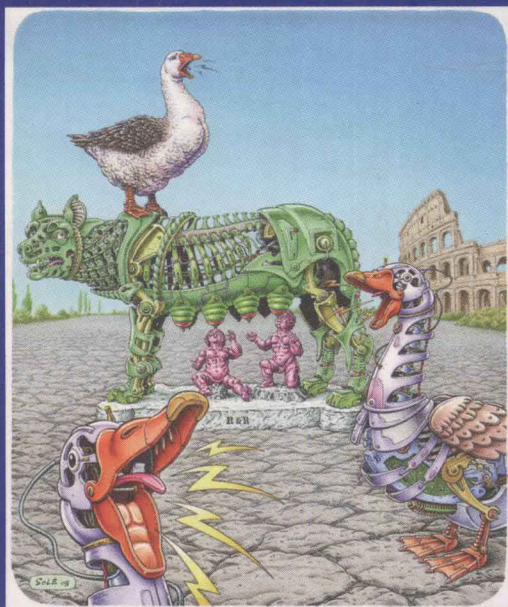


LNAI 4095

Stefano Nolfi Gianluca Baldassarre
Raffaele Calabretta John C. T. Hallam
Davide Marocco Jean-Arcady Meyer
Orazio Miglino Domenico Parisi (Eds.)

From Animals to Animats 9

9th International Conference
on Simulation of Adaptive Behavior, SAB 2006
Rome, Italy, September 2006, Proceedings



Stefano Nolfi Gianluca Baldassarre
Raffaele Calabretta John C. T. Hallam
Davide Marocco Jean-Arcady Meyer
Orazio Miglino Domenico Parisi (Eds.)

From Animals to Animats 9

9th International Conference
on Simulation of Adaptive Behavior, SAB 2006
Rome, Italy, September 25-29, 2006
Proceedings

Series Editors

Jaime G. Carbonell, Carnegie Mellon University, Pittsburgh, PA, USA
Jörg Siekmann, University of Saarland, Saarbrücken, Germany

Volume Editors

Stefano Nolfi

Institute of Cognitive Science and Technology ISTC-CNR
Via S. Martino della Battaglia 44, 00185 Rome, Italy
E-mail: s.nolfi@istc.cnr.it

Gianluca Baldassarre

E-mail: gianluca.baldassarre@istc.cnr.it

Raffaele Calabretta

E-mail: raffaele.calabretta@istc.cnr.it

John C. T. Hallam

E-mail: john@mip.sdu.dk

Davide Marocco

E-mail: davide.marocco@istc.cnr.it

Jean-Arcady Meyer

E-mail: jean-arcady.meyer@lip6.fr

Orazio Miglino

E-mail: orazio.miglino@unina.it

Domenico Parisi

E-mail: parisi@istc.cnr.it

Library of Congress Control Number: 2006931575

CR Subject Classification (1998): I.2.11, I.2, I.6, F.1.1-2, K.4, H.5, J.4

LNCS Sublibrary: SL 7 – Artificial Intelligence

ISSN 0302-9743

ISBN-10 3-540-38608-4 Springer Berlin Heidelberg New York

ISBN-13 978-3-540-38608-7 Springer Berlin Heidelberg New York

This work is subject to copyright. All rights are reserved, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, re-use of illustrations, recitation, broadcasting, reproduction on microfilms or in any other way, and storage in data banks. Duplication of this publication or parts thereof is permitted only under the provisions of the German Copyright Law of September 9, 1965, in its current version, and permission for use must always be obtained from Springer. Violations are liable to prosecution under the German Copyright Law.

Springer is a part of Springer Science+Business Media

springer.com

© Springer-Verlag Berlin Heidelberg 2006

Printed in Germany

Typesetting: Camera-ready by author, data conversion by Scientific Publishing Services, Chennai, India
Printed on acid-free paper SPIN: 11840541 06/3142 5 4 3 2 1 0

Lecture Notes in Artificial Intelligence

4095

Edited by J. G. Carbonell and J. Siekmann

Subseries of Lecture Notes in Computer Science

Lecture Notes in Artificial Intelligence (LNAI)

- Vol. 4188: P. Sojka, I. Kopeček, K. Pala (Eds.), Text, Speech and Dialogue. XIV, 721 pages. 2006.
- Vol. 4180: M. Kohlhase, OMDoc – An Open Markup Format for Mathematical Documents [version 1.2]. XIX, 428 pages. 2006.
- Vol. 4155: O. Stock, M. Schaerf (Eds.), Reasoning, Action and Interaction in AI Theories and Systems. XVIII, 343 pages. 2006.
- Vol. 4149: M. Klusch, M. Rovatsos, T.R. Payne (Eds.), Cooperative Information Agents X. XII, 477 pages. 2006.
- Vol. 4139: T. Salakoski, F. Ginter, S. Pyysalo, T. Pahikkala, Advances in Natural Language Processing. XVI, 771 pages. 2006.
- Vol. 4133: J. Gratch, M. Young, R. Aylett, D. Ballin, P. Olivier (Eds.), Intelligent Virtual Agents. XIV, 472 pages. 2006.
- Vol. 4130: U. Furbach, N. Shankar (Eds.), Automated Reasoning. XV, 680 pages. 2006.
- Vol. 4114: D.-S. Huang, K. Li, G.W. Irwin (Eds.), Computational Intelligence, Part II. XXVII, 1337 pages. 2006.
- Vol. 4108: J.M. Borwein, W.M. Farmer (Eds.), Mathematical Knowledge Management. VIII, 295 pages. 2006.
- Vol. 4106: T.R. Roth-Berghofer, M.H. Göker, H. A. Güvenir (Eds.), Advances in Case-Based Reasoning. XIV, 566 pages. 2006.
- Vol. 4099: Q. Yang, G. Webb (Eds.), PRICAI 2006: Trends in Artificial Intelligence. XXVIII, 1263 pages. 2006.
- Vol. 4095: S. Nolfi, G. Baldassarre, R. Calabretta, J.C. T. Hallam, D. Marocco, J.-A. Meyer, O. Miglino, D. Parisi (Eds.), From Animals to Animats 9. XV, 869 pages. 2006.
- Vol. 4093: X. Li, O.R. Zaiane, Z. Li (Eds.), Advanced Data Mining and Applications. XXI, 1110 pages. 2006.
- Vol. 4092: J. Lang, F. Lin, J. Wang (Eds.), Knowledge Science, Engineering and Management. XV, 664 pages. 2006.
- Vol. 4088: Z.-Z. Shi, R. Sadananda (Eds.), Agent Computing and Multi-Agent Systems. XVII, 827 pages. 2006.
- Vol. 4087: F. Schwenker, S. Marinai (Eds.), Artificial Neural Networks in Pattern Recognition. IX, 299 pages. 2006.
- Vol. 4068: H. Schärfe, P. Hitzler, P. Øhrstrøm (Eds.), Conceptual Structures: Inspiration and Application. XI, 455 pages. 2006.
- Vol. 4065: P. Perner (Ed.), Advances in Data Mining. XI, 592 pages. 2006.
- Vol. 4062: G. Wang, J.F. Peters, A. Skowron, Y. Yao (Eds.), Rough Sets and Knowledge Technology. XX, 810 pages. 2006.
- Vol. 4049: S. Parsons, N. Maudet, P. Moraitis, I. Rahman (Eds.), Argumentation in Multi-Agent Systems. XIV, 313 pages. 2006.
- Vol. 4048: L. Goble, J.-J.C. Meyer (Eds.), Deontic Logic and Artificial Normative Systems. X, 273 pages. 2006.
- Vol. 4045: D. Barker-Plummer, R. Cox, N. Swoboda (Eds.), Diagrammatic Representation and Inference. XII, 301 pages. 2006.
- Vol. 4031: M. Ali, R. Dapoigny (Eds.), Advances in Applied Artificial Intelligence. XXIII, 1353 pages. 2006.
- Vol. 4029: L. Rutkowski, R. Tadeusiewicz, L.A. Zadeh, J.M. Zurada (Eds.), Artificial Intelligence and Soft Computing – ICAISC 2006. XXI, 1235 pages. 2006.
- Vol. 4027: H.L. Larsen, G. Pasi, D. Ortiz-Arroyo, T. Andreassen, H. Christiansen (Eds.), Flexible Query Answering Systems. XVIII, 714 pages. 2006.
- Vol. 4021: E. André, L. Dybkjær, W. Minker, H. Neumann, M. Weber (Eds.), Perception and Interactive Technologies. XI, 217 pages. 2006.
- Vol. 4020: A. Bredendfeld, A. Jacoff, I. Noda, Y. Takahashi (Eds.), RoboCup 2005: Robot Soccer World Cup IX. XVII, 727 pages. 2006.
- Vol. 4013: L. Lamontagne, M. Marchand (Eds.), Advances in Artificial Intelligence. XIII, 564 pages. 2006.
- Vol. 4012: T. Washio, A. Sakurai, K. Nakajima, H. Takeda, S. Tojo, M. Yokoo (Eds.), New Frontiers in Artificial Intelligence. XIII, 484 pages. 2006.
- Vol. 4008: J.C. Augusto, C.D. Nugent (Eds.), Designing Smart Homes. XI, 183 pages. 2006.
- Vol. 4005: G. Lugosi, H.U. Simon (Eds.), Learning Theory. XI, 656 pages. 2006.
- Vol. 3978: B. Hnich, M. Carlsson, F. Fages, F. Rossi (Eds.), Recent Advances in Constraints. VIII, 179 pages. 2006.
- Vol. 3963: O. Dikenelli, M.-P. Gleizes, A. Ricci (Eds.), Engineering Societies in the Agents World VI. XII, 303 pages. 2006.
- Vol. 3960: R. Vieira, P. Quaresma, M.d.G.V. Nunes, N.J. Mamede, C. Oliveira, M.C. Dias (Eds.), Computational Processing of the Portuguese Language. XII, 274 pages. 2006.
- Vol. 3955: G. Antoniou, G. Potamias, C. Spyropoulos, D. Plexousakis (Eds.), Advances in Artificial Intelligence. XVII, 611 pages. 2006.
- Vol. 3949: F. A. Savacı (Ed.), Artificial Intelligence and Neural Networks. IX, 227 pages. 2006.

- Vol. 3946: T.R. Roth-Berghofer, S. Schulz, D.B. Leake (Eds.), *Modeling and Retrieval of Context*. XI, 149 pages. 2006.
- Vol. 3944: J. Quiñonero-Candela, I. Dagan, B. Magnini, F. d'Alché-Buc (Eds.), *Machine Learning Challenges*. XIII, 462 pages. 2006.
- Vol. 3930: D.S. Yeung, Z.-Q. Liu, X.-Z. Wang, H. Yan (Eds.), *Advances in Machine Learning and Cybernetics*. XXI, 1110 pages. 2006.
- Vol. 3918: W.K. Ng, M. Kitsuregawa, J. Li, K. Chang (Eds.), *Advances in Knowledge Discovery and Data Mining*. XXIV, 879 pages. 2006.
- Vol. 3913: O. Boissier, J. Padget, V. Dignum, G. Lindemann, E. Matson, S. Ossowski, J.S. Sichman, J. Vázquez-Salceda (Eds.), *Coordination, Organizations, Institutions, and Norms in Multi-Agent Systems*. XII, 259 pages. 2006.
- Vol. 3910: S.A. Brueckner, G.D.M. Serugendo, D. Hales, F. Zambonelli (Eds.), *Engineering Self-Organising Systems*. XII, 245 pages. 2006.
- Vol. 3904: M. Baldoni, U. Endriss, A. Omicini, P. Torroni (Eds.), *Declarative Agent Languages and Technologies III*. XII, 245 pages. 2006.
- Vol. 3900: F. Toni, P. Torroni (Eds.), *Computational Logic in Multi-Agent Systems*. XVII, 427 pages. 2006.
- Vol. 3899: S. Frintrop, *VOCUS: A Visual Attention System for Object Detection and Goal-Directed Search*. XIV, 216 pages. 2006.
- Vol. 3898: K. Tuyls, P.J. 't Hoen, K. Verbeeck, S. Sen (Eds.), *Learning and Adaption in Multi-Agent Systems*. X, 217 pages. 2006.
- Vol. 3891: J.S. Sichman, L. Antunes (Eds.), *Multi-Agent-Based Simulation VI*. X, 191 pages. 2006.
- Vol. 3890: S.G. Thompson, R. Ghanea-Hercock (Eds.), *Defence Applications of Multi-Agent Systems*. XII, 141 pages. 2006.
- Vol. 3885: V. Torra, Y. Narukawa, A. Valls, J. Domingo-Ferrer (Eds.), *Modeling Decisions for Artificial Intelligence*. XII, 374 pages. 2006.
- Vol. 3881: S. Gibet, N. Courty, J.-F. Kamp (Eds.), *Gestures in Human-Computer Interaction and Simulation*. XIII, 344 pages. 2006.
- Vol. 3874: R. Missaoui, J. Schmidt (Eds.), *Formal Concept Analysis*. X, 309 pages. 2006.
- Vol. 3873: L. Maicher, J. Park (Eds.), *Charting the Topic Maps Research and Applications Landscape*. VIII, 281 pages. 2006.
- Vol. 3864: Y. Cai, J. Abascal (Eds.), *Ambient Intelligence in Everyday Life*. XII, 323 pages. 2006.
- Vol. 3863: M. Kohlhaase (Ed.), *Mathematical Knowledge Management*. XI, 405 pages. 2006.
- Vol. 3862: R.H. Bordini, M. Dastani, J. Dix, A.E.F. Seghrouchni (Eds.), *Programming Multi-Agent Systems*. XIV, 267 pages. 2006.
- Vol. 3849: I. Bloch, A. Petrosino, A.G.B. Tettamanzi (Eds.), *Fuzzy Logic and Applications*. XIV, 438 pages. 2006.
- Vol. 3848: J.-F. Boulicaut, L. De Raedt, H. Mannila (Eds.), *Constraint-Based Mining and Inductive Databases*. X, 401 pages. 2006.
- Vol. 3847: K.P. Jantke, A. Lunzer, N. Spyratos, Y. Tanaka (Eds.), *Federation over the Web*. X, 215 pages. 2006.
- Vol. 3835: G. Sutcliffe, A. Voronkov (Eds.), *Logic for Programming, Artificial Intelligence, and Reasoning*. XIV, 744 pages. 2005.
- Vol. 3830: D. Weyns, H. V.D. Parunak, F. Michel (Eds.), *Environments for Multi-Agent Systems II*. VIII, 291 pages. 2006.
- Vol. 3817: M. Faundez-Zanuy, L. Janer, A. Esposito, A. Satue-Villar, J. Roure, V. Espinosa-Duro (Eds.), *Nonlinear Analyses and Algorithms for Speech Processing*. XII, 380 pages. 2006.
- Vol. 3814: M. Maybury, O. Stock, W. Wahlster (Eds.), *Intelligent Technologies for Interactive Entertainment*. XV, 342 pages. 2005.
- Vol. 3809: S. Zhang, R. Jarvis (Eds.), *AI 2005: Advances in Artificial Intelligence*. XXVII, 1344 pages. 2005.
- Vol. 3808: C. Bento, A. Cardoso, G. Dias (Eds.), *Progress in Artificial Intelligence*. XVIII, 704 pages. 2005.
- Vol. 3802: Y. Hao, J. Liu, Y.-P. Wang, Y.-m. Cheung, H. Yin, L. Jiao, J. Ma, Y.-C. Jiao (Eds.), *Computational Intelligence and Security, Part II*. XLII, 1166 pages. 2005.
- Vol. 3801: Y. Hao, J. Liu, Y.-P. Wang, Y.-m. Cheung, H. Yin, L. Jiao, J. Ma, Y.-C. Jiao (Eds.), *Computational Intelligence and Security, Part I*. XLI, 1122 pages. 2005.
- Vol. 3789: A. Gelbukh, Á. de Albornoz, H. Terashima-Marín (Eds.), *MICA 2005: Advances in Artificial Intelligence*. XXVI, 1198 pages. 2005.
- Vol. 3782: K.-D. Althoff, A. Dengel, R. Bergmann, M. Nick, T.R. Roth-Berghofer (Eds.), *Professional Knowledge Management*. XXIII, 739 pages. 2005.
- Vol. 3763: H. Hong, D. Wang (Eds.), *Automated Deduction in Geometry*. X, 213 pages. 2006.
- Vol. 3755: G.J. Williams, S.J. Simoff (Eds.), *Data Mining*. XI, 331 pages. 2006.
- Vol. 3735: A. Hoffmann, H. Motoda, T. Scheffer (Eds.), *Discovery Science*. XVI, 400 pages. 2005.
- Vol. 3734: S. Jain, H.U. Simon, E. Tomita (Eds.), *Algorithmic Learning Theory*. XII, 490 pages. 2005.
- Vol. 3721: A.M. Jorge, L. Torgo, P.B. Brazdil, R. Camacho, J. Gama (Eds.), *Knowledge Discovery in Databases: PKDD 2005*. XXIII, 719 pages. 2005.
- Vol. 3720: J. Gama, R. Camacho, P.B. Brazdil, A.M. Jorge, L. Torgo (Eds.), *Machine Learning: ECML 2005*. XXIII, 769 pages. 2005.
- Vol. 3717: B. Gramlich (Ed.), *Frontiers of Combining Systems*. X, 321 pages. 2005.
- Vol. 3702: B. Becker (Ed.), *Automated Reasoning with Analytic Tableaux and Related Methods*. XIII, 343 pages. 2005.
- Vol. 3698: U. Furbach (Ed.), *KI 2005: Advances in Artificial Intelligence*. XIII, 409 pages. 2005.
- Vol. 3690: M. Pěchouček, P. Petta, L.Z. Varga (Eds.), *Multi-Agent Systems and Applications IV*. XVII, 667 pages. 2005.

Preface

This book regroups the articles that were presented at the ninth international Conference on the Simulation of Adaptive Behavior (SAB 2006) held at the Italian National Research Council, Rome, on September 25-29, 2006. The objective of the biennial SAB conference is to bring together researchers in computer science, artificial intelligence, alife, complex systems, robotics, neurosciences, ethology, evolutionary biology, and related fields so as to further our understanding of the behaviors and underlying mechanisms that allow natural and artificial animals to adapt and survive in uncertain environments.

Adaptive behavior research is distinguished by its focus on the modelling and creation of complete animal-like systems, which—however simple at the moment—may be one of the best routes to understanding intelligence in natural and artificial systems. The conference is part of a long series that started with the first SAB conference, which was held in Paris in September 1990, and was followed by conferences in Honolulu 1992, Brighton 1994, Cape Cod 1996, Zurich 1998, Paris 2000, Edinburgh 2002, and Los Angeles 2004. In 1992, the MIT Press introduced the quarterly journal *Adaptive Behavior* now published by SAGE Publications. The establishment of the International Society for Adaptive Behavior (ISAB) in 1995 further underlined the emergence of adaptive behavior as a fully fledged scientific discipline. The present proceedings are a comprehensive and up-to-date resource of the latest progress in this exciting field.

The 35 papers and 35 poster summaries published here were selected from 140 submissions after a two-pass review process designed to ensure high and consistent overall quality. The articles cover all main areas in animats research, including perception and motor control, action selection, motivation and emotion, internal models and representation, collective behavior, language evolution, evolution and learning. The authors focus on well-defined models, computer simulations or robotic models, that help to characterize and compare various organizational principles, architectures, and adaptation processes capable of inducing adaptive behavior in real animals or synthetic agents, the animats. We hope that these articles will provide stimulating reading material, with a good overview of the latest developments in this exciting field.

The conference and its proceedings would not exist without the substantial help of a wide range of people. Foremost, we would like to thank the members of the Program Committee, who thoughtfully reviewed all the submissions and provided detailed suggestions on how to improve the articles. We are also indebted to our sponsors.

The enthusiasm and hard work of numerous individuals were essential to the conference's success. Above all, we would like to acknowledge the significant contributions of Diana Giorgini, Gisella Pellegrini, and all the members of the Laboratory of Autonomous Robots and Artificial Life, ISTC-CNR, Rome, for

their help with the local arrangements. Finally, once again, we would like to warmly thank Jean Solé for the artistic conception of the SAB 2006 poster and the proceedings cover.

We invite readers to enjoy and profit from the papers in this book, and look forward for the next SAB conference in 2008.

September 2006

Stefano Nolfi
Program Chair
SAB 2006

Organization

From Animals to Animats 9, The Ninth International Conference on the Simulation of Adaptive Behavior (SAB 2006) was organized by the Institute of Cognitive Sciences and Technologies of the Italian National Research Council (CNR), and ISAB (International Society for Adaptive Behavior).

Executive Committee

Conference Chair:	Stefano Nolfi, Institute of Cognitive Sciences and Technologies, CNR, Italy
Conference Co-chairs:	Gianluca Baldassarre, Institute of Cognitive Sciences and Technologies, CNR, Italy Raffaele Calabretta, Institute of Cognitive Sciences and Technologies, CNR, Italy Davide Marocco, Institute of Cognitive Sciences and Technologies, CNR, Italy Orazio Miglino, University of Naples II and Institute of Cognitive Sciences and Technologies, CNR, Italy Domenico Parisi, Institute of Cognitive Sciences and Technologies, CNR, Italy
General Chairs:	John Hallam, University of Southern Denmark, Denmark Jean-Arcady Meyer, University of Paris 6 - CNRS, France
Local Organization Chairs:	Diana Giorgini, Institute of Cognitive Sciences and Technologies, CNR, Italy Gisella Pellegrini, Institute of Cognitive Sciences and Technologies, CNR, Italy

Program Committee

H. Abbass	L. Berthouze	R. Calabretta
R. Arkin	A. Billard	A. Cangelosi
A. Arleo	E. Bilotta	J.M. Carmona
M. Asada	A. Bonarini	A. Clark
G. Baldassarre	A. Borghi	T. Collett
C. Balkenius	J.J. Bryson	H. Cruse
R. Beer	S. Bullock	K. Dautenhahn

Y. Demiris	Y. Kuniyoshi	M. Schlesinger
M. Dorigo	H. Mallot	J. Schmidhuber
M. Dyer	D. Marocco	N. Sharkey
G. Eiben	A. Martinoli	O. Sigaud
Ö. Ekeberg	C. Melhuish	O. Sporns
D. Floreano	J-A Meyer	J. Tani
L. Gambardella	O. Miglino	C. Taylor
P. Gaussier	M. Mirolli	T. Taylor
S. Ghirlanda	F. Mondada	G. Theraulaz
T. Gomi	R. Nakano	P. Todd
A. Guillot	C.L. Nehaniv	V. Trianni
J. Hallam	U. Nehmzow	E. Tuci
I. Harvey	S. Nolfi	R. Vaughan
G. Hayes	P. Pantano	P. Vogt
G. Hornby	D. Parisi	R. Walker
P. Husbands	F. Pasemann	B. Webb
A.J. Ijspeert	R. Pfeifer	J. Wiles
T. Ikegami	E. Postma	M.S. Wilson
F. Kaplan	T. Prescott	T. Ziemke
L. Keller	H.L. Roitblat	

Sponsoring Institutions

Applied AI Systems, Inc. - AAI

The European Network for the Advancement of Artificial Cognitive Systems -
euCognition

Institute of Cognitive Sciences and Technologies - ISTC-CNR

Italian Society for Cognitive Science - AISC

The International Society for Adaptive Behavior - ISAB

Kteam

Laboratoire Informatique de Paris 6 - LIP6

The University of Edinburgh

Université Pierre et Marie Curie - UPMC

The University of Southern Denmark

Table of Contents

The Animat Approach to Adaptive Behaviour

Emotions as a Bridge to the Environment: On the Role of Body
in Organisms and Robots

Carlos Herrera Pérez, David C. Moffat, Tom Ziemke 3

Some Adaptive Advantages of the Ability to Make Predictions

Daniele Caligiore, Massimo Tria, Domenico Parisi 17

Perception and Motor Control

Early Perceptual and Cognitive Development in Robot Vision

Xing Zhang, Mark H. Lee 31

Visual Control of Flight Speed and Height in the Honeybee

*Emily Baird, Mandyam V. Srinivasan, Shaowu Zhang,
Richard Lamont, Ann Cowling* 40

Visual Learning of Affordance Based Cues

*Gerald Fritz, Lucas Paletta, Manish Kumar, Georg Dorffner,
Ralph Breithaupt, Erich Rome* 52

Modelling the Peripheral Auditory System of Lizards

Lei Zhang, John Hallam, Jakob Christensen-Dalsgaard 65

A Model of Sensorimotor Coordination in the Rat Whisker System

*Ben Mitchinson, Martin Pearson, Chris Melhuish,
Tony J. Prescott* 77

Biological Actuators Are Not Just Springs

Thomas Buehrmann, Ezequiel Di Paolo 89

Investigation of Reality Constraints: Morphology and Controller
of Two-Link Legged Locomotors for Dynamically Stable Locomotion

*Kojiro Matsushita, Hiroshi Yokoi,
Tamio Arai* 101

Synchronization and Gait Adaptation in Evolving Hexapod Robots

Mariagiovanna Mazzapioda, Stefano Nolfi 113

Computer Simulation of a Climbing Insectomorphic Robot <i>Yury F. Golubev, Victor V. Korianov</i>	126
Adaptive Four Legged Locomotion Control Based on Nonlinear Dynamical Systems <i>Giorgio Brambilla, Jonas Buchli, Auke Jan Ijspeert</i>	138
The Control of Turning in Real and Simulated Stick Insects <i>Hugo Rosano, Barbara Webb</i>	150
Kinematic Modeling and Dynamic Analysis of the Long-Based Undulation Fin of <i>Gymnarchus Niloticus</i> <i>Guangming Wang, Lincheng Shen, Tianjiang Hu</i>	162
An Environmental Adaptation Mechanism for a Biped Walking Robot Control Based on Elicitation of Sensorimotor Constraints <i>Shunsuke Iida, Toshiyuki Kondo, Koji Ito</i>	174
Dynamic Generation and Switching of Object Handling Behaviors by a Humanoid Robot Using a Recurrent Neural Network Model <i>Kuniaki Noda, Masato Ito, Yukiko Hoshino, Jun Tani</i>	185
Action Selection and Behavioral Sequences	
Distributed Action Selection by a Brainstem Neural Substrate: An Embodied Evaluation <i>Mark Humphries, Tony Prescott</i>	199
A Schema Based Model of the Praying Mantis <i>Giovanni Pezzulo, Gianguglielmo Calvi</i>	211
Perceptual-Motor Sequence Learning Via Human-Robot Interaction <i>Jean-David Boucher, Peter Ford Dominey</i>	224
Navigation and Internal World Models	
POTBUG: A Mind's Eye Approach to Providing BUG-Like Guarantees for Adaptive Obstacle Navigation Using Dynamic Potential Fields <i>Michael Weir, Anthony Buck, Jon Lewis</i>	239
Navigation in Large-Scale Environments Using an Augmented Model of Visual Homing <i>Lincoln Smith, Andrew Philippides, Phil Husbands</i>	251

Evolutionary Active Vision Toward Three Dimensional Landmark-Navigation	
<i>Mototaka Suzuki, Dario Floreano</i>	263
Global Navigation Through Local Reference Frames	
<i>John Pisokas</i>	274
Transition Cells for Navigation and Planning in an Unknown Environment	
<i>Nicolas Cuperlier, Mathias Quoy, Christophe Giovannangeli, Philippe Gaussier, Philippe Laroque</i>	286
Use Your Illusion: Sensorimotor Self-simulation Allows Complex Agents to Plan with Incomplete Self-knowledge	
<i>Richard Vaughan, Mauricio Zuluaga</i>	298
Learning and Adaptation	
Stabilising Hebbian Learning with a Third Factor in a Food Retrieval Task	
<i>Adedoyin Maria Thompson, Bernd Porr, Florentin Wörgötter</i>	313
Investigating STDP and LTP in a Spiking Neural Network	
<i>Daniel Bush, Andrew Philippides, Phil Husbands, Michael O'Shea</i>	323
Spike-Timing Dependent Plasticity Learning for Visual-Based Obstacles Avoidance	
<i>Hédi Soula, Guillaume Beslon</i>	335
An Adaptive Robot Motivational System	
<i>George Konidaris, Andrew Barto</i>	346
Incremental Skill Acquisition for Self-motivated Learning Animats	
<i>Andrea Bonarini, Alessandro Lazaric, Marcello Restelli</i>	357
Piagetian Adaptation Meets Image Schemas: The Jean System	
<i>Yu-Han Chang, Paul R. Cohen, Clayton T. Morrison, Robert St. Amant, Carole Beal</i>	369
A Model of Reaching that Integrates Reinforcement Learning and Population Encoding of Postures	
<i>Dimitri Ognibene, Angelo Rega, Gianluca Baldassarre</i>	381

Combining Self-organizing Maps with Mixtures of Experts: Application to an Actor-Critic Model of Reinforcement Learning in the Basal Ganglia
Mehdi Khamassi, Louis-Emmanuel Martinet, Agnès Guillot 394

From Motor Babbling to Purposive Actions: Emerging Self-exploration in a Dynamical Systems Approach to Early Robot Development
Ralf Der, Georg Martius 406

Modelling Multi-modal Learning in a Hawkmoth
Anna Balkenius, Almut Kelber, Christian Balkenius 422

Adaptive Learning Application of the MDB Evolutionary Cognitive Architecture in Physical Agents
Francisco Bellas, Andres Faiña, Abraham Prieto, Richard J. Duro 434

Evolution

Why Are Evolved Developing Organisms Also Fault-Tolerant?
Diego Federici, Tom Ziemke 449

GasNets and CTRNNs – A Comparison in Terms of Evolvability
Sven Magg, Andrew Philippides 461

Incremental Evolution of Robot Controllers for a Highly Integrated Task
Anders Lyhne Christensen, Marco Dorigo 473

An Evolutionary Selection Model Based on a Biological Phenomenon: The Periodical Magicicadas
Marco Remondino, Alessandro Cappellini 485

Evolving Reaction-Diffusion Controllers for Minimally Cognitive Animats
Kyran Dale 498

Emergence of Coherent Coordinated Behavior in a Network of Homogeneous Active Elements
Gentaro Morimoto, Takashi Ikegami 510

Searching for Emergent Representations in Evolved Dynamical Systems
Thomas Hope, Ivilin Stoianov, Marco Zorzi 522

Modular Design of Irreducible Systems
Martin Hülse, Frank Pasemann 534

Spatially Constrained Networks and the Evolution of Modular Control Systems

*Peter Fine, Ezequiel Di Paolo,
Andrew Philippides* 546

Evolving Spatiotemporal Coordination in a Modular Robotic System

Mikhail Prokopenko, Vadim Gerasimov, Ivan Tanev 558

Spiking Neural Controllers for Pushing Objects Around

Răzvan V. Florian 570

Hierarchical Cooperative CoEvolution Facilitates the Redesign of Agent-Based Systems

Michail Maniadakis, Panos Trahanias 582

Bubbleworld.Evo: Artificial Evolution of Behavioral Decisions in a Simulated Predator-Prey Ecosystem

Thomas Schmickl, Karl Crailsheim 594

Incremental Evolution of Target-Following Neuro-controllers for Flapping-Wing Animats

Jean-Baptiste Mouret, Stéphane Doncieux, Jean-Arcady Meyer 606

Evolution and Adaptation of an Agent Driving a Scale Model of a Car with Obstacle Avoidance Capabilities

Ivan Tanev, Michal Joachimeczak, Katsunori Shimohara 619

Evolving Robot's Behavior by Using CNNs

Eleonora Bilotta, Giuseppe Cutrí, Pietro Panano 631

Collective and Social Behaviours

Experimental Study on Task Teaching to Real Rats Through Interaction with a Robotic Rat

*Hiroyuki Ishii, Motonori Ogura, Shunji Kurisu, Atsushi Komura,
Atsuo Takanishi, Naritoshi Iida, Hiroshi Kimura* 643

Believability Testing and Bayesian Imitation in Interactive Computer Games

*Bernard Gorman, Christian Thureau, Christian Bauckhage,
Mark Humphrys* 655

Asynchronous Cyclic Pursuit

Andaç Tore Şamiloğlu, Veysel Gazi, Buğra Koku 667

Evolved Homogeneous Neuro-controllers for Robots with Different Sensory Capabilities: Coordinated Motion and Cooperation <i>Elio Tuci, Christos Ampatzis, Federico Vicentini, Marco Dorigo</i>	679
Robot Learning in a Social Robot <i>Salvador Dominguez, Eduardo Zalama, Jaime Gómez García-Bermejo, Jaime Pulido</i>	691
Integration of an Autonomous Artificial Agent in an Insect Society: Experimental Validation <i>Grégory Sempo, Stéphanie Depickère, Jean-Marc Amé, Claire Detrain, José Halloy, Jean-Louis Deneubourg</i>	703
Collective Decision-Making Based on Individual Discrimination Capability in Pre-social Insects <i>Jean-Marc Amé, Jesus Millor, José Halloy, Grégory Sempo, Jean-Louis Deneubourg</i>	713
Economic Optimisation in Honeybees: Adaptive Behaviour of a Superorganism <i>Ronald Thenius, Thomas Schmickl, Karl Crailsheim</i>	725
Cumulative Cultural Evolution: Can We Ever Learn More? <i>Paul Vogt</i>	738
Agents Adopting Agriculture: Modeling the Agricultural Transition <i>Elske van der Vaart, Bart de Boer, Albert Hankel, Bart Verheij</i>	750
Adaptive Behavior in Language and Communication	
Noisy Preferential Attachment and Language Evolution <i>Samarth Swarup, Les Gasser</i>	765
The Emergence of Communication by Evolving Dynamical Systems <i>Steffen Wischmann, Frank Pasemann</i>	777
Origins of Communication in Evolving Robots <i>Davide Marocco, Stefano Nolfi</i>	789
The Complexity of Finding an Optimal Policy for Language Convergence <i>Kiran Lakkaraju, Les Gasser</i>	804

Applied Adaptive Behavior

Behavioral Analysis of Mobile Robot Trajectories Using a Point Distribution Model <i>Pierre Roduit, Alcherio Martinoli, Jacques Jacot</i>	819
Simbad: An Autonomous Robot Simulation Package for Education and Research <i>Louis Hugues, Nicolas Bredeche</i>	831
Comparing Robot Controllers Through System Identification <i>Ulrich Nehmzow, Otar Akanyeti, Roberto Iglesias Rodriguez, Theocharis Kyriacou, Stephen A. Billings</i>	843
Adaptive Fuzzy Sliding Mode Controller for the Snorkel Underwater Vehicle <i>Eduardo Sebastián</i>	855
Author Index	867