidirectional image and odometry data whenever it traversed a distance equal to $0.1m$. The robot captured a total of 515 images and traveled around $55m$. The map is composed of a set of 381 images placed on a grid with a resolution of $0.4m$. The map has a size of $11m$ in the x axis and $25m$ in the y axis.

To test the performance of our appearance-based Monte-Carlo Localization method we have carried out a series of simulation experiments of robot tracking using the sets of images described in the previous paragraph. We have used an associations number B equal to 4. We have computed the average error in the robot position along the trajectory, depending on the number of Fourier components for different number of particles. The average error has been obtained taking as a reference the real path (ground truth) (Figure 1 (a)). We must take into account the average error of the robot odometry data comparing with the ground truth is $0.736m$. As shown in Figure 1 (a) as we increase the number of Fourier components, the localization error along the trajectory tends

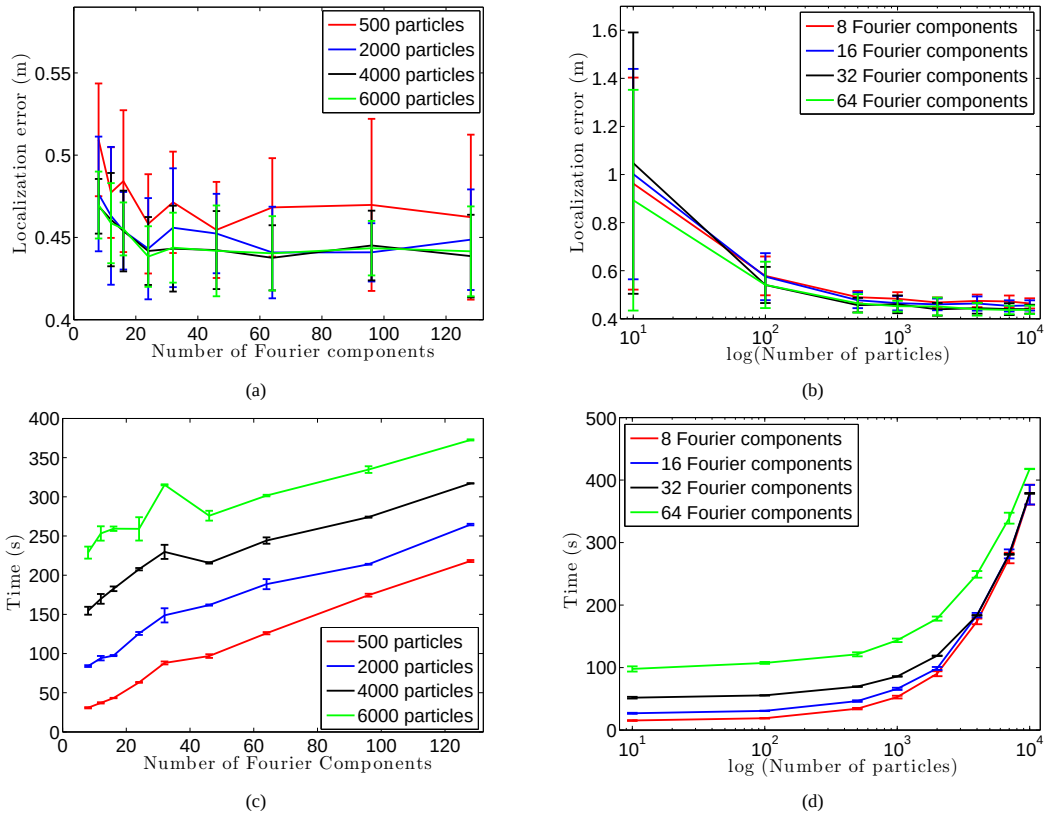


Figure 1: (a) Trajectory average error in position versus the number of Fourier components for different number of particles and (b) trajectory average error in position versus the number of particles for different number of Fourier components, with respect to the real path, (c) computation time needed to complete the estimation of the trajectory of the robot versus the number of Fourier components for different number of particles and (d) versus the number of particles for different number of Fourier components.

to decrease, but a threshold number of components appears and when we increase this number, the error does not decrease significantly (this threshold is around 24 Fourier Components for a relatively high number of particles). We can also see that the graph tendency is quite similar for the four different number of particles tested.

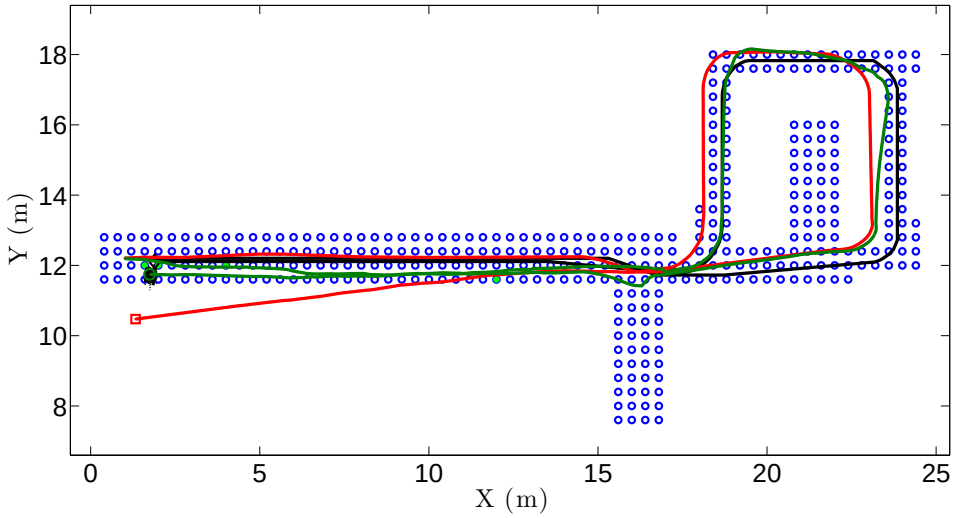
To compare the performance of our method with respect to the number of particles we have carried out a set of experiments of robot tracking in which we have tested the trajectory average error in the position of the robot depending of this number of particles. Figure 1 (b) shows how the increase of the number of particles makes the error with respect the real path to decrease until a certain value from which the error remains small (about 2000 particles). We arrive to the same conclusion as in the previous experiment.

Figure 1 (c) shows the average time needed to carry out the complete Monte-Carlo localization experiment with respect to the number of Fourier components and for different number of particles. On the other hand, Figure 1 (d) show the dependence of the computation time with respect to the number of particles.

Figure 2 presents an example of a relatively accurate case of robot tracking using 4000 particles and 32 Fourier components. In this figure, the position of the map images is indicated with a blue circle, the position of the associated landmarks is indicated with a green solid circle (four associations are used, as stated before), the real path is represented by a black line, the robot odometry path is presented by a red line, the path obtained with our method is shown as a green line and finally, the particles are represented as black dots. As we can observe, our algorithm is able to cope with robot turnings and the trajectory estimated is accurate enough for many robot applications in indoor environments.

4 CONCLUSIONS

In this paper we have tested the performance of a Monte-Carlo localization technique using the global



(a)

Figure 2: An experiment of Monte-Carlo localization using 4000 particles and 32 Fourier components.

appearance of panoramic images. We compare our results with the real trajectory in an large indoor environment. We have built the appearance-based descriptor using the Fourier signature of panoramic images. We have evaluated the performance of the method in the case of a local localization. Our system is able to track the position of the robot while moving if we tune correctly the parameters involved in the process. We have proved that the precision of our method varies with the number of particles used and the number of Fourier components. Furthermore, as we increase the number of particles in the system, the average error of localization decreases rapidly until a certain point from which the error remains small with no appreciable improvement. Finally, as we increase the number of Fourier components, the localization error decreases, but from a number of components the error does not decrease significantly. These experiments show the feasibility of using appearance-based techniques in robot localization, maintaining a reasonable computational cost, so, the navigation can be carried out in real time.

ACKNOWLEDGEMENTS

This work has been supported by the Spanish government through the project DPI2010-15308. "Exploración Integrada de Entornos Mediante Robots Cooperativos para la Creación de Mapas 3D Visuales y Topológicos que Puedan ser Usados en Navegación con 6 Grados de Libertad".

REFERENCES

Fernandez, L., Paya, L., Reinoso, O., and Amoros, F. (2011). Appearance-based visual odometry with omnidirectional images. a practical application to topological mapping. In *Proc. of ICINCO*, pages 205–210.

Fox, D., Burgard, W., and Thrun, S. (1999). Markov localization for mobile robots in dynamic environments. *JAIR*, 11:391–427.

Kirby, M. (2001). *Geometric data analysis*. Wiley Interscience.

Kröse, B., Bunschoten, R., Hagen, S. T., Terwijn, B., and Vlassis, N. (2004). Environment modeling and localization from an omnidirectional vision system. *IEEE Robotics and Automation Magazine*.

Menegatti, E., Maeda, T., and Ishiguro, H. (2004a). Image-based memory for robot navigation using properties of omnidirectional images. *Robotics and Autonomous Systems*, 47(4):251–276.

Menegatti, E., Zocaratto, M., Pagello, E., and Ishiguro, H. (2004b). Image-based monte carlo localisation with omnidirectional images. *Robotics and Autonomous Systems*, 48(1):17–30.

Rubin, D. B. (1988). Bayesian statistics 3. *Oxford University Press*.

Smith, A. F. M. and Gelfand, A. E. (1992). Bayesian statistics without tears: a sampling-resampling perspective. *American Statistician*, 46(2):84–88.

Thrun, S., Fox, D., Burgard, W., and Dellaert, F. (2000). Robust monte carlo localization for mobile robots. *Artificial Intelligence*, 128(1-2):99–141.