Preface

The 10th RoboCup International Symposium was held during June 19–20, 2006 at the Fair & Convention Center in Bremen, Germany, immediately after the 2006 Soccer, Rescue and Junior Competitions. RoboCup is increasingly seen by the robotics community as a significant approach to the evaluation of the effectiveness of the proposed solutions to the many difficult robotics problems.

The RoboCup International symposium hosted scientific contributions in all the areas relevant to RoboCup Competitions. The number of submissions to the Symposium increased again and totalled 143. Each paper was reviewed by at least three Program Committee members. The Program Committee included researchers involved in RoboCup and other scientists from outside the RoboCup community. Papers that received dissenting recommendations were discussed among the reviewers, moderated by the Co-chairs. The final decisions were made by the Co-chairs, who selected 22 submissions as full papers and 36 submissions as posters. This means an acceptance rate of less than 16% for full papers and less than 41% considering posters.

The symposium was run in single-track to allow coverage of all robotic-related topics by all attendees. We had five sessions for oral presentations and two poster sessions. We were also delighted to have two outstanding invited speakers. Hod Lipson (Cornell University, USA) spoke about his work on biologically inspired robotics in his talk “Biologically Inspired Robotics: From Evolving to Self-Reproducing Machines.” Sebastian Thrun (Stanford University, USA) described how his team won the DARPA Grand Challenge in his talk “Winning the DARPA Grand Challenge.”

The Symposium Co-chairs selected a few papers as nominees for the Best Paper Award and for the Best Student Paper Award. The RoboCup trustees made the final decision and selected “A 3D Simulator of Multiple Legged Robots Based on USARSim” by M. Zaratti, M. Fratarcangeli, L. Iocchi as Best Paper and “Half Field Offense in RoboCup Soccer: A Multiagent Reinforcement Learning Case Study” by S. Kalyanakrishnan, Y. Liu, P. Stone as Best Student Paper.

As the quality of the symposium depends heavily on the quality of the generous Program Committee members, we wish to particularly thank them for their work, which was very hard and concentrated in a very short time. We would also like to thank the Local Organizing Committee, headed by Ubbo Visser, for turning Robocup 2006 into such a memorable and enjoyable event. Last but not least we thank Stefan Schiffer for his help in preparing these proceedings.

Congratulations to the RoboCup Competitions and the RoboCup Symposium, which celebrated their tenth anniversary this year in Bremen!

December 2006

Gerhard Lakemeyer
Elizabeth Sklar
Domenico G. Sorrenti
Tomoichi Takahashi
# Organization

## Symposium Co-chairs

<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gerhard Lakemeyer</td>
<td>RWTH Aachen, Germany</td>
</tr>
<tr>
<td>Elizabeth Sklar</td>
<td>City University of New York, USA</td>
</tr>
<tr>
<td>Domenico G. Sorrenti</td>
<td>Università di Milano - Bicocca, Italy</td>
</tr>
<tr>
<td>Tomoichi Takahashi</td>
<td>Meijo University, Japan</td>
</tr>
</tbody>
</table>

## International Symposium Program Committee

<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ahmed Tawfik, Canada</td>
<td>Igor Verner, Israel</td>
</tr>
<tr>
<td>Alan Schultz, USA</td>
<td>Ituki Noda, Japan</td>
</tr>
<tr>
<td>Amy Eguchi, USA</td>
<td>Jacky Baltes, Canada</td>
</tr>
<tr>
<td>Andrea Bonarini, Italy</td>
<td>Jeffrey Johnson, UK</td>
</tr>
<tr>
<td>Andreas Birk, Germany</td>
<td>Kamal Karlapalem, India</td>
</tr>
<tr>
<td>Andreas Zell, Germany</td>
<td>Kaspar Althoefer, UK</td>
</tr>
<tr>
<td>Ansgar Bredenfeld, Germany</td>
<td>Luca Iocchi, Italy</td>
</tr>
<tr>
<td>Bernhard Nebel, Germany</td>
<td>Luis Almeida, Portugal</td>
</tr>
<tr>
<td>Brahim Chaib-draa, Canada</td>
<td>Luis Paulo Reis, Portugal</td>
</tr>
<tr>
<td>Brett Browning, USA</td>
<td>M. Bernardine Dias, USA</td>
</tr>
<tr>
<td>Carlos Cardeira, Portugal</td>
<td>Maja Mataric, USA</td>
</tr>
<tr>
<td>Claude Sammut, Portugal</td>
<td>Manuela Veloso, USA</td>
</tr>
<tr>
<td>Daniel Polani, UK</td>
<td>Marcello Restelli, Italy</td>
</tr>
<tr>
<td>Daniele Nardi, Italy</td>
<td>Maria Hybinette, USA</td>
</tr>
<tr>
<td>David Jahshan, Australia</td>
<td>Marie desJardins, USA</td>
</tr>
<tr>
<td>Dieter Fox, USA</td>
<td>Martijn Schut, The Netherlands</td>
</tr>
<tr>
<td>Emanuele Menegatti, Italy</td>
<td>Martin Riedmiller, Germany</td>
</tr>
<tr>
<td>Emanuele Frontoni, Italy</td>
<td>Mary-Anne Williams, Australia</td>
</tr>
<tr>
<td>Fernando Ribeiro, Portugal</td>
<td>Masayuki Ohta, Japan</td>
</tr>
<tr>
<td>Fiora Pirri, Italy</td>
<td>Matteo Matteucci, Italy</td>
</tr>
<tr>
<td>Francesco Amigoni, Italy</td>
<td>Michael Beetz, Germany</td>
</tr>
<tr>
<td>Franz Wotawa, Austria</td>
<td>Michael Bowling, Canada</td>
</tr>
<tr>
<td>Gal A. Kaminka, Israel</td>
<td>Michele Folgheraiter, Italy</td>
</tr>
<tr>
<td>Gerd Mayer, Germany</td>
<td>Mikhail Prokopenko, Australia</td>
</tr>
<tr>
<td>Gerhard Kraetschmar, Germany</td>
<td>Milind Tambe, USA</td>
</tr>
<tr>
<td>Giovanni Indiveri, Italy</td>
<td>Mohan Sridharan, USA</td>
</tr>
<tr>
<td>Giuseppina Gini, Italy</td>
<td>Nabil Ouerhani, Switzerland</td>
</tr>
<tr>
<td>Gordon Wyeth, Australia</td>
<td>Nobuhiro Ito, Japan</td>
</tr>
<tr>
<td>H. Levent Akin, Turkey</td>
<td>Pedro Lima, Portugal</td>
</tr>
<tr>
<td>Hod Lipson, USA</td>
<td>Peta Wyeth, Australia</td>
</tr>
<tr>
<td>Holly Yanco, USA</td>
<td>Peter Stone, USA</td>
</tr>
</tbody>
</table>
Pieter Jonker, The Netherlands
Raul Rojas, Germany
Riccardo Cassinis, Italy
Saeed Shiry, Iran
Sergio A. Velastin, UK
Sheila Tejada, USA
Simon Levy, USA
Simon Parsons, USA
Stefano Carpin, Germany
Steffen Gutmann, Japan
Tadashi Naruse, Japan
Tairo Nomura, Japan
Testuya Kimura, Japan
Tomoharu Nakashima, Japan
Tucker Balch, USA
Vincenzo Caglioti, Italy
Yashutake Takahashi, Japan
Yoshitaka Kuwata, Japan

Additional Reviewers

Brenna Argall
Alejandra Barrera
Sonia Chernova
Antonio D’angelo
Tomas de Boer
Enrique Munoz de Cote
Ugo Di Profio
Alessandro Farinelli
Alexander Ferrein
Michele Folgheraiter
Daniel Goehring
Giorgio Grisetti
Yang Gu
Manfred Hild
Matthias Juengel
Kemal Kaplan
Hatice Kose-Bagci
Alessandro Lazaric
Luca Marchetti
Colin McMillen
Cetin Mericli
Utku Tatlıdede
Vittorio Amos Ziparo
Table of Contents

Full Papers

Simulation and Control

Bridging the Gap Between Simulation and Reality in Urban Search and Rescue .......................................................... 1
  Stefano Carpin, Mike Lewis, Jijun Wang, Steve Balakirsky, and Chris Scraper

A 3D Simulator of Multiple Legged Robots Based on USARSim ........... 13
  Marco Zaratti, Marco Fratarcangeli, and Luca Iocchi

3D2Real: Simulation League Finals in Real Robots ...................... 25
  Norbert Michael Mayer, Joschka Boedecker, Rodrigo da Silva Guerra,
  Oliver Obst, and Minoru Asada

Motion Control of Swedish Wheeled Mobile Robots in the Presence of
Actuator Saturation ............................................................. 35
  Giovanni Indiveri, Jan Paulus, and Paul G. Plöger

Learning

Imitative Reinforcement Learning for Soccer Playing Robots .......... 47
  Tobias Latzke, Sven Behnke, and Maren Bennewitz

The Chin Pinch: A Case Study in Skill Learning on a Legged Robot .... 59
  Peggy Fidelman and Peter Stone

Half Field Offense in RoboCup Soccer: A Multiagent Reinforcement
Learning Case Study .............................................................. 72
  Shivaram Kalyanakrishnan, Yaxin Liu, and Peter Stone

Autonomous Learning of Ball Trapping in the Four-Legged Robot
League ................................................................................. 86
  Hayato Kobayashi, Tsugutoyo Osaki, Eric Williams,
  Akira Ishino, and Ayumi Shinohara

Learning, MAS, and Education

Autonomous Learning of Stable Quadruped Locomotion ............... 98
  Manish Saggar, Thomas D’Silva, Nate Kohl, and Peter Stone
Using the Simulated Annealing Algorithm for Multiagent Decision Making .......................................................... 110
   Jiang Dawei and Wang Shiyuan

From RoboLab to Aibo: A Behavior-Based Interface for Educational Robotics ........................................................ 122
   Rachel Goldman, M.Q. Azhar, and Elizabeth Sklar

The Robotics and Mechatronics Kit “qfix” .................................................. 134
   Stefan Enderle

Vision

Cooperative Visual Tracking in a Team of Autonomous Mobile Robots .............................................................. 146
   Walter Nisticò, Matthias Hebbel, Thorsten Kerkhof, and Christine Zarges

Selective Visual Attention for Object Detection on a Legged Robot .... 158
   Daniel Stronger and Peter Stone

Towards Probabilistic Shape Vision in RoboCup: A Practical Approach ............................................................... 171
   Sven Olufs, Florian Adolf, Ronny Hartanto, and Paul Plöger

Parabolic Flight Reconstruction from Multiple Images from a Single Camera in General Position ......................... 183
   Raúl Rojas, Mark Simon, and Oliver Tenchio

Vision and Localization

On the Calibration of Non Single Viewpoint Catadioptric Sensors ...... 194
   Alberto Colombo, Matteo Matteucci, and Domenico G. Sorrenti

An Automated Refereeing and Analysis Tool for the Four-Legged League ............................................................ 206
   Javier Ruiz-del-Solar, Patricio Loncomilla, and Paul Vallejos

Detecting Motion in the Environment with a Moving Quadruped Robot ............................................................... 219
   Peggy Fidelman, Thayne Coffman, and Risto Miikkulainen

Using Temporal Consistency to Improve Robot Localisation .......... 232
   David Billington, Vlad Estivill-Castro, René Hexel, and Andrew Rock

Multi-cue Localization for Soccer Playing Humanoid Robots .......... 245
   Hauke Strasdat, Maren Bennewitz, and Sven Behnke
Proprioceptive Motion Modeling for Monte Carlo Localization .......... 258

Jan Hoffmann

Posters

Session 1

Autonomous Planned Color Learning on a Legged Robot ............... 270

*Mohan Sridharan and Peter Stone*

Sensor Modeling Using Visual Object Relation in Multi Robot Object Tracking ................................................................. 279

*Daniel Gohring and Jan Hoffmann*

Robust Color Segmentation Through Adaptive Color Distribution Transformation ................................................................. 287

*Luca Iocchi*

$H_\infty$ Filtering for a Mobile Robot Tracking a Free Rolling Ball .... 296

*Xiang Li and Andreas Zell*

Balancing Gains, Risks, Costs, and Real-Time Constraints in the Ball Passing Algorithm for the Robotic Soccer ......................... 304

*Vadim Kyrylov*

Learning in a High Dimensional Space: Fast Omnidirectional Quadrupedal Locomotion ......................................................... 314

*Matthias Hebbel, Walter Nistico, and Denis Fisseler*

A Novel Approach to Efficient Monte-Carlo Localization in RoboCup . 322

*Patrick Heinemann, Jürgen Haase, and Andreas Zell*

Representing Spatial Activities by Spatially Contextualised Motion Patterns ................................................................. 330

*Björn Gottfried and Jörn Witte*

Mobile Robots for an E-Mail Interface for People Who Are Blind ...... 338

*V. Estivill-Castro and S. Seymon*

Robust and Efficient Field Features Detection for Localization ........ 347

*D. Herrero-Pérez and H. Martínez-Barberá*

Coordination Without Negotiation in Teams of Heterogeneous Robots ................................................................. 355

*Michael Isik, Freek Stulp, Gerd Mayer, and Hans Utz*

Towards a Calibration-Free Robot: The ACT Algorithm for Automatic Online Color Training ......................................................... 363

*Patrick Heinemann, Frank Sehnke, Felix Streichert, and Andreas Zell*
Session 2

Learning to Shoot Goals Analysing the Learning Process and the Resulting Policies ................................................ 371
Markus Geipel and Michael Beetz

Cognitive Robotics: Command, Interrogation and Teaching in Robot Coaching ....................................................... 379
Alfredo Weitzenfeld and Peter Ford Dominey

Panoramic Localization in the 4-Legged League ...................... 387
Jürgen Sturm, Paul van Rossum, and Arnoud Visser

Orientation Extraction and Identification of the Opponent Robots in RoboCup Small-Size League ................................. 395
Saori Umemura, Kazuhito Murakami, and Tadashi Naruse

Rolling Shutter Image Compensation ....................................... 402
Steven P. Nicklin, Robin D. Fisher, and Richard H. Middleton

Evaluating Learning Automata as a Model for Cooperation in Complex Multi-agent Domains ........................................ 410
Mohammad Reza Khojasteh and Mohammad Reza Meybodi

Cooperative 3-Robot Passing and Shooting in the RoboCup Small Size League .......................................................... 418
Ryota Nakanishi, James Bruce, Kazuhito Murakami, Tadashi Naruse, and Manuela Veloso

Logfile Player and Analyzer for RoboCup 3D Simulation .............. 426
Steffen Planthaber and Ubbo Visser

Local Movement Control with Neural Networks in the Small Size League ................................................................. 434
Steffen Prüter, Ralf Salomon, and Frank Golatowski

A Comparative Analysis of Particle Filter Based Localization Methods ................................................................. 442
Luca Marchetti, Giorgio Grisetti, and Luca Iocchi

A New Mechatronic Component for Adjusting the Footprint of Tracked Rescue Robots .................................................... 450
Winai Chonnaparamutt and Andreas Birk

Vectorization of Grid Maps by an Evolutionary Algorithm .............. 458
Ivan Delchev and Andreas Birk

Session 3

Ego-Motion Estimation and Collision Detection for Omnidirectional Robots ............................................................ 466
Martin Lauer
<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integrating Simple Unreliable Perceptions for Accurate Robot Modeling in the Four-Legged League</td>
<td>474</td>
</tr>
<tr>
<td>Tim Laue and Thomas Röfer</td>
<td></td>
</tr>
<tr>
<td>Distributed, Play-Based Coordination for Robot Teams in Dynamic Environments</td>
<td>483</td>
</tr>
<tr>
<td>Colin McMillen and Manuela Veloso</td>
<td></td>
</tr>
<tr>
<td>Development of an Autonomous Rescue Robot Within the USARSim 3D Virtual Environment</td>
<td>491</td>
</tr>
<tr>
<td>Giuliano Polverari, Daniele Calisi, Alessandro Farinelli, and Daniele Nardi</td>
<td></td>
</tr>
<tr>
<td>Appearance-Based Robot Discrimination Using Eigenimages</td>
<td>499</td>
</tr>
<tr>
<td>Sascha Lange and Martin Riedmiller</td>
<td></td>
</tr>
<tr>
<td>Fuzzy Naive Bayesian Classification in RoboSoccer 3D: A Hybrid Approach to Decision Making</td>
<td>507</td>
</tr>
<tr>
<td>Carlos Bustamante, Leonardo Garrido, and Rogelio Soto</td>
<td></td>
</tr>
<tr>
<td>A Novel Omnidirectional Wheel Based on Reuleaux-Triangles</td>
<td>516</td>
</tr>
<tr>
<td>Jochen Brunhorn, Oliver Tenchio, and Raúl Rojas</td>
<td></td>
</tr>
<tr>
<td>Development of Three Dimensional Dynamics Simulator with Omnidirectional Vision Model</td>
<td>523</td>
</tr>
<tr>
<td>Fumitaka Otsuka, Hikari Fujii, and Kazuo Yoshida</td>
<td></td>
</tr>
<tr>
<td>Real-Time Randomized Motion Planning for Multiple Domains</td>
<td>532</td>
</tr>
<tr>
<td>James Bruce and Manuela Veloso</td>
<td></td>
</tr>
<tr>
<td>Towards a Methodology for Stabilizing the Gaze of a Quadrupedal Robot</td>
<td>540</td>
</tr>
<tr>
<td>Marek Marcinkiewicz, Mikhail Kunin, Simon Parsons, Elizabeth Sklar, and Theodore Raphan</td>
<td></td>
</tr>
<tr>
<td>Automatic Acquisition of Robot Motion and Sensor Models</td>
<td>548</td>
</tr>
<tr>
<td>A. Tuna Ozgelen, Elizabeth Sklar, and Simon Parsons</td>
<td></td>
</tr>
<tr>
<td>Ambulance Decision Support Using Evolutionary Reinforcement Learning in Robocup Rescue Simulation League</td>
<td>556</td>
</tr>
<tr>
<td>Ivette C. Martínez, David Ojeda, and Ezequiel A. Zamora</td>
<td></td>
</tr>
<tr>
<td>Author Index</td>
<td>565</td>
</tr>
</tbody>
</table>