

# **Tucker Balch**

**Assistant Professor  
College of Computing  
Georgia Institute of Technology  
Atlanta, GA 30332-0280**

## EDUCATIONAL BACKGROUND

<b>Degree</b>	<b>Year</b>	<b>University</b>	<b>Field</b>
<b>Ph.D.</b>	1998	Georgia Institute of Technology	Computer Science
<b>M.S.</b>	1988	University of California, Davis	Computer Science
<b>B.S.</b>	1984	Georgia Institute of Technology	Information and Computer Science

## EMPLOYMENT HISTORY

<b>Title</b>	<b>Organization</b>	<b>Dates</b>
<b>Assistant Professor</b>	College of Computing Georgia Institute of Technology	2001-Present
<b>Adjunct Research Scientist</b>	Robotics Institute Carnegie Mellon University	2001-2003
<b>Research Scientist</b>	Robotics Institute Carnegie Mellon University	1999-2001
<b>Postdoctoral Fellow</b>	Computer Science Department Carnegie Mellon University	1998-1999
<b>Fighter Pilot</b>	United States Air Force	1988-1996

## CURRENT FIELDS OF INTEREST

Dr. Balch is interested in understanding and building effective large-scale physical multi-agent systems. Current research projects include:

- Observing, tracking and modeling the behavior of multi-agent systems, including live social insect colonies.
- Diversity in multi-agent systems.
- Distributed multi-robot sensing, communication and coordination.
- Behavior-based strategies for multi-robot cooperation.
- Reinforcement learning in multi-agent systems.

## I. TEACHING

### A. Courses Taught

<i>Semester</i>	<i>Course Number &amp; Title</i>		<i>Enrollment</i>	<i>Comments</i>
<b>Carnegie Mellon University</b>				
Fall 1999	CS 16-869 Autonomous Multi-Robot Systems	12		new course
Fall 2000	CS 16-869 Autonomous Multi-Robot Systems	22		
<b>Georgia Institute of Technology</b>				
Spring 2002	CS 4631A: Intelligent Robotics and Perception	15		revised
Summer 2002	CS 8803A: Robot System Building	6		revised
Fall 2002	CS 8803L: Autonomous Multi-Robot Systems	15		
Spring 2003	CS 4631A: Intelligent Robotics and Perception	40		
Spring 2004	CS 4631A: Intelligent Robotics and Perception	45		
Fall 2004	CS 1322: Object-Oriented Programming	186		
Spring 2005	CS 3630: Introduction to Perception and Robotics	15		new course
Fall 2005	CS 4632: Advance Mobile Robotics	TBD		new course
<b>Seminars</b>				
Fall 2002	CS 8001: Computational Perception and Robotics	40		
Spring 2002	CS 4801: Hot Topics in C.S. Research	40		new course

### B. Curriculum Development

Professor Balch developed or substantially revised the following courses:

1. **CS 8803L: Autonomous Multi-Robot Systems**, Fall 1999, Fall 2000, Fall 2002. This course surveys the inspiration and motivation for multi-robot systems, the unique challenges in this field and the wide range of solutions developed thus far. Students learn about the theoretical and algorithmic aspects of multi-agent and multi-robot systems, including communication, coordination and cooperation.
2. **CS 4631 & 3630: Intelligent Robots and Perception**, Spring 2002, Spring 2003, Spring 2005. This course provides an introduction to the key AI and intelligent systems issues involved in autonomous robot development. It is a “hands-on” class requiring the students to develop and evaluate their own robot control system. The course reviews the foundations of autonomous robot systems, including state-of-the-art perception algorithms, control strategies and learning. This course is appropriate for graduate and advanced undergraduate students with strong programming skills.
3. **CS 8803A: Robot System Building**, Summer 2002. This is a fast-paced self-directed course during which students build and evaluate a robotic system of their own design. Students may focus on the hardware or software aspects of robotic systems, or some mix of the two. Projects may include autonomous robots, automated perception systems, or robot teams. Students should have a

solid idea of what they want to do before they sign up for the course. A written project proposal will be due in the first two weeks. The class meets as a group once per week to review progress and share ideas.

4. **CS 4801: Hot Topics in Computer Science Research**, Spring 2003. This new seminar is designed to introduce upper class undergraduates to computer science research, and to motivate and assist them to attend graduate school. It is intended to augment the Undergraduate Research Opportunities in Computing (UROC) program (also co-organized by Dr. Balch).

### C. Individual Student Guidance

#### Graduated Ph.D. Student (Primary Advisor)

1. **Ashley Stroupe**, Robotics, Carnegie Mellon University.  
Fall 1999-Fall 2003.  
Publications with Ashley: 1 journal article, 1 journal article in submission, 6 conference papers.  
Research: cooperative observation and localization for multi-robot teams.  
*Dr. Stroupe is a staff engineer at NASA/JPL.*

#### Ph.D. Students (Primary Advisor)

2. **Adam Feldman**, Computer Science, Georgia Institute of Technology.  
Spring 2003-Present.  
Publications with Adam: 1 journal article, 1 conference paper.  
Research: recognition and modeling of social agent behavior.  
*Adam is a third year student, he passed the qualifier in Fall 2004.*
3. **Arya Irani**, Computer Science, Georgia Institute of Technology.  
Spring 2004-Present.  
Publications with Arya: 1 conference paper.  
Research: Distributed multi-robot systems.  
*Arya is a second year student.*
4. **Keith O'Hara**, Computer Science, Georgia Institute of Technology.  
Fall 2003-Present.  
Research: Robot swarms.  
Publications with Keith: 4 conference papers.  
*Keith is a third year student, he passed the qualifier Spring 2005.*
5. **Matt Powers**, Computer Science, Georgia Institute of Technology.  
Spring 2003-Present.  
Research: cooperative sensing for multi-robot teams.  
Publications with Matt: 2 conference papers.  
*Matt is a third year student, he passed the qualifier Spring 2005.*

#### M.S. Students (Primary Advisor)

6. **Victor Bigio**, Computer Science, Georgia Institute of Technology.  
Spring 2004-Present.  
Research: distributed control of robot teams.  
Publications with Victor: 1 conference paper.
7. **Eric Dodson**, Computer Science, Georgia Institute of Technology.  
Spring 2004-Present.  
Research: distributed control of robot teams.  
Publications with Eric: 1 conference paper.
8. **Kevin Sikorski**, Robotics, Carnegie Mellon University.  
Fall 1999-Spring 2001  
Publications with Kevin: 4 conference papers.  
Research: reinforcement learning and behavior-based control of robot teams.  
*Completed M.S. in Robotics in 2001, now a Ph.D. student in C.S. at the University of Washington.*

### **Undergraduates**

1. **James Bruce**, Computer Science, Carnegie Mellon University.  
Spring 1998-Spring 1999.  
Publications with Jim: 2 conference papers.  
Research: color vision based tracking.  
*Completed B.S., C.S., at Carnegie Mellon University in 1999; now a Ph.D. student in C.S. at Carnegie Mellon University.*
2. **Stephen Culpepper**, Aerospace Engineering, Georgia Institute of Technology.  
Spring 2004-Present.  
Research: agent tracking and behavior recognition.  
*Stephen is a sophomore.*
3. **Jason Fortner**, Computer Science, Georgia Institute of Technology.  
Spring 2002-Present  
Research: robot team programming for kids (CS 3911 Project).  
*Jason completed his B.S. in C.S. in Fall 2002.*
4. **Richard Guily**, Computer Science, Georgia Institute of Technology.  
Fall 2003-Present  
Research: machine learning of robot form and control  
Award: Second Place, 2004 CoC Undergraduate Research Symposium (UROC)  
*Richard is a senior.*

5. **Andrew Guillory**, Computer Science, Georgia Institute of Technology.  
Spring 2004-Present  
Research: automated learning of physical agent controllers  
First Place, 2005 CoC Undergraduate Research Symposium Judges' Award  
First Place, 2005 CoC Undergraduate Research Symposium People's Choice  
Publications: 1 paper submitted to NIPS 05  
*Andrew is a junior.*
  
6. **Stephen Ingram**, Computer Science, Georgia Institute of Technology.  
Spring 2003-Spring 2004  
Research: tracking and labeling insect behavior.  
Awards: Honorable Mention, CRA Outstanding Undergraduate Competition,  
Second Place, 2004 CoC Undergraduate Research Symposium (UROC)  
*Stephen is a graduating senior.*
  
7. **Zia Khan**, Biology and Computer Science, Carnegie Mellon University.  
Fall 1999-Fall 2001.  
Publications with Zia: 2 journal articles, 6 conference papers.  
Research: tracking and modeling insect behavior.  
*Zia completed a dual B.S. in C.S. and Biology at Carnegie Mellon University in 2002; now a Ph.D. Student at Georgia Tech.*
  
8. **John Parish**, Aerospace Engineering, Georgia Institute of Technology.  
Spring 2004-Present  
Research: underwater robotics.  
Award: Goldwater Scholarship.  
*John is a senior.*
  
9. **Tipp Mosley**, Computer Science, Georgia Institute of Technology.  
Fall 2002 - Spring 2003.  
Research: analysis of physical multi-agent behavior (CS 3901 Project).  
*Tipp completed his B.S. in C.S. in Spring 2002; he is now a PhD student in Computer Science at the University of Colorado.*
  
10. **Jesse Scherer**, Computer Science, Georgia Institute of Technology.  
Spring 2004-Present  
Research: insect husbandry  
Jesse is a sophomore.
  
11. **Hank Wilde**, Computer Science, Georgia Institute of Technology.  
Spring 2003 - Present  
Research: analysis of tracked social animal behavior.  
*Hank completed his B.S. in CS in Fall 2004.*

## **E. Teaching Honors and Awards**

1. Class of 1969 Teaching Fellow, Georgia Institute of Technology, 2002.

## F. Other Academic and Teaching Activities

1. **Co-chair of the Undergraduate Research Opportunities in Computing (UROC)** program in the College of Computing, 2002-2004. The UROC program is considered a model for undergraduate research programs at Georgia Tech.
2. **Co-organizer of the Georgia Tech Robotics Initiative.** 2003-Present. This project is focused on raising the visibility of robotics research at Georgia Tech. See <http://www.robotics.gatech.edu>.
3. **Member of College of Computing ad hoc committee on the evaluation of teaching for promotion and tenure.** 2003. The committee created a set of recommendations for evaluating and improving teaching in the CoC.
4. **Intelligent Systems Area Coordinator** 2003-Present. Responsible for administration of one of the college's 11 academic areas, including: leading the design of graduate and undergraduate curricula, administering qualifying exams, and advising graduate and undergraduate students in our area.
5. **Member of the College of Computing Graduate Program Committee** 2003-present.
6. **Co-Chair of the Ph.D. in Robotics at Georgia Tech development committee** 2004-present

## II. RESEARCH AND CREATIVE SCHOLARSHIP

### A. Ph.D. Thesis

1. ***Behavioral Diversity in Learning Robot Teams***, Balch, T., Ph.D. Thesis, College of Computing, Georgia Institute of Technology, December, 1998. Advisor: Ronald Arkin.

### B. Published Journal Articles

#### Peer-Reviewed Journal Articles

1. **Communication in Reactive Multiagent Robotic Systems**, Balch, T. and Arkin, R.C., *Autonomous Robots*, 1(1): 27-52, 1995.
2. **AuRA: Principles and Practice in Review**, Arkin, R.C. and Balch, T., *Journal of Experimental and Theoretical Artificial Intelligence*, 9 175-189, 1997.
3. **Behavior-Based Formation Control for Multiagent Robot Teams**, Balch, T. and Arkin, R.C., *IEEE Transactions on Robotics and Automation*, December 1998.
4. **Hierarchic Social Entropy: An Information Theoretic Measure of Robot Team Diversity**, Balch, T., *Autonomous Robots*, July, 2000.

5. **Value-Based Action Selection for Observation with Robot Teams Using Probabilistic Techniques**, Stroupe, A. and Balch, T., *Journal of Robotics and Autonomous Systems*. 2004. (also published at ICAR 2003).
6. **Niche Selection in Foraging Tasks in Multi-Robot Teams Using Reinforcement Learning**. Ulam, P., and Balch, T., *Adaptive Behavior* 12 (4). 2004.
7. **A 3-d Visual Tracking System for the Study of Spatial Navigation and Memory in Rhesus Monkeys**, Z. Khan, R. A. Herman, K. Wallen, and T. Balch, *Behavior Research Methods, Instruments & Computers*, 2004.
8. **A Human Trainable System for Automated Social Insect Behavior Recognition**, Feldman, A., and Balch, T., *Adaptive Behavior* 12 (4). 2004.
9. **MCMC-Based Particle Filtering for Tracking a Variable Number of Interacting Targets**, Khan, Z., Balch, T., and Dellaert, F., *IEEE Transactions on Pattern Analysis and Machine Intelligence (PAMI)*. Accepted for publication, 2005.
10. **How A.I. and multi-robot systems research will accelerate our understanding of social animal behavior**, Balch, T., Dellaert, F., Feldman, A., Guillory, A., Isbell, C., Khan, Z., Stein, A., and Wilde, H., *Proceedings of the IEEE*. Accepted for publication, 2005.

#### **Invited Journal Articles and Magazine Articles**

11. **Io, Ganymede and Callisto: A Multiagent Robot Trash-Collecting Team**, Balch, T., Boone, G., Collins, T., Forbes, H., MacKenzie, D. and Santamaria, J., *AI Magazine*, 16(2): 39-53, 1995.
12. **Grid-Based Navigation for Mobile Robots**, Balch, T., *The Robotics Practitioner*, 2(1), 1996.
13. **Fast obstacle detection via triangulation of light spots**, Matthies, L., Balch, T. and Wilcox, B., *NASA Tech Briefs*, 21(3): 52, 1997. (Also published as conference paper at ICRA-96).
14. **Profile of a winner: Georgia Tech** (a review of our winning multi-robot entry in the AAI-97 Mobile Robot Competition), Balch, T., *AI Magazine*, Fall, 1998.
15. **Overview of RoboCup-99**, Coradeschi, S., Karlsson, L., Stone, P., Balch, T., Kraetzschmar, G. and Asada, M. *AI Magazine*, 21(3), Fall, 2000. (Invited review article).
16. **On the Directional Correlation of Axial Rotation in Inverted Felines and Planetary Spin**, Donahoo, M., Boone, G., Balch, T., *Journal of Irreproducible Results*, 44(5), January, 2000. (Scientific humor).

17. **The AAI 1999 Mobile Robot Competitions and Exhibitions**, Meeden, L., Schultz, A., Balch, T., Bhargava, R., Haigh, K., Bohlen, M., Stein, C. and Miller, D. *AI Magazine*, 21(3), Fall, 2000.
18. **Guest Editorial**, Balch, T. and Parker, L., *Autonomous Robots Special Issue on Heterogeneous Multi-Robot Systems*, 8(3), 2000.
19. **The AAI-98 Mobile Robot Exhibition**, Haigh, K., Balch, T., *AI Magazine*, Spring, 2000.
20. **RoboCup-2001: The Fifth Robotic Soccer World Championships**, Veloso, M., Balch, T., and Stone, P., *AI Magazine*, Spring, 2002.
21. **Ten Years of the AAI Mobile Robot Competition**, Balch, T., Yanco, H., *AI Magazine*, Spring, 2002.

Note: Two additional journal articles are in preparation or submission. See Section F below.

## C. Books and Parts of Books

### Books

1. ***Robot Teams: From Diversity to Polymorphism***, Balch, T. and Parker, L. (eds), AK Peters, 2002.
2. ***RoboCup-2000: Robot Soccer World Cup IV***, Stone, P., Balch, T., Kraetzschmar, G. (eds), Springer-Verlag, 2001.

### Book Chapters

1. **Cooperative Multiagent Robotic Systems**, Arkin, R.C. and Balch, T., *AI-based Mobile Robots: Case Studies of Successful Robot Systems*, D. Kortenkamp, R.P. Bonasso, and R. Murphy (eds), MIT Press, 1998.
2. **Introduction and Overview of RoboCup-99**, Veloso, M., Kitano, H., Pagello, E., Kraetzschmar, G., Stone, P., Balch, T., Asada, M., Coradeschi, S., Karlsson, L. and Fujita, M., in *RoboCup-99: Robot Soccer World Cup III*, Veloso, Pagello, Kitano (eds), Springer-Verlag, 2000.
3. **Intelligent Robots**, Balch, T., *World Book 2001 Science Year*, World Book Encyclopedia, 2001.
4. **Communication and Coordination in Reactive Robotic Teams (book chapter)**, Arkin, R.C. and Balch, T., in *Coordination Theory and Collaboration Technology*, Olsen, G. (ed), 2001.
5. **Mission-Relevant Collaborative Observation and Localization**, Stroupe, A., Balch, T., in Schultz, A. and Parker, L. (eds) *Multi-Robot Systems: From Swarms to Intelligent Automata*, Kluwer, 2002.

6. **Taxonomies of Multi-Robot Task and Reward**, Balch, T., in *Robot Teams: From Diversity to Polymorphism*, Balch, T. and Parker, L. (eds), AK Peters, 2002.
7. **Communication, Diversity and Learning: Cornerstones of Swarm Behavior**, Balch, T., in *Swarm Robotics*, Sahin E., and Spears, W. (eds). Springer Verlag, 2005.

#### D. Edited Proceedings and Edited Journal Special Issues

1. **Special Issue on Heterogeneous Multi-Robot Systems**, *Autonomous Robots*, Balch, T. and Parker, L. (eds), vol. 8, no. 3, July, 2000.
2. **Proceedings of the 2<sup>nd</sup> International Workshop on the Mathematics and Algorithms of Social Insects**, Balch, T., Anderson, C. (eds), 2003.
3. **Special Issue on the Mathematics of Social Insects**, *Adaptive Behavior (Journal)*, 12 (4), Anderson, C., and Balch, T. (eds), December 2004.

#### E. Conference Presentations and Publications

##### Keynotes

1. **From Insects to Robots and Back**, Balch, T., *Autonomous Minirobots for Edutainment (AmiRE-2001)*, Paderborn, Germany, 2001.
2. **Social Insects: A Domain for AI Research**, Balch, T., *Brazilian Symposium for Artificial Intelligence (SBAI)*, Bauru Brazil, 2003.
3. **How can AI and robotics help us understand social animal behavior?**, Balch, T., *2005 National Conference on AI (AAAI-05)*.

##### Papers at Strongly Refereed Peer Reviewed Conferences

4. **Avoiding the Past: A Simple but Effective Strategy for Reactive Navigation**, Balch, T. and Arkin R.C., *IEEE International Conference on Robots and Automation (ICRA-93)*, Atlanta, May 1993, 678-685.
5. **Communication of Behavioral State in Multi-Agent Retrieval Tasks**, Arkin, R.C., Balch, T. and Nitz, E., *IEEE International Conference on Robots and Automation (ICRA-93)*, Atlanta, May 1993.
6. **Motor Schema-Based Formation Control for Multiagent Robot Teams**, Balch, T. and Arkin R.C., *IEEE International Conference on Multiagent Systems (ICMAS-95)*, San Francisco, April 1995.
7. **Fast Optical Hazard Detection for Planetary Rovers Using Multiple Spot Laser Triangulation**, Matthies, L., Balch, T. and Wilcox B., *IEEE International Conference on Robots and Automation (ICRA-97)*, Albuquerque, NM, April 1997.

8. **The Impact of Diversity on Performance in Robot Foraging**, Balch, T., *Autonomous Agents (Agents-99)*, Seattle, WA, May, 1999.
9. **Vision-Servoed Localization and Behaviors for an Autonomous Quadruped Legged Robot**, Veloso, M., Winner, E., Lenser, S., Bruce, J., and Balch, T., *Artificial Intelligence Planning Systems (AIPS-2000)*, 2000.
10. **Integrating Information, Planning, and Execution Monitoring Agents**, Veloso, M., Balch, T., and Lenser, S., *Autonomous Agents (Agents-2000)*, Barcelona, 2000.
11. **Social Potentials for Scalable Multirobot Formations**, Balch, T. and Hybinette, M., *IEEE International Conference on Robotics and Automation (ICRA-2000)*, San Francisco, 2000.
12. **Fast and Inexpensive Color Image Segmentation for Interactive Robots**, Bruce, J., Balch, T. and Veloso, M., *IEEE Intelligent Robot Systems (IROS-2000)*. 2000.
13. **Behavior-Based Coordination of Large-Scale Robot Formations**, Balch, T. and Hybinette, M., *IEEE International Conference on Multiagent Systems (ICMAS-2000)*, Boston, 2000.
14. **Behavior-Based Control of a Non-Holonomic Robot in Pushing Tasks**, Emery, R. and Balch, T., *IEEE International Conference on Robotics and Automation (ICRA-2001)*, Seoul, 2001.
15. **Distributed Sensor Fusion for Object Position Estimation by Multi-Robot Systems**. Ashley W. Stroupe, Martin C. Martin and Tucker Balch. *IEEE International Conference on Robotics and Automation (ICRA-2001)*. Seoul, May 2001.
16. **Symmetry in Markov Decision Problems and implications for Single and Multiagent Learning**. Zinkevich, M. and Balch, T., *IEEE International Conference on Machine Learning (ICML-2001)*. 2001.
17. **Automatically Tracking and Analyzing the Behavior of Live Insect Colonies**, Balch, T., Khan, Z. and Veloso, M., *ACM Autonomous Agents (Agents 2001)*, Montreal, 2001.
18. **Protocols for Collaboration, Coordination and Dynamic Role Assignment in a Robot Team**, Emery, R., Sikorski, K., and Balch, T., *IEEE International Conference on Robotics and Automation (ICRA-2002)*. Washington D.C., 2002.
19. **Collaborative Constraint-Based Multi-Robot Localization**. Stroupe, A., and Balch, T. *IEEE Intelligent Robot Systems (IROS-2002)*. Lausanne, 2002.
20. **Value-Based Observation with Robot Teams (VBORT) Using Probabilistic Techniques**. Stroupe, A., and Balch, T., *2003 International Conference on Advanced Robotics (ICAR 2003)*.

21. **Efficient Particle Filter-Based Tracking of Multiple Interacting Targets Using an MRF-based Motion Model**, Khan, Z., Balch, T., Dellaert, F., *Proceedings of the 2003 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS'03)*, 2003.
22. **An MCMC-Based Particle Filter for Tracking Multiple Interacting Targets**, Khan, Z., Balch, T., and Dellaert, F., *European Conference on Computer Vision (ECCV-04)*. 2004.
23. **Value-Based Action Selection for Exploration and Dynamic Target Observation with Robot Teams**, Stroupe, A., Ravichandran, R., and Balch, T., *2004 IEEE International Conference on Robotics and Automation (ICRA-04)*, 2004.
24. **Value-Based Communication Preservation for Mobile Robots**, Powers, M., and Balch, T. *Proceedings of 7th International Symposium on Distributed Autonomous Robotic Systems (DARS-04)*. Toulouse, France. 2004.
25. **A Rao-Blackwellized Particle Filter for EigenTracking**, Z. Khan, T. Balch, and F. Dellaert, *IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR'04)*, 2004.
26. **Pervasive Sensor-less Networks for Cooperative Multi-Robot Tasks**, O'Hara, K, and Balch, T., *Seventh International Symposium on Distributed Autonomous Robot Systems (DARS-04)*. 2004.
27. **Distributed Path Planning for Robots in Dynamic Environments Using a Pervasive Embedded Network**. O'Hara, K., and Balch, T. *Proceedings of Third International Conference on Autonomous Agents and Multi-Agent Systems (AAMAS)*. July 2004.
28. **Improving Multirobot Multitarget Tracking by Communicating Negative Information**. Powers, M., Ravichandran, R., and Balch, T. *Third International Multi-Robot Systems Workshop*. Washington, D.C. March 2005.
29. **The GNATs -- Low-Cost Embedded Networks for Supporting Mobile Robots**, O'Hara, K, and Balch, T. *Third International Multi-Robot Systems Workshop*. Washington, D.C., March 2005.
30. **What Are the Ants Doing? Vision-Based Tracking and Reconstruction of Control Programs**. Egerstedt, M., Balch, T., Dellaert, F., Delmotte, F., and Khan, Z. *2005 IEEE International Conference on Robotics and Automation*, Barcelona, Spain, Apr. 2005.
31. **Physical Path Planning Using the GNATs**, K.J. O'Hara and V.L. Bigio and E.R. Dodson and A. Irani and D.B. Walker and T.R. Balch. *2005 IEEE International Conference on Robotics and Automation*, Barcelona, Spain, Apr. 2005.

32. **Data-Driven MCMC for Learning and Inference in Switching Linear Dynamic Systems**, Oh, S. M., Rehg, J., Balch, T., Dellaert, F., *2005 National Conference on AI (AAAI-05)*, Pittsburgh, July 2005.
33. **Learning and Inference in Parametric Switching Linear Dynamic Systems**, Oh, S. M., Rehg, J., Balch, T., Dellaert, F., *2005 International Conference on Computer Vision (ICCV-05)*.

#### **Papers at Peer-Reviewed Conferences and Workshops**

34. **Buzz: An Instantiation of a Schema-Based Reactive Robotic System**, Arkin, R.C., Balch, T., Collins, T., Henshaw, A., MacKenzie, D., Nitz, E., Rodriguez, R., and Ward, K., *International Conference on Intelligent Autonomous Systems: IAS-3*, Pittsburgh, Feb. 1993, 418-427.
35. **Making a Clean Sweep: Behavior-Based Vacuuming**, MacKenzie, D. and Balch, T., *AAAI Fall Symposium: Instantiating Real-world Agents*, Raleigh, NC, March 1993.
36. **Dynamic Scheduling for Mobile Robots**, Balch, T., Forbes, H., and Schwan, K., *6<sup>th</sup> EUROMICRO Workshop on Real-time Systems*, Vasteraas, Sweden, June 1994.
37. **Lessons Learned in the Implementation of a Multirobot Trash-Collecting Team**, Balch, T., *AAAI 1995 Spring Symposium*, Stanford, March 1995.
38. **Social Entropy: A New Metric for Learning Multirobot Teams**, Balch, T., *10<sup>th</sup> International FLAIRS Conference (FLAIRS-97)*, Daytona, 1997.
39. **Lightweight Rovers for Mars Science Exploration and Sample Return**, Schenker, P., Sword, L., Ganino, A., Bickler, D., Hickey, G., Brown, D., Baumgartner, E., Matthies, L., Wilcox, B., Balch, T., Aghazarian, H. and M. S. Garrett, *SPIE Intelligent Robotics and Computer Vision XVI*, SPIE Proc. 320, Pittsburgh, Oct. 14-17, 1997.
40. **Design and Implementation of a Teleautonomous Hummer**, Bentivegna, D.C., Ali, K.S., Arkin, R.C., Balch, T., *SPIE Conference on Mobile Robots XII*, Pittsburgh, Oct 1997.
41. **Learning Roles: Behavioral Diversity in Robot Teams**, Balch, T., Proc. Of the 1997 AAAI Workshop on Multiagent Learning, Providence RI, July 1997.
42. **JavaBots**, Balch, T., *Video Proceedings of the 1998 AAAI Mobile Robot Exhibition*, AAAI. Madison WI, July 1998.
43. **Integrating Robotics Research with JavaBots**, Balch, T. and Ram, A., 1998. Working Notes of the AAAI 1998 Spring Symposium, Stanford.

44. **Integrating RL and Behavior-Based Control for Soccer**, Balch, T., *RoboCup-97: Proceedings of the First Robot World Cup Soccer Games and Conferences*, Springer-Verlag, 1998.
45. **JavaSoccer**, Balch, T., *RoboCup-97: Proceedings of the First Robot World Cup Soccer Games and Conferences*, Springer-Verlag, 1998.
46. **Robots Move** (position paper on robot simulation), Balch, T., 1998. Working Notes of the AAAI 1998 Spring Symposium, Stanford. 1998.
47. **Reward and Diversity in Multirobot Foraging**, Balch, T., *IJCAI-99 Workshop on Agents Learning About and with Other Agents*, Stockholm, 1999.
48. **Behavioral Diversity as Multiagent Cooperation**, Balch, T., *SPIE '99 Workshop on Multiagent Systems*, Boston, 1999.
49. **Progress in RoboCup Soccer Research in 2000**, M. Asada, A. Birk, E. Pagello, M. Fujita, I. Noda, S. Tadokoro, D. Duhaut, P. Stone, M. Veloso, T. Balch, H. Kitano, B. Thomas. *International Symposium on Experimental Robotics*, Honolulu, Dec, 2000.
50. **Hierarchic Social Entropy and Behavioral Difference: New Measures of Robot Group Diversity**, Balch, T., *NIST Workshop on Metrics for Intelligent Systems*, Gaithersburg, July, 2000.
51. **Model-based and Model-free Learning in Markovian and non-Markovian Domains**, Sikorski, K. and Balch, T., *Autonomous Agents (Agents 2001) Workshop on Learning Agents*, Montreal, 2001.
52. **Merging Gaussian Distributions for Object Localization in Multi-Robot Systems**. Stroupe, A., Martin, M., and Balch, T. *Experimental Robotics VII (Proceedings ISEER 2000)*. Rus and Singh (Eds). Springer, March 2001.
53. **Mission-Relevant Collaborative Observation and Localization**. Stroupe, A. and Balch, T. A.C. Schultz and L.E. Parker (eds) *Multi-Robot Systems: From Swarms to Intelligent Automata*, Kluwer, 2002.
54. **Constraint-Based Landmark Localization**. Ashley W. Stroupe, Kevin Sikorski, and Tucker Balch. *2002 RoboCup Symposium*, 2002.
55. **Niche Selection for Foraging Tasks in Multi-Robot Teams Using Reinforcement Learning**. Ulam, P., and Balch, T., *Proceedings of the 2<sup>nd</sup> International Workshop on the Mathematics and Algorithms of Social Insects*, 2003.

#### **Presentations without Proceedings**

56. **The AAAI Mobile Robot Competition and Exhibition Panel**, (organizer and panelist), *AAAI National Conference on AI*, Edmonton, Canada, 2002.

57. **Mixture Trees for Density Estimation and Fast Conditional Sampling.** Dellaert, F, Khan, Z., and Tucker Balch. *Snowbird* 2003.

## F. Other

### Submitted Journal Articles

1. **Value-Based Action Selection for Robot Teams in Exploration and Dynamic Target Observation**, Stroupe, A., and Balch, T. in revision for *Transactions on Robotics*.

### Software

1. **TeamBots:** Tucker Balch is the lead designer of TeamBots, a collection of application programs and libraries designed to support multiagent mobile robotics research. The system is used by a number of universities and other institutions for education and research. TeamBots supports simulation of robot control systems and execution of the same control systems on mobile robots. The simulation can execute complex scenarios involving multiple heterogeneous, possibly adversarial agents. The robot executive runs on several popular commercially available robot platforms including Nomadic Technologies' Nomad 150 robot, Personal Robotics' Cye robot, ActivMedia's AmigoBot, and RWI's ATRV series. In addition to simulation and real robot execution, the TeamBots environment includes a communications package (RoboComm), and Clay, a library to support coding of behavior-based control system. TeamBots is available online: <http://www.teambots.org>
2. **CMVision:** Balch assisted James Bruce (the lead designer) in the development of this real-time color-based computer vision tracking system. CMVision is widely used in the RoboCup robot soccer community. CMVision is available online: <http://www-2.cs.cmu.edu/~jbruce/cmvision/>
3. **TeamBots Junior:** This is a special version of TeamBots designed for education. TeamBots Junior enables children to program simulated robot soccer teams. This software was developed in conjunction with an undergraduate software engineering project at Georgia Tech. TeamBots Junior is available online at: <http://www.cc.gatech.edu/~borg/teambotsjunior/>

### Technical Reports and Other Publications (non-refereed)

1. **CMU Hammerheads** (a description of our robot team entry in RoboCup-2000), Emery, R., Stroupe, A., Shern, R., Sikorski, K., and Balch, T., in *RoboCup-2000: Robot Soccer World Cup IV*, Stone, P., Balch, T., Kraetzschmar, G. (eds), Springer-Verlag, 2001.
2. **CMU Hammerheads 2001** (a description of our robot team entry in RoboCup-2001), Stancliff, S., Emery, R., Stroupe, A., Sikorski, K., and Balch, T., in

*RoboCup-2001: Robot Soccer World Cup V*, Birk, A., Coradeschi, S. and Tadokoro, S. (eds), Springer-Verlag, 2002.

3. **Teaming Up: Georgia Tech's Multirobot Competition Teams**, Collins, T. and Balch, T., *AAAI National Conference on A.I. (AAAI-97)*, Providence, July 1997, 785-86.
4. **Energy-Optimal Trajectories for Overactuated Robots**, Balasubramanian, R., and Balch, T., technical report CMU-RI-TR-02-17, Robotics Institute, Carnegie Mellon University, July, 2002.

## **G. Research Proposals and Grants**

Funding for proposals with Professor Balch as an investigator total \$13.5M. As lead principal investigator his awards total \$3.3M.

### **Approved and Funded as lead Principal Investigator**

#### **Reconnaissance, Surveillance and Targeting Unmanned Ground Combat Vehicle.**

Sponsor: UGCV Program, DARPA.

Investigators: Catalan, M. (Battelle), Dodson, M. (Battelle), and Balch, T.

Amount: \$100,000 over six months for Balch. \$500K total.

Submitted September 2000. Funded: November 2000.

#### **TeamBots as a RoboCup Junior Simulation Platform,**

Sponsor: Kitano Symbiotic

Investigator: Balch, T.

Amount: \$40,000.

*Submitted: Spring 2000. Funded: Spring 2000.*

#### **Robot Swarms.**

Sponsor: Northrop-Grumman.

Investigators: Balch, T. and Choset, H.

Amount: \$50,000.

*Submitted: Fall 2000. Funded: Fall 2000.*

#### **Intel Equipment Grant.**

Sponsor: Intel.

Investigators: Balch, T. and Dellaert, F.

Amount: \$25,000 (equipment).

*Submitted: Spring 2002. Funded: Spring 2002.*

#### **Observing, Tracking and Modeling Social Multi-agent Systems**

Sponsor: ITR Program, National Science Foundation.

Investigators: Balch, T. and Dellaert, F.

Amount: \$450,000 over three years.

*Submitted Fall 2001. Funded: Fall 2002.*

#### **Sun Microsystems Equipment Grant.**

Sponsor: Sun Microsystems.  
Investigators: Balch, T.  
Amount: \$70,000 (equipment).  
*Submitted: Fall 2002. Funded: Spring 2003.*

**NSF CAREER: Learning Executable Models of Physical Social Agent Behavior**

Sponsor: NSF  
Investigator: Balch, T.  
Amount: \$500,000 over five years.  
*Submitted: Fall 2003. Funded Spring 2004.*

**Learning Visual Feature Graphs, Vision and Control for Ground Robots**

Sponsor: DARPA/LAGR  
Investigators: Balch, T., Dellaert, F., Egerstedt, M., Rehg, J.  
Amount: \$2,000,000 over three years.  
*Submitted: Summer 2004. Funded Fall 2004.*

**Multiagent Control for Intelligent Minefields**

Sponsor: Naval Surface Warfare Center  
Investigator: Balch, T.  
Amount: \$60,000  
*Submitted: Fall 2004. Funded Fall 2004.*

**Approved and Funded as Co-Principal Investigator**

**Teams of Autonomous, Cooperative and Adaptive Agents.**

Sponsor: Mobile Autonomous Robot Software Program, DARPA.  
Investigators: Veloso, M., Balch, T., and Browning, B.  
Amount: \$1,200,000 over three years.  
Submitted: Spring 1999. Funded: Summer 1999.

**Learning Structure, Reusability, and Real-time Modeling in Teams of Autonomous Robots.**

Sponsor: Control of Agent Based Systems Program, DARPA.  
Investigators: Veloso, M., Balch, T., Kaminka, G.  
Amount: \$1,500,000 over four years.  
*Submitted: Spring 1998. Funded Summer 1998.*

**TEAMS: Communication Sensitive Behaviors for Teams of Mobile Robots.**

Sponsor: MARS 2020 Program, DARPA.  
Investigators: Kumar, V., Arkin, R., Balch, T., Sukhatme, G., Reddy, J.  
Amount: \$4,500,000 over three years.  
*Submitted Spring 2002. Funded Fall 2002.*

**ITR: Morphable Software Services: Self-Modifying Programs for Distributed Embedded Systems**

Sponsor: NSF ITR.  
Investigators: Schwan, K., Balch, T., Eisenhauer, G., Pande, S., Pu, C., and Gupta, R. (U of Arizona)

Amount: \$3,000,000 over 5 years.  
*Submitted: Spring 2003. Funded: Fall 2003.*

## **Declined**

### **Behavior Based Control of Multi-Robot Teams with Guaranteed Performance**

Sponsor: Intelligent Autonomy Program, Office of Naval Research.  
Investigator: Balch, T., Arkin, R., Kumar, V., Mettala, E., MacKenzie, D.  
Amount: \$3,600,000 over 3 years.  
Submitted: Fall 2002.

### **ITR: Pickup Teams of Soccer Robots**

Sponsor: NSF ITR Medium.  
Investigators: Veloso, M. (CMU), Balch, T., Stone, P. (UT Austin).  
Amount: \$5,000,000 over 5 years.  
*Submitted: Spring 2003.*

## **I. Research Honors and Awards**

1. **First Place, AAI Mobile Robot Competition**, American Association for Artificial Intelligence, Clean Up the Office Event, 1994.
2. **First Place, AAI Mobile Robot Competition**, American Association for Artificial Intelligence, Find Life on Mars Event, 1997.
3. **Outstanding Graduate Research Assistant**, College of Computing, Georgia Tech, 1996.
4. **NASA Award for Technical Innovation**, Jet Propulsion Laboratory, 1997.
5. **NSF CAREER Award**, National Science Foundation, 2004.

## **III. SERVICE**

### **A. Professional Activities**

#### **Memberships and Activities in Professional Societies**

- Board of Trustees, The RoboCup Federation.
- Member, Institute of Electrical and Electronics Engineers (IEEE).
- Member, American Association for Artificial Intelligence (AAAI).
- Member, Association for Computing Machinery (ACM).

#### **Conference Committee Activities**

- Co-Chair, RoboCup Small Robot League 1998.

- Chair, RoboCup Small Robot League 1999,2000.
- Chair and Organizer, Workshop on Interactive Robotics and Entertainment 2000.
- Co-Chair, AAAI Mobile Robot Competition and Exhibition 1998,1999,2000.
- Co-Chair, RoboCup Workshop 2000.
- Associate Chair for Robot Events, RoboCup-2001.
- Chair, AAAI Mobile Robot Competition and Exhibition 2001, 2002.
- Co-Chair, RoboCup American Open, 2003.
- Chair and Organizer, International Workshop on the Algorithms and Mathematics of Social Insects, 2003.
- Chair, 2005 RoboCup U.S. Open, held at Georgia Tech, May 2005

#### **B. On-Campus Committees**

- Chair, Graduate Student Admissions Committee, Robotics, Carnegie Mellon University, 2001.
- Member, Graduate Student Admissions Committee, Robotics, Carnegie Mellon University, 2000.
- Co-Chair, Undergraduate Research Opportunities in Computing (UROC), College of Computing, Georgia Institute of Technology, 2001-2003.

#### **C. External Member of Ph.D. Examining Committees**

##### **Ph.D. Qualifying Exam Committees - Georgia Tech:**

- **Amin Atrash**, College of Computing, Spring 2002.
- **Eric Martinsen**, College of Computing, Fall 2002.
- **Lilia Moshkina**, College of Computing, Fall 2002.
- **Yochiro Endo**, College of Computing, Fall 2002.
- **Tracy Westyn**, College of Computing, Spring 2004.
- **Alan Wagner**, College of Computing, Fall 2004.
- **Ananth Ranganathan**, College of Computing, Fall 2004.

##### **Ph.D. Proposal Committees – Georgia Tech:**

- **Darrin Bentivegna**, College of Computing, Spring 2002.

- **Alex Stoychev**, College of Computing, Spring 2003.
- **Robert Zlot**, CMU, Spring 2004.

**External Member of Ph.D. Examining Committee:**

- **Brett Browning**, Ph.D. 2001, University of Queensland, Australia.
- **Ashley Tews**, Ph.D. 2002, University of Queensland, Australia.
- **Daniel Rodic**, University of Pretoria, South Africa.

**E. Research Project Reviewer**

- **Proposal Review Panelist**, FCT Portugal (similar to NSF), 2001.
- **NSF ITR Panel**, 2003.
- **NSF State of US Robotics Evaluation Panel**, 2004.

**F. Civic Service**

- **City of Suwanee Zoning Board of Appeals**, Member, 2003-Present.
- **City of Suwanee Zoning Board of Appeals**, Chair, January 2004.

**IV. NATIONAL AND INTERNATIONAL PROFESSIONAL RECOGNITION**

**A. Editorial and Reviewer for Technical Journals and Publishers**

- Autonomous Robots.
- IEEE Transactions on Robotics and Automation.
- IEEE Transactions on Robotics.
- IEEE Transactions on Systems, Man and Cybernetics.
- Robotics and Autonomous Systems.
- ACM SIGGRAPH.

**B. Military Honors**

- Distinguished Graduate USAF Pilot Training, 1989.
- Top Instrument Pilot USAF Pilot Training, 1989.
- National Defense Service Medal 1991.
- Top Gun Team 128th Fighter Squadron, 1991, 1992.

- Air Force Achievement Medal 1993.
- Air Force Outstanding Unit Award 1991, 1992, 1995.
- Air Force Commendation Medal 1992, 1995.

## C. Media Coverage

### Print

- **The Associated Press**, "Computers, Robots Set to Play Soccer," August, 2000.
- **The Associated Press**, "Rescue Robots: Competition Tests Robot's Life-Saving Abilities," Connie Mabin, July 31, 2000.
- **New York Times**, Robots Learn Soccer (and the Game of Life) November 27, 2001, Yudhijit Bhattacharjee.
- **New Scientist Magazine**, "Follow that Ant," Catherine Zandonella, June, 2001.
- **Atlanta Journal Constitution**, "Research Wags the Robot Dog at Georgia Tech," Rebecca MacCarthy, December 7, 2002.
- **Washington Post**, "The Games Robots Play," Guy Gugliotta, May 13, 2003.
- **Associated Press**, "Artificial Athletes Compete in RoboCup," Elliott McLaughlin, May 10, 2005. Carried by: Sports Illustrated, ABC News, Washington Post, L.A. Times.
- **BBC News Online**, "Robots compete in football league," May 11, 2005.

### Radio

- **National Public Radio**, story about soccer robots, Lee Gutkind, July, 2001.
- **National Public Radio**, story about the RoboCup US Open, May 11, 2005.
- **WABE Atlanta**, story about the RoboCup US Open, Ted Vigodsky, May 26, 2005.

## Television

- **Scientific American Frontiers (PBS)**, "Natural Born Robots," November 2, 1999.
- **Public Broadcasting System**, "Beyond Human," Thomas Lucas Productions, May, 2001.
- **CNN**, "Robot Dog Soccer," June 2, 2003.
- **CNN**, "Honey Bee Dancing," September 2003.
- **CNN**, "New Explorers," Fall 2004.
- **Reuters TV**, "RoboCup US Open," May 15, 2005. Carried by BBC World.

## V. OTHER CONTRIBUTIONS

### A. Invited Talks

1. **Royal Institute of Technology (Sweden), Robotics Seminar, Invited Speaker**, Stockholm, Sweden, 1998.
2. **AAAI-98 Robot Competition Workshop, Invited Panelist**, Madison, WI, 1998.
3. **CMU VASC Seminar, Invited Speaker**, Pittsburgh, 1999.
4. **Westinghouse High School Initiative, Invited Speaker**, Pittsburgh, January, 2000.
5. **CMU Robotics Institute Seminar, Educating with and about Robots, (organizer and speaker)**, Pittsburgh, December, 2000.
6. **CMU Seminar on Robotics Education, Invited Speaker**, Pittsburgh, June, 2000.
7. **ICRA-2000 Workshop on Sensor-based Navigation, Invited Speaker**, San Francisco, April, 2000. **NIST Workshop on Performance Metrics for Intelligent Systems, Invited Speaker**, Gaithersburg, August, 2000.
8. **Autonomous Minirobots for Research and Edutainment, Keynote Speaker**, Paderborn, Germany, December, 2001.
9. **Smithsonian Institution, Invited Demonstration** of soccer robots, December, 2000.
10. **Navy Center for Applied Research in Artificial Intelligence Seminar Series, Invited Speaker**, Washington, DC, February, 2002.

11. **Stanford Research Institute, AI Seminar Series**, Invited Speaker, Stanford, CA, November, 2002.
12. **NATO Workshop on Multi-Robot Systems**, Invited Speaker. Naval Research Lab, Washington, D.C., March 2003.
13. **Robotics Institute Seminar**, Invited Speaker. CMU, February 2004.
14. **National Conference on AI**, Invited Speaker, Pittsburgh, July 2005.
15. **Gordon Research Conference**, Invited Speaker, Oxford University, July 2005.
16. **Swarm Robotics Workshop**, Invited Speaker, Napa Valley, August 2005.

## VI. PERSONAL DATA

Born: July 4, Miami, Florida.  
Telephone: 678-482-6595  
Wife: Maria Hybinette (Assistant Professor, C.S., University of Georgia).  
Sons: Gunnar (born 2001), Tucker (born 2003).  
Citizenship: USA  
Email: [tucker@cc.gatech.edu](mailto:tucker@cc.gatech.edu)  
WWW: <http://www.cc.gatech.edu/~tucker>