

# RAJIV T. MAHESWARAN

## CURRENT POSITIONS

**Research Assistant Professor**, Computer Science Department  
**Research Scientist**, Information Sciences Institute

USC Viterbi School of Engineering  
University of Southern California  
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**Visa Status: U.S. Citizen**

## RESEARCH INTERESTS

**Networked Agent Systems:** Multi-Agent Systems, Communication Networks, Complex Systems; **Design and Analysis of Decentralized Mechanisms:** Game Theory, Decision Theory, Market-Based Control, Operations Research, Distributed Constraint Optimization; **Domains:** Uncertainty, Dynamism, Scalability, Adjustable Autonomy, Privacy Preservation

## EDUCATION

### Doctor of Philosophy

Electrical Engineering

University of Illinois at Urbana-Champaign

Thesis: *A Game-Theoretic Analysis of Agent-Mediated Resource Allocation*

Committee: Dr. Tamer Başar (chair), Dr. Leslie Gasser, Dr. George Gross, Dr. Sean Meyn, Dr. Rayadurgam Srikant

Received: May 03

Sep 98 - May 03

### Master of Science

Electrical Engineering

University of Illinois at Urbana-Champaign

Thesis: *Multi-User Flow Control as a Nash Game: Performance of Various Algorithms*

Advisor: Dr. Tamer Başar

Received: Aug 98

Sep 95 - Aug 95

### Bachelor of Science

Applied Mathematics / Engineering / Physics

University of Wisconsin - Madison

University of Wisconsin - Marathon County

Received: May 95

Sep 93 - May 95

Sep 91 - May 93

**PROFESSIONAL EXPERIENCE**

**Research Assistant Professor** May 04 - Jun 05, Sep 06 - Present  
**Computer Science Department, USC** Los Angeles, CA  
*Managed multiple threads of research including analysis of distributed coordination based on graphical games, POMDPs for adjustable autonomy in uncertain domains and quantitative measures for privacy in multi-agent aspects of the CALO (Collaborative Agent that Learns and Organizes) personal assistant agent project. Coordinated the implementation and integration of newly developed technology into CALO. Participated in the generation of multiple grant proposals including a successful DARPA grant from the COORDINATORS program. Contributed in advising several graduate students. Assisted in the graduate admission process and faculty administration.*

**Research Scientist** Jun 05 - Present  
**Information Sciences Institute, USC** Marina Del Rey, CA  
*Developed algorithms for distributed coordination in uncertain, dynamic environments under partial and subjective information for the DARPA COORDINATORS program. Contributed to the implementation and testing of graph-traversal and probabilistic reasoning components of delivered multi-agent system. Participated in the generation of multiple grant proposals. Assisted in advising several graduate students.*

**Postdoctoral Research Associate** Aug 03 - Apr 04  
**Computer Science Department, USC** Los Angeles, CA  
*Conducted multiple threads of research including distributed coordination and adjustable autonomy issues in multi-agent aspects of the CALO (Collaborative Agent that Learns and Organizes) personal assistant agent project. Coordinated the implementation and integration of newly developed technology into CALO system. Contributed in the advising of several graduate students. Participated in the generation of multiple grant proposals.*

**Research Assistant** Sep 96 - May 03  
**Coordinated Science Laboratory, UIUC** Urbana-Champaign, IL  
*Research focused on game-theoretic analysis of market-based management of resource allocation for mobile agents in ad-hoc networks as part of the ActComm Project on Transportable Agents and Wireless Networks. Areas of investigation included convergence of distributed control algorithms, effects of coalition formation, equilibrium and dynamics for coupled multiple-resource settings and design principles for decentralized efficiency. Additional responsibilities included system administration and organization of Network Control Seminar series.*

**Teaching Assistant** Sep 95 - Dec 02  
**Dept. of Electrical and Computer Engineering, UIUC** Urbana-Champaign, IL  
*Taught for eight semesters. Experience includes conducting preparatory lectures, overseeing laboratories, creating examinations, grading and evaluation, managing teams of graders, and addressing students' concerns (see "Teaching Assistantships" section for more details).*

## PUBLICATIONS

### Journal Papers

R. T. Maheswaran, J. P. Pearce, E. Bowring, P. Varakantham and M. Tambe, "Privacy Loss in Distributed Constraint Reasoning: A Quantitative Framework for Analysis and its Applications," in *Autonomous Agents and Multiagent Systems*, vol. 13, no. 1, pp. 27-60, July 2006.

R. T. Maheswaran and T. Başar, "Efficient Signal Proportional Allocation (ESPA) Mechanisms: Decentralized Social Welfare Maximization for Divisible Resources," *IEEE Journal on Selected Areas in Communication: Price-Based Access Control and Economics for Communication Networks*, vol. 24, no. 4, pp. 1000-1009, May 2006.

R. T. Maheswaran and T. Başar, "Nash Equilibrium and Decentralized Negotiation in Auctioning Divisible Resources," *Group Decision and Negotiation*, vol. 12, no. 5, pp. 361-395, September 2003.

J. Bredin, R. T. Maheswaran, O. Ç. Imer, D. Kotz, D. Rus and T. Başar, "Computational Markets to Regulate Mobile-Agent Systems," *Autonomous Agents and Multi-Agent Systems*, vol. 6, no. 3, pp. 235-263, May 2003.

### Conference Papers

P. Varakantham, R. T. Maheswaran and M. Tambe, "Expected Value Approximation and Dynamic Disjunctive Beliefs: Efficient Techniques for Obtaining High Quality Solutions in POMDPs," in *Proceedings of the 20th International Joint Conference on Artificial Intelligence*, Hyderabad, India, January 6-12, 2007.

J. P. Pearce, R. T. Maheswaran and M. Tambe, "Solution Sets for DCOPs and Graphical Games," in *Proceedings of the 5th International Joint Conference on Autonomous Agents and Multiagent Systems*, Hakodate, Japan, May 10-12, 2006.

P. Szekely, M. Becker, S. Fitzpatrick, G. Gati, D. Hanak, J. Jin, G. Karsai, R. T. Maheswaran, R. Neches, C. M. Rogers, R. Sanchez and C. VanBuskirk, "CSC: Criticality-Sensitive Coordination," in *Proceedings of the 5th International Joint Conference on Autonomous Agents and Multiagent Systems*, Hakodate, Japan, May 10-12, 2006.

R. T. Maheswaran and T. Başar, "On Revenue Generation When Auctioning Network Resources," in *Proceedings of the 44th IEEE Conference on Decision and Control*, Seville, Spain, December 12-15, 2005.

R. T. Maheswaran, "On Efficiency and Revenue Maximization When Allocating a Divisible Resource," in *Proceedings of the 43rd Annual Allerton Conference on Communication, Control, and Computing*, Monticello, Illinois, September 28-30, 2005.

R. T. Maheswaran, J. P. Pearce, P. Varakantham, E. Bowring and M. Tambe, "Valuations of Possible States: A Unifying Quantitative Framework for Evaluating Privacy in Collaboration," in *Proceedings of the 4th International Joint Conference on Autonomous Agents and Multi-Agent Systems*, Utrecht, The Netherlands, July 25-29, 2005.

P. Varakantham, R. T. Maheswaran and M. Tambe, "Exploiting Belief Bounds: Practical POMDPs for Personal Assistant Agents," in *Proceedings of the 4th International Joint Conference on Autonomous Agents and Multi-Agent Systems*, Utrecht, The Netherlands, July 25-29, 2005.

M. Tambe, E. Bowring, H. Jung, G. Kaminka, R. T. Maheswaran, J. Marecki, P. J. Modi, R. Nair, J. Pearce, P. Paruchuri, D. Pynadath, P. Scerri, N. Schurr, P. Varakantham, "Conflicts in Teamwork: Hybrids to the Rescue," in *Proceedings of the 4th International Joint Conference on Autonomous Agents and Multiagent Systems*, Utrecht, The Netherlands, July 25-29, 2005.

R. T. Maheswaran and T. Başar, "Social Welfare of Selfish Agents: Motivating Efficiency for Divisible Resources," in *Proceedings of the 43rd IEEE Conference on Decision and Control*, Atlantis, Paradise Island, Bahamas, December 14-17, 2004.

R. T. Maheswaran, J. P. Pearce and M. Tambe, "Distributed Algorithms for DCOP: A Graphical-Game-Based Approach," in *Proceedings of the 17th International Conference on Parallel and Distributed Computing Systems*, San Francisco, California, September 15-17, 2004.

R. T. Maheswaran, M. Tambe, E. Bowring, J. P. Pearce and P. Varakantham, "Taking DCOP to the Real World: Efficient Complete Solutions for Distributed Multi-Event Scheduling," in *Proceedings of the 3rd International Joint Conference on Autonomous Agents and Multi-Agent Systems*, New York, New York, July 19-13, 2004.

R. T. Maheswaran and T. Başar, "Equilibrium and Negotiation in Multiple Resource Auctions," in *Proceedings of the 42nd IEEE Conference on Decision and Control*, Maui, Hawaii, December 9-12, 2003.

R. T. Maheswaran and T. Başar, "Coalition Formation in Proportionally Fair Divisible Auctions," in *Proceedings of the 2nd International Joint Conference on Autonomous Agents and Multi-Agent Systems*, Melbourne, Australia, July 14-18, 2003.

R. T. Maheswaran and T. Başar, "Decentralized Network Resource Allocation as a Repeated Noncooperative Market Game," in *Proceedings of the 40th IEEE Conference on Decision and Control*, pp. 4565-4570, Orlando, Florida, December 4-7, 2001.

J. Bredin, R. T. Maheswaran, O. Ç. Imer, T. Başar, D. Kotz and D. Rus, "A Game-Theoretic Formulation of Multi-Agent Resource Allocation," in *Proceedings of the 4th International Conference on Autonomous Agents*, pp. 349-356, Barcelona, Spain, June 2000.

R. T. Maheswaran, O. Ç. Imer and T. Başar, “Agent Mobility in Computer Networks Under Price Incentives,” in *Proceedings of the 38th IEEE Conference on Decision and Control*, pp. 4020-4025, Phoenix, Arizona, Dec 7-10, 1999.

R. T. Maheswaran and T. Başar, “Multi-User Flow Control as a Nash Game: Performance of Various Algorithms,” in *Proceedings of the 37th IEEE Conference on Decision and Control*, pp. 1090-1095, Tampa, Florida, December 16-18, 1998.

### Conference Papers Under Review

J. Jin, R. Maheswaran, R. Sanchez and P. Szekely “VizScript: A High-Level Language for Rapidly Creating Custom Visualizations for Multi-Agent Systems,” *submitted to the 2007 International Conference on Intelligent User Interfaces* Hawaii, USA, January 28-31, 2007.

R. T. Maheswaran, C. M. Rogers, R. Sanchez and P. Szekely, “Distributed Coordination in Uncertain Multiagent Systems,” *submitted to the 5th International Joint Conference on Autonomous Agents and Multiagent Systems*, Honolulu, Hawaii, May 14-18, 2007.

### Book Chapters

R. T. Maheswaran, J. P. Pearce and M. Tambe, “A Family of Graphical-Game-Based Algorithms for Distributed Constraint Optimization Problems,” in *Coordination of Large-Scale Multiagent Systems*, P. Scerri, R. Vincent, and R. Mailler (Eds.), pp. 127-146, Springer, 2006.

N. Schurr, R. T. Maheswaran, M. Tambe and P. Scerri, “Evolution of a Teamwork Model,” in *Cognition and Multi-Agent Interaction*, R. Sun (Ed.), pp. 307-327, Cambridge University Press, 2006.

R. T. Maheswaran, M. Tambe, P. Varakantham and K. Myers, “Adjustable Autonomy Challenges in Personal Assistant Agents: A Position Paper,” in *Agents and Computational Autonomy: Potential, Risks, Solutions*, M. Nickles, M. Rovatsos and G. Weiss (Eds.), Lecture Notes in Artificial Intelligence, vol. 2969, pp. 187-194, Springer-Verlag, 2004.

R. T. Maheswaran and T. Başar, “Auctions for Divisible Resources: Price Functions, Nash Equilibria and Decentralized Update Schemes,” in *Agent-Mediated Electronic Commerce IV: Designing Mechanisms and Systems*, J. Padget, O. Shehory, D. Parkes, N. Sadeh and W.E. Walsh (Eds.), Lecture Notes in Artificial Intelligence, vol. 2531, pp. 87-102, Springer-Verlag, 2002.

J. Bredin, D. Kotz, D. Rus and R. T. Maheswaran, O. Ç. Imer, T. Başar, “A Market-Based Model for Resource Allocation in Agent Systems,” in *Coordination of Internet Agents: Models, Technologies and Applications*, A. Omicini, F. Zambonelli, M. Klusch and R. Tolksdorf (Eds.), ch. 17, pp. 426-442, Springer-Verlag, 2001.

## Symposium and Workshop Papers

R. T. Maheswaran, C. M. Rogers, R. Sanchez, P. Szekely and P. Chen, “Scaling in Domains with Uncertainty: Criticality-Sensitive Coordination,” in *Workshop on Massively Multiagent Systems / Large-Scale Multiagent Systems*, Hakodate, Japan, May 9, 2006.

R. T. Maheswaran, C. M. Rogers, R. Sanchez, P. Szekely and P. Chen, “Distributed Scheduling for Multi-Agent Teamwork in Uncertain Domains: Criticality-Sensitive Coordination,” in *Workshop on Multiagent Sequential Decision Making*, Hakodate, Japan, May 9, 2006.

P. Varakantham, R. T. Maheswaran and M. Tambe, “Implementation Techniques for Solving POMDPs in Personal Assistant Domains,” in *Workshop on Programming Multi-Agent Systems*, Hakodate, Japan, May 9, 2006.

P. Szekely, R. T. Maheswaran, R. Neches, C. M. Rogers, R. Sanchez, M. Becker, S. Fitzpatrick, G. Gati, D. Hanak, G. Karsai and C. VanBuskirk, “An Examination of Criticality-Sensitive Approaches to Coordination,” in *AAAI Spring Symposium on Distributed Plan and Schedule Management*, Menlo Park, California, March 27-29, 2006.

J. P. Pearce, R. T. Maheswaran and M. Tambe, “Graph-Based Bounds on  $k$ -Optimal Joint-Action Sets for Multiple Agents,” in *AAMAS 2005 Workshop on Declarative Agent Languages and Technologies (DALT)*, Utrecht, The Netherlands, July 25, 2005.

J. P. Pearce, R. T. Maheswaran and M. Tambe, “Local Algorithms for Distributed Constraint Optimization in Dynamic, Anytime Environments,” in *AAMAS 2005 Workshop on Ambient Agents - Agents for Ubiquitous Environments (AmbiAgents)*, Utrecht, The Netherlands, July 26, 2005.

R. T. Maheswaran, J. P. Pearce, P. Varakantham, E. Bowring and M. Tambe, “Valuations of Possible Worlds (VPW): A Quantitative Framework for Analysis of Privacy Loss Among Collaborative Personal Assistant Agents,” in *AAAI Spring Symposium on Persistent Assistants: Living and Working with AI*, Menlo Park, California, March 21-23, 2005.

P. Varakantham, R. T. Maheswaran and M. Tambe, “Practical POMDPs for Personal Assistant Domains,” in *AAAI Spring Symposium on Persistent Assistants: Living and Working with AI*, Menlo Park, California, March 21-23, 2005.

J. P. Pearce, R. T. Maheswaran and M. Tambe, “DCOP Games for Multi-Agent Coordination,” in *5th International Workshop on Distributed Constraint Reasoning*, Toronto, Canada, September 27, 2004.

R. T. Maheswaran, J. P. Pearce and M. Tambe, “Distributed Algorithms for DCOP: A Graphical-Game-Based Approach” in *AAMAS Workshop on Challenges in the Coordination of Large-Scale Multi-Agent Systems*, New York, New York, July 19-23, 2004.

P. Varakantham, R. T. Maheswaran and M. Tambe, “Agent Modeling in Partially Observable Domains” in *AAMAS Workshop on Modeling Other Agents from Observations*, New York, New York, July 19-23, 2004.

## INVITED PRESENTATIONS

“How Important Is It? Utilizing Marginal Utility When Reasoning Under Uncertainty,”  
Joint Operations Research / Computer Science Department Seminar Series,  
*Naval Postgraduate School,*  
Monterey, California, August 24, 2006

“On the Effects of Interaction on Equilibrium in Multi-Agent Decision Making,”  
Workshop on Games, Teams and Decisions,  
*University of Illinois at Urbana-Champaign,*  
Urbana, Illinois, September 30, 2006.

“Probabilistic Planning in Multi-Agent Systems,”  
Workshop on Learning and Information in Games and Control,  
*California Institute of Technology,*  
Pasadena, California, March 22-23, 2006.

“Design and Analysis of Resource Allocation in Competitive and Cooperative Multi-Agent Systems,”  
Decision, Control and Optimization Seminar Series,  
*University of Illinois at Urbana-Champaign,*  
Urbana, Illinois, November 11, 2004.

“Design and Analysis of Resource Allocation in Competitive and Cooperative Multi-Agent Systems,”  
Discovery and Systems Health Seminar Series,  
*NASA Ames Research Center,*  
Moffett Field, California, November 8, 2004.

“Market-Based Control for Multi-Agent Systems: A Game-Theoretic Approach to Allocating Divisible Resources,”  
Systems, Dynamics and Control Seminar Series,  
*University of California - Los Angeles,*  
Los Angeles, California, March 5, 2004.

“Market-Based Allocation of Divisible Resources,”  
Teamcore Research Group Seminar Series,  
*University of Southern California,*  
Los Angeles, California, June 9, 2003.

“Market-Based Allocation of Divisible Resources,”  
Department of Electrical Engineering and Computer Science,  
*Washington State University,*  
Pullman, Washington, April 23, 2003.

## AWARDS

Information Sciences Institute Meritorious Service Award (2006)  
Incomplete List of Teachers Ranked as Excellent by Their Students (1996)  
Ahrnsbrak Award for Unselfish Leadership (1993)  
William R. Schmitz Award for the Sciences (1992)  
Mathematics Departmental Distinction Award (1992)  
Robert C. Byrd Scholarship for Wisconsin All-State Academic Scholars (1991)  
State of Wisconsin Academic Excellence Award (1991)  
National Merit Commendation (1991)  
Kickbush Memorial Scholarship (1991)

## PROFESSIONAL ACTIVITIES

### **Program Committee Member**

4th International Joint Conference on Autonomous Agents and Multiagent Systems  
2nd International Joint Conference on Autonomous Agents and Multiagent Systems

### **Reviewer**

IEEE Transactions on System, Man and Cybernetics, Part A  
19th International Joint Conference on Artificial Intelligence  
24th American Control Conference  
IEEE Journal on Selected Areas in Communications  
IEEE Transactions on Automatic Control  
43rd IEEE Conference on Decision and Control  
Journal of Artificial Intelligence Research  
Automatica  
40th IEEE Conference on Decision and Control

### **Other**

Organizer, Invited Session on “Game-Theoretic Issues in Distributed Control of Multiagent Systems”, 43rd IEEE Conference on Decision and Control  
Session Chair, 43rd IEEE Conference on Decision and Control  
Session Chair, 42nd IEEE Conference on Decision and Control

**TEACHING ASSISTANTSHIPS**

Static and Dynamic Game Theory (Fall 2002)

*Advanced special topics graduate course on game theory*

Optimum Control Systems (Spring 2002)

*Advanced graduate course on foundations of optimal control theory*

Random Processes (Fall 1998)

*Graduate course on random processes, spectral analysis, Markov chains and filtering*

Control Systems Laboratory (Fall 1997)

*Undergraduate course on modeling, analysis, simulation and design of control systems*

Analog Signal Processing (Spring 1997)

*Undergraduate course on linear systems, transformations and stability*

Random Processes (Fall 1996)

*Graduate course on random processes, spectral analysis, Markov chains and filtering*

Introduction to Electrical and Computer Engineering Laboratory (Spring 1996)

*First year undergraduate course on circuits and electronics*

Introduction to Electrical and Computer Engineering Laboratory (Fall 1995)

*First year undergraduate course on circuits and electronics*

**STUDENTS SUPERVISED**

Po-An Chen                      Doctoral Student, Computer Science Department  
University of Southern California

Jing Jin                              Doctoral Student, Computer Science Department  
University of Southern California

Nader Noori                      Doctoral Student, Computer Science Department  
University of Southern California

Emma Bowring                      Doctoral Student, Computer Science Department  
University of Southern California

Jonathan P. Pearce                      Doctoral Student, Computer Science Department  
University of Southern California

Pradeep Varakantham                      Doctoral Student, Computer Science Department  
University of Southern California

## PROJECTS

Project CSC (Criticality-Sensitive Coordination)  
Program COORDINATORS  
Agency DARPA IPTO  
Program Managers Dr. Tom Wagner

*The Coordinators program is creating distributed intelligent software systems that will help fielded units adapt their mission plans as the situation around them changes and impacts their plans. Intelligent software Coordinators do this by reasoning about the tasks assigned to a given unit, the task timings, how the tasks interact with those of other units, and by evaluating possible changes such as changing task timings, task assignments, or selecting from pre-planned contingencies.*

Project CALO (Collaborative Agent that Learns and Organizes)  
Program PAL (Personal Assistant that Learns)  
Agency DARPA IPTO  
Program Managers Dr. David Gunning

*The mission of the PAL program is to radically improve the way computers support humans by enabling systems that are cognitive, i.e., computer systems that can reason, learn from experience, be told what to do, explain what they are doing, reflect on their experience, and respond robustly to surprise. More specifically, PAL will develop a series of prototype cognitive systems that can act as an assistant for commanders and staff. Successful completion of this program will usher in a new era of computational support for a broad range of human activity.*

Project ActComm Project on Transportable Agents in Wireless Networks  
Program Department of Defense Multidisciplinary University Research Initiative  
Agency AFOSR  
Program Managers Capt. Kilpatrick, Dr. Bob Herklotz

*The goal of the ActComm project is to develop technologies that will maximize the usability of complex, global computer and communications networks, focusing especially on wireless networks, for modern command-and-control applications. The main technical innovation is the concept of an active communications system. An active communications system consists of dynamic elements - active software, active information, active hybrid networks and active resource allocation. These active elements are introduced to make future military wireless computer and communications networks more robust, more powerful and more flexible under a wide variety of operating environments. Active elements will be coordinated by a novel architecture that uses advanced agents to manage network, computer and information assets delivering high confidence communications and computing.*