Michael Bowling

Curriculum Vitae

Computer Science Department
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Research Interests

Multiagent learning, multiagent planning, game theory, competitive and cooperative multiagent systems, reinforcement learning, machine learning, mobile robots, and computer game environments.

Education

Ph.D. candidate, Computer Science, **Carnegie Mellon University** 1997–Present
Advisor: Professor Manuela Veloso

I am investigating the problem of learning behavior in stochastic multiagent environments. Specifically, I am examining the problem of learning in the presence of agents that have limited capabilities, physical or rational. I have developed a rational and convergent multiagent learning technique that is capable of exploiting limited opponents and compensating for limited teammates. This technique has also been combined with approximate reinforcement learning solutions and applied to domains with intractably large state spaces, including an adversarial robot task. Expected completion: February 2003.

M.Sc., Computer Science **Carnegie Mellon University** December 1999

B.S., Math and Computer Science, **Carnegie Mellon University** 1996
University Honors

Honors

IJCAI Excellent Paper Spring 2001
Conference paper entitled "Rational and Convergent Learning in Stochastic Games" invited as a fast-track submission to *Artificial Intelligence*.

Allen Newell Medal for Research Excellence Fall 1998

RoboCup-98 Robot Soccer Champion Team Summer 1998
Small-size robot league.

EDS Academic Excellence Award Spring 1995

Research Experience

CMUnited and CMDragons RoboCup Teams 1998,1999,2001,2002
Team Member and Leader. Developed a team of robots that competed in the small-size league of RoboCup, an international, fully autonomous, robot soccer competition. Served as team leader in 1998, 1999, and 2001. Developed novel algorithms for fast real-time motion control and path-planning, Kalman-based tracking and prediction, and individual and team behavior architectures. We were league champions in 1998 and reached the quarter finals in 1999 and 2002. In 2002, we were the first known RoboCup robot team to employ any form of online adaptation, which we used to effectively select team plans.

Kitano Symbiotic Systems Project, Tokyo, Japan Summer 2000
Visiting Researcher. Worked on the development of a generic urban disaster simulation environment as a testbed for multiagent technologies. Work focused on creating a flexible kit to simplify agent development and a number of presentations promoting the new area of research.

Digital Mapping Laboratory, CMU, Pittsburgh, PA 1994–1997
Undergraduate Researcher. Developed new automatic and semi-automatic techniques for extracting road data from aerial imagery. Work included improving visualization techniques, as well as incorporating photogrammetric data to improve the accuracy of the extracted road network.

B & W Research Center, Alliance, OH Summer 1994
Internship. Performed various tasks, including software support, developing networking tools, and assisting the creation and maintenance of a software sharing system on a large computer network.

Publications

Journal Articles (Submitted and In Print)

Michael Bowling and Manuela Veloso. Existence of multiagent equilibria with limited agents. *Journal of Artificial Intelligence Research*, 2002. Submitted in October.

Michael Bowling and Manuela Veloso. Multiagent learning using a variable learning rate. *Artificial Intelligence*, 136:215–250, 2002.

Manuela Veloso, Michael Bowling, Sorin Achim, Kwun Han, and Peter Stone. The CMUnited-98 champion small robot team. *Advanced Robotics*, 2000. An earlier version appeared in *RoboCup-98: Robot Soccer World Cup II, Asada and Kitano (Eds.)*, Springer, 1999, pages 77–92. A shorter version appeared in the *AI Magazine*, 21:29–36.

Refereed Conferences

James Bruce, Michael Bowling, Brett Browning, and Manuela Veloso. Multi-robot team response to a multi-robot opponent team. In *Proceedings of the IEEE International Conference on Robotics and Automation*, 2003. To Appear.

Gal A. Kaminka and Michael Bowling. Towards robust teams with many agents. In *Proceedings of the First International Joint Conference on Autonomous Agents and Multi-Agent Systems*, Bologna, Italy, July 2002.

Brett Browning, Michael Bowling, and Manuela Veloso. Improbability filtering for rejecting false positives. In *Proceedings of the International Conference on Robotics and Automation*, Washington, D.C., May 2002.

Rune M. Jensen, Manuela M. Veloso, and Michael H. Bowling. OBDD-based optimistic and strong cyclic adversarial planning. In *Proceedings of the Sixth European Conference on Planning*, Toledo, Spain, September 2001.

Michael Bowling and Manuela Veloso. Rational and convergent learning in stochastic games. In *Proceedings of the Seventeenth International Joint Conference on Artificial Intelligence*, pages 1021–1026, Seattle, WA, August 2001.

Michael Bowling and Manuela Veloso. Convergence of gradient dynamics with a variable learning rate. In *Proceedings of the Eighteenth International Conference on Machine Learning*, pages 27–34, Williams College, June 2001.

Michael Bowling. Convergence problems of general-sum multiagent reinforcement learning. In *Proceedings of the Seventeenth International Conference on Machine Learning*, pages 89–94, Stanford University, June 2000. Morgan Kaufman.

Michael Bowling and Manuela Veloso. Bounding the suboptimality of reusing subproblems. In *Proceedings of the Sixteenth International Joint Conference on Artificial Intelligence*, pages 1340–1345, Stockholm, Sweden, August 1999. Morgan Kaufman. An earlier version appeared in the *Proceedings of the NIPS Workshop on Abstraction in Reinforcement Learning*, 1998.

Manuela Veloso, Michael Bowling, Sorin Achim, Kwun Han, and Peter Stone. CMUnited-98: a team of robotic soccer agents. In *Proceedings of IAAI-99*, Orlando, FL, 1999.

Refereed Workshops

Michael Bowling and Manuela Veloso. Scalable learning in stochastic games. In *AAAI Workshop on Game Theoretic and Decision Theoretic Agents*, Edmonton, Canada, July 2002.

Michael Bowling, Rune Jensen, and Manuela Veloso. A formalization of equilibria for multiagent planning. In *AAAI Workshop on Planning with and for Multiagent Systems*, Edmonton, Canada, July 2002.

James Bruce, Michael Bowling, Brett Browning, and Manuela Veloso. Multi-robot team response to a multi-robot opponent team. In *IROS Workshop on Collaborative Robots*, 2002.

Michael Bowling and Manuela Veloso. Motion control in dynamic multi-robot environments. In *Proceedings of the 1999 IEEE International Symposium on Computational Intelligence in Robotics and Automation*, pages 168–173, Monterey, CA, November 1999. IEEE.

Manuela Veloso, Peter Stone, and Michael Bowling. Anticipation as a key for collaboration in a team of agents: A case study in robotic soccer. In *Proceedings of SPIE Sensor Fusion and Decentralized Control in Robotic Systems II*, volume 3839, Boston, MA, September 1999.

Michael Bowling and Manuela Veloso. Reusing learned policies between similar problems. In *Proceedings of the AI*IA-98 Workshop on New Trends in Robotics*, Padua, Italy, October 1998.

Michael Bowling, Peter Stone, and Manuela M. Veloso. Predictive memory for an inaccessible environment. In *Working Notes of the IROS-96 Workshop on RoboCup*, Osaka, Japan, November 1996.

David M. McKeown, Jr., Michael Bowling, G. Edward Bulwinkle, Steven Douglas Cochran, Stephen J. Ford, Wilson A. Harvey, Dirk Kalp, Chris McGlone, Jeff McMahill, Michael F. Polis, Jefferey A. Shufelt, and Daniel Yocum. Research in image

understanding and automated cartography: 1995-1996. In *Proceedings of the DARPA Image Understanding Workshop*, pages 779–812. Morgan Kaufman, 1997.

Unrefereed Technical Reports

Michael Bowling and Manuela M. Veloso. Existence of multiagent equilibria with limited agents. Technical report CMU-CS-02-104, Computer Science Department, Carnegie Mellon University, 2002.

Michael Bowling and Manuela M. Veloso. An analysis of stochastic game theory for multiagent reinforcement learning. Technical report CMU-CS-00-165, Computer Science Department, Carnegie Mellon University, 2000.

Michael Bowling. Robocup rescue: Agent development kit, version 0.4, 2000. Manual.

Invited Presentations

"Learning, Equilibria, Limitations, and Robots". NIPS Workshop on Multiagent Learning, December 2002. Vancouver, Canada.

"Plan-Based Adaptation for Control of Robotic Agents". Dagstuhl Seminar on Plan-based Control of Robotic Agents, October 2001. Schloss Dagstuhl, Germany.

"Multiagent Learning in the Presence of Agents with Realistic Limitations". IJCAI Doctoral Consortium, August 2001. Seattle, WA.

"Rational Learning of Mixed Equilibria in Stochastic Games". Beyond MDPs: Univertainty in Artificial Intelligence 2000 Workshop, June 2000. Stanford University.

"A Parallel Between Multiagent Reinforcement Learning and Stochastic Game Theory". 1999 New England Spring Symposium on Reinforcement Learning, April 1999. Invited Presentation at University of Massachusetts, Amherst.

Other Presentations

"Approximation Techniques in Multiagent Learning", Poster at Symposium on Abstraction, Reformulation, and Approximation, Kananaskis, Canada, 2002.

"Can Multiagent Learning Scale?", University of Toronto, June, 2002.

"How Engineers Think?", Graduate Christian Fellowship, Carnegie Mellon University, October, 2001.

"Multiagent Reinforcement Learning using a Variable Learning Rate", Student Seminar Series, Carnegie Mellon University, October 2000.

Teaching Experience

15-889: Multiagent Systems, Theory and Practice — Spring 2001
Designed and taught with Prof. Manuela Veloso and Dr. Gal Kaminka.

15-451: Algorithms — Fall 2000
Teaching assistant for Prof. Avrim Blum.

15-889: Planning, Execution, and Learning — Spring 1999
Guest lecturer.

15-211: Fundamental Structures of Computer Science I Fall 1998
Teaching assistant for Prof. Seth Goldstein.

Service and Outreach

IJCAI Tutorial Speaker Summer 2003
Forthcoming tutorial on "Multiagent Learning: A Game Theoretic Perspective." Joint presentation with Prof. Michael Littman.

Workshop Co-Chair Summer 2002
Workshop on Agents in Computer Games. Computers and Games, Edmonton, Alberta. Co-chaired with Regis Vincent.

Special Session Coordinator 2003
Special session on "Multiagent Learning" at the RoboCup Symposium.

Program Committee Member
Conference on Autonomous Agents and Multiagent Systems (AAMAS) 2002
International Conference on Machine Learning (ICML) 2002
AAMAS Workshop on Game Theoretic and Decision Theoretic Planning 2003
RoboCup Symposium 2000, 2002, 2003

Reviewer 1998–Present
Artificial Intelligence Journal (AIJ)
Journal of Artificial Intelligence Research (JAIR)
Journal of Machine Learning Research (JMLR)
Complex Systems
International Joint Conference of Artificial Intelligence (IJCAI)
International Conference on AI Planning and Scheduling (AIPS)
Neural Information Processing Systems (NIPS)
International Conference on Machine Learning (ICML)
International Conference on Autonomous Agents
IEEE International Conference on Robotics and Automation (ICRA)
AAAI Spring Symposium on Collaborative Learning Agents

Competition Organizer Spring 2003
Small-size robot competition organizer for the upcoming first RoboCup American Open.

Organizing Committee 2001–Present
RoboCup special interest group on multiagent learning.

Head Referee 2000–2001
Head referee for the RoboCup small-size league. Overseeing all of the referees and responsible for the semi-finals and finals.

School Assembly Spring 2001
Presentation and demonstration of robotics at Minadeo Elementary School, Pittsburgh.

Botball (KISS Institute) Spring 2000
Organizer for a regional high school and middle school robotics competition to foster interest in mathematics, engineering, and computers.

Tutor 1997 – 1999
Worked with *Urban Impact Foundation* targeting at-risk inner-city youth.

Code Released

CMDragons'02 Small-Size Robot Team Summer 2002
The source code for the entire system was made available, including modules for vision, tracking, motion control, behavior execution, play-based team coordination, a simulator, graphical user interface, and utilities.

RoboCup Rescue ADK Summer 2000
The ADK is a package for simplifying the development of agents for the RoboCup Rescue disaster mitigation simulator. It simplifies agent-kernel and agent-agent communication protocols, provides a complete world model, and defines basic tools for agent navigation and reasoning.

Major Media Attention

National Geographic Today, 2002

New York Times, 2000, 2001.

Scientific American Frontiers, PBS, 1999, 2001.

National Museum of American History, Smithsonian Institution, Washington, DC., December 1999. Public demonstration.

KDKA Action News, 1998, 1999.

Pittsburgh Penguins, Demonstrations during the Stanley Cup playoffs at the Civic Arena, Pittsburgh, PA, April, 1998.

Japan Broadcasting Corporation (NHK), 1998.

Personal Information

Citizenship: United States

Hobbies: Disc golf, connoisseur of European (and American) board games, and ice hockey.