Autonomous Mental Development: A New Interdisciplinary Transactions for Natural and Artificial Intelligence

ALTHOUGH some baby animals can get up and walk within hours after birth, what a human child learns during the first two years of life easily exceeds what those animals learn in their entire lifetime. Furthermore, besides the explosive growth that occurs during this period, it is now well documented that a human brain continues its life-long development and learning [1]. The human brain is one of the most complex systems we know of in the world, composed of about 100 billion strongly interconnected neurons. A single neuron may have more than 10 000 connections to other neurons. For thousands of years, the mind has been the center of myths and human beings have endeavored to understand our own brain and the mind arising from it.

With the recent advances in cognitive science and neuroscience, e.g., with the help of brain imaging technologies such as the fMRI, EEG and PET, and many other direct observation and intervention techniques, more and deeper details of the brain's inner workings are being revealed. Together with the advances in computational intelligence, computer science, and robotics, these discoveries have stimulated the birth and rapid growth of a new interdisciplinary research field known as *Autonomous Mental Development* (AMD) [2]. Mental development is a process during which a brain-like natural or artificial embodied system, under the control of its intrinsic species-specific developmental program, develops mental capabilities through its real-time interactions with its environment (including the brain's own internal environment) using its own sensors and effectors. The mental capabilities that develop in this way include perceptual, cognitive, behavioral, motivational, and all other mental capabilities that are exhibited by humans, higher animals, and artificial systems. The intrinsic developmental program and the interaction with the environment are both important for normal mental development: The environment affects how the developmental program in the genes works, which in turn regulates how the environment and experience give rise to the brain's internal representations, mental capabilities, and internal and external behaviors.

In recognition of the gains made in this field and to support its further development, the IEEE has approved this new IEEE TRANSACTIONS ON AUTONOMOUS MENTAL DEVELOPMENT (TAMD). Published four times a year, it will serve as an archival repository for significant work on this subject. The scope of TAMD includes:

- — Computational modeling of mental development, including mental architecture, theories, algorithms, properties and experiments;
- — Experimental investigations relevant to the goal of achieving a computational understanding of developmental processes in humans and animals, especially those focusing on the role of experience and on the active exploration of the environment;
- — Engineering applications of autonomous mental development such as mechanisms enabling highly complex capabilities by robots and other artificial systems.

Investigations in AMD are expected to improve our systematic understanding of the working of the wide variety of mental capabilities in humans, to help develop biotechnology solutions, such as drugs and neural implants, to brain disorders, and to build truly intelligent machines by enabling the machines' brains to autonomously develop. We expect big breakthroughs in all of these areas.

The TAMD encourages papers submitted from all areas related to mental development, including, but not limited to, computer science, engineering, robotics, neuroscience, psychology, biology, medicine, and philosophy. No one can be expected to be an expert in all these areas. By bringing researchers and practitioners from different areas together in this forum, we are exposed to knowledge from other areas. This process will facilitate interactions with experts in other areas and fertilize the development of this interdisciplinary field. I would like to offer an advice to the interested authors to submit their research works. To ensure a wide audience and a large impact, the authors should write papers that are as readable and interesting as possible, accessible to researchers who are not in your specific area. As far as appropriate, a paper will be reviewed by peers from natural as well as from artificial intelligence sides. Due to the existence of many empirically oriented journals in the field of developmental psychology, the TAMD will emphasize computational approaches to mental development and experimental studies that make contact with computational approaches. Of course, it will be free to evolve with the community it serves.

The publication of the TAMD is the fruit of the collective effort of the AMD community supported by the IEEE Computational Intelligence Society (CIS) and the Cognitive Science Society. IEEE CIS established the Technical Committee on Autonomous Mental Development (AMD TC) in 2004. The AMD TC members are actively involved in the organization of the annual *International Conference on Development and Learning* (ICDL), and the annual *International Conference on Epigenetic Robotics* (EpiRob). The AMD TC has also explored alternative publishing mechanisms, including five special issues in IEEE TRANSACTIONS ON EVOLUTIONARY COMPUTION (IEEE TEVC) [3], *Advanced Robotics* [4], *Neurocomputing* [5], *Adaptive Behavior* [6], and *International Journal of Humanoid Robotics* [7] in 2006 and 2007. With this publication, we expect the AMD community to grow bigger and stronger.

I would like to thank Juyang (John) Weng (Founding AMD TC Chair), James (Jay) L. McClelland (Former President of the Cognitive Science Society), David Fogel (CIS President), Jim

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Keller (Former CIS VP Publications), Vincenzo Piuri (Former CIS President), Brian Scassellati (Former AMD TC Chair), and Xin Yao (CIS VP Publications, Former Editor-in-Chief of IEEE TEVC) for their immense support and personal encouragement to start this TRANSACTIONS. Special thanks are also owed to the AMD community, and especially the AMD TC members, for helping me putting together a strong TAMD proposal. Finally, I would like to express my appreciation to all of the Associated Editors who are volunteering their time and effort to support this new publication. The quality of the TAMD depends critically on the quality of service of its editorial board and the vitality of its AMD research community. We are lucky to have so many dedicated volunteers and energetic researchers. I trust that our efforts together will serve the AMD community well in the years to come.

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Dr. Zhang is an Associate Editor of the IEEE TRANSACTIONS ON MULTIMEDIA, an Associate Editor of the *International Journal of Computer Vision*, an Associate Editor of the *International Journal of Pattern Recognition and Artificial Intelligence*, and an Associate Editor of *Machine Vision and Applications*. He served on the Editorial Board of the IEEE TRANSACTIONS ON PATTERN ANALYSIS AND MACHINE INTELLIGENCE from 2000 to 2004, among others. He has been on the program committees for numerous international conferences in the areas of autonomous mental development, computer vision, signal processing, multimedia, and human–computer interaction. He was an Area Chair and a Demo Chair of the International Conference on Computer Vision, October 2003, a Program Co-Chair of the Asian Conference on Computer Vision, January 2004, a Demo Chair of the International Conference on Computer Vision, October 2005, a Program Co-Chair of the International Workshop of Multimedia Signal Processing (MMSP), October 2006, a Program Co-Chair of the International Workshop on Motion and Video Computing, November 2006, and a Program Co-Chair of the International Conference on Development and Learning, June 2009. He is a member of ACM.

Introduction of the TAMD Associate Editors

Minoru Asada (F'05) received the B.E., M.E., and Ph.D., degrees in control engineering from Osaka University, Osaka, Japan, in 1977, 1979, and 1982, respectively.

In April 1995, he became a Professor of the Osaka University. Since April 1997, he has been a Professor of the department of Adaptive Machine Systems at the Graduate School of Engineering, Osaka University. From August 1986 to October 1987, he was a Visiting Researcher of Center for Automation Research, University of Maryland, College Park.

Dr. Asada received many awards such as the best paper award of IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS92) and the Commendation by the Minister of Education, Culture, Sports, Science and Technology, Japanese Government as Persons of distinguished services to enlightening people on science and technology. He was the president of the International RoboCup Federation (2002–2008). Since 2005, he has been the Research Director of "ASADA Synergistic Intelligence Project" of ERATO (Exploratory Research for Advanced Technology by Japan Science and Technology Agency).

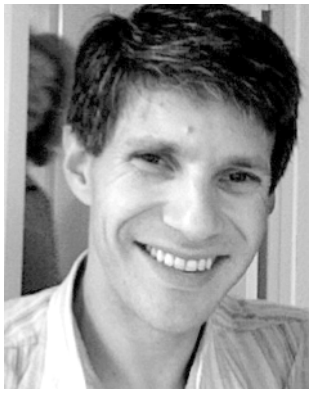
Luc Berthouze received the M.Sc. degree in sciences for the Engineer (applied mathematics) from the University of Paris XII, France, in 1994, and the Ph.D. degree from the University of Evry in 1996.

Since 2007, he is a Senior Lecturer in evolutionary and adaptive systems at the University of Sussex, U.K., and a honorary Senior Lecturer in the developmental cognitive neuroscience unit of the UCL Institute of Child Health, U.K. From 1996 to 2001, he was a Research Scientist at the Electrotechnical Laboratory, Japan. In 2001, he joined the Neuroscience Research Institute (AIST), Japan, first as a Research Scientist, and from 2005 as a Senior Research Scientist. He has authored more than 50 refereed research articles in the fields of cognitive science, robotics, cognitive neuroscience, and developmental psychology. His current research interests include motor development in infants and in machines, clinical applications of a dynamical systems approach to characterizing infant early movements (particularly in cerebral palsy) and intelligent neuroprostheses.

Kerstin Dautenhahn received the Ph.D. degree from the Biological Cybernetics Department of the University of Bielefeld, Bielefeld, Germany, in 1993.

She is Research Professor in the School of Computer Science at University of Hertfordshire, U.K., where she coordinates the Adaptive Systems Research Group. She has published more than 200 research articles on social robotics, human-robot interaction, assistive technology and Artificial Life. She has edited several books and frequently gives invited keynote lectures at international meetings. She regularly organizes conferences, and was general Chair of IEEE RO-MAN 2006 with the theme of "Getting to Know Socially Intelligent Robots" and co-general chair of the ACM/IEEE conference HRI'08. She has been Principal Investigator in several European projects on developmental robotics (Robotcub), robot companions (Cogniron and LIREC), educational virtual environments (Victec and eCircus), and robotics and assistive technology (IROMEC, RoboSkin).

Prof. Dautenhahn is Editor-in-Chief of the journal *Interaction Studies: Social Behaviour and Communication in Biological and Artificial Systems*, as well as Associate Editor of *Adaptive Behavior* (Sage Publications), the *International Journal of Social Robotics* (Springer).



Gedeon Deak received the B.A. degree (*cum laude*), Vassar College, in 1990 and the Ph.D. degree from the University of Minnesota, 1995.

He is an Associate Professor of Cognitive Science and Human Development at the University of California at San Diego. From 1995 to 1999, he was on the faculty at Vanderbilt University (1995–1999). He and his colleagues investigate how young children learn and use language, and how they use changing verbal information to make inferences about complex objects and situations. They also investigate how infants learn social and communication skills, using experiments, naturalistic observation, physiological responses, and simulations with computers and robots. He teaches undergraduate and graduate classes on cognitive development, language learning, infancy, and education and cognition. He has received research grants from the National Science Foundation, National Academy of Education/Spencer Foundation, M.I.N.D. Institute, National Alliance for Autism Research, Nicholas Hobbs Foundation, and the Hellmans. He is on the executive council of the Center for Human Development at UCSD, is a co-investigator in the Temporal Dynamics Learning Center, and is a co-editor of the *Journal of Cognition and Development*.

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Dr. Dorigo is the Editor-in-Chief of the *Swarm Intelligence* journal, and an Associate Editor or member of the editorial board for many journals in computational intelligence and adaptive systems. He was awarded the Italian Prize for Artificial Intelligence in 1996, the Marie Curie Excellence Award in 2003, the Dr. A. De Leeuw-Damry-Bourlart award in applied sciences in 2005, and the Cajastur International Prize for Soft Computing in 2007. He is a Fellow of the ECCAI.

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He is Professor of Psychological and Brain Sciences at Dartmouth College, MA. He directs Dartmouth College's interdisciplinary Brain Engineering Laboratory, with research projects ranging from computation and robotics to cognitive neuroscience. He has authored more than 100 scientific papers and numerous patents, and is a recipient of many awards and honors, including election as a Fellow of the American Association for the Advancement of Science, and he serves on the boards of a number of technology corporations and government agencies. He is co-inventor of FDA-approved devices and drugs in clinical trials, and has been the principal architect of a series of advanced computational systems for military, commercial and medical applications.

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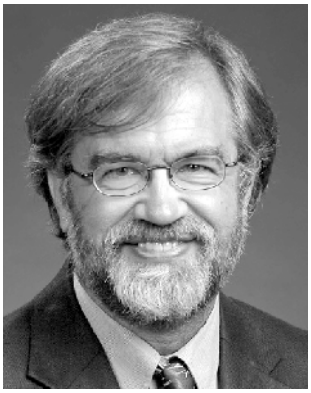

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He joined the University of Michigan, Ann Arbor, in January 2009 as Professor of Computer Science and Engineering. Prior to that, he held an endowed Professorship in computer sciences at the University of Texas at Austin. He investigates the representation of commonsense and expert knowledge, with particular emphasis on the effective use of incomplete knowledge. His research accomplishments include developing the TOUR model of spatial knowledge in the cognitive map, the QSIM algorithm for qualitative simulation, the Algernon system for knowledge representation, and the spatial semantic hierarchy model of knowledge for robot exploration and mapping.

Dr. Kuipers has served as Department Chair at University of Texas, Austin, and is a Fellow of AAAI.

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In 1976, he joined the Technical Staff of Bell Laboratories, Murray Hill, NJ, where he conducted research in the areas of speech recognition and understanding. In 1990, he became head of the Linguistics Research Department at AT&T Bell Laboratories. In 1997, he joined the University of Illinois at Urbana-Champaign, where he leads research in speech synthesis and automatic language acquisition. He is also a full-time faculty member of the Beckman Institute for Advanced Science and Technology.

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Denis Mareschal received the first degree in physics and theoretical physics from Cambridge University, Cambridge, MA. He then received the Master's degree in psychology from McGill University, Canada, before receiving the Ph.D. degree from Oxford University, Oxford, U.K.

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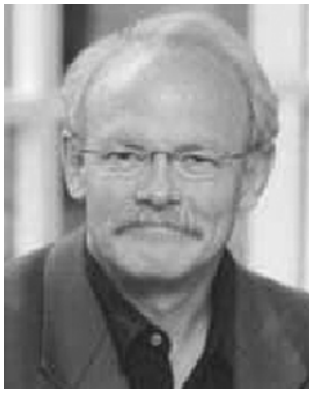

James L. (Jay) McClelland received the Ph.D. degree in cognitive psychology from the University of Pennsylvania, Philadelphia, in 1975.

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Dr. McClelland received the 1996 Distinguished Scientific Contribution Award from the American Psychological Association jointly with Dr. Rumelhart and the 2002 IEEE Neural Networks Pioneer Award for this work. He is President-Elect of the Federation of the Behavioral, Psychological, and Cognitive Sciences. He is a member of the National Academy of Sciences, and he received the APS William James Fellow Award for lifetime contributions to the basic science of psychology.

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Dr. Oudeyer is Editor of the IEEE CIS Newsletter on Autonomous Mental Development, and Associate Editor of *Frontiers in Neurorobotics* and of the *International Journal of Social Robotics* (http://www.pyoudeyer.com).

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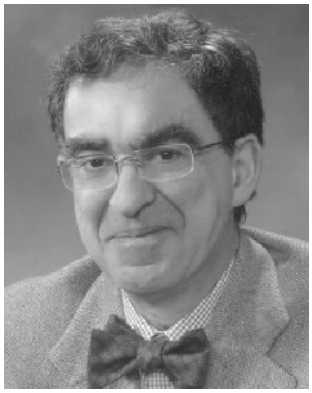
After holding faculty positions at Nottingham University and the Open University in the U.K., he moved to the Institute of Psychology, Aarhus University, Denmark, where he investigated children's acquisition of Scandinavian languages. In 1986, he became affiliated to the University of California, San Diego, to study the application of neural networks to modelling linguistic and cognitive development in young children. Since 1991, he has been a member of the faculty in the Department of Experimental Psychology, Oxford University, where he holds the position of Professor of Cognitive Neuroscience. He has been a Director of the International Association for the Study of Child Language and Executive Board member of the Cognitive Science Society. In 1993, he established the Oxford BabyLab which is a research facility for the experimental investigation of linguistic and cognitive development in babies and young children. His current research focuses on early lexical development using experimental and neuro-imaging approaches and neural network modeling.



Tomaso A. Poggio (A'86) is the Eugene McDermott Professor at the Department of Brain and Cognitive Sciences and the McGovern Institute and a member of the Computer Science and Artificial Intelligence Laboratory at the Massachusetts Institute of Technology (MIT), Cambridge. He is author or coauthor of over 400 papers in the fields of learning theory, computer science, computational neuroscience, and nonlinear systems theory and he belongs to the editorial board of several scientific journals. He is an honorary member of the Neuroscience Research Program, a member of the American Academy of Arts and Sciences and a Founding Fellow of AAAI. He received several awards including the Otto-Hahn Award of the Max-Planck-Society, the Laurea Honoris Causa from the University of Pavia and the 2003 Gabor Award. His research has been interdisciplinary, between brains and computers. It is now focused on the mathematics of learning theory, on the applications of learning techniques to computer vision, bioinformatics, computer graphics and especially on the computational neuroscience of the visual cortex in close collaboration with several physiology labs. A former Corporate Fellow of Thinking Machines Corporation, he was involved in starting several other high tech companies. For more information see http://cbcl.mit.edu.

Danil V. Prokhorov (SM'02) began his technical career in St. Petersburg, Russia, after graduating with Honors from Saint Petersburg State University of Aerospace Instrumentation in 1992 (M.S. degree in robotics). He worked as a research engineer in St. Petersburg Institute for Informatics and Automation of the Russian Academy of Sciences. He came to United States in late 1993 to study for the Ph.D. degree in neurocomputing.

Upon his graduation from the Electrical Engineering Department of Texas Tech University, Lubbock, in 1997, he joined Ford to pursue application-driven research on neural networks and other machine learning algorithms. At Ford, he took part in several production-bound projects including neural network based engine misfire detection. Since 2005, he has been with Toyota Research Institute NA, Toyota Technical Center, Ann Arbor, MI, overseeing important mid- and long-term research projects in computational intelligence. In addition to contributing with his numerous technical papers and patents, he has been helping research community with reviewing for many conferences, journals, and for the U.S. funding agencies.

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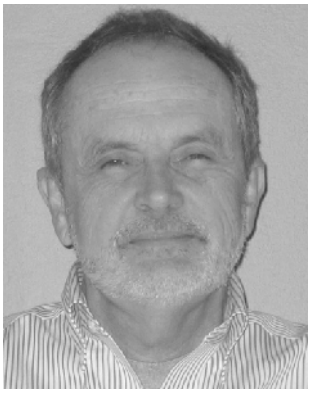

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