BALARAMAN RAVINDRAN

OFFICE ADDRESS
Department of Computer Science
University of Massachusetts
Amherst, MA 01003, U. S. A.
Tel: +1 (413) 545-1596 Fax: +1 (413) 545 1249
Email: ravi@cs.umass.edu
URL: http://www-all.cs.umass.edu/ ˜ravi

HOME ADDRESS
990 N. Pleasant St.
Apt A3
Amherst, MA 01002, U. S. A.
Tel: +1 (413) 546-0806

RESEARCH INTERESTS

Machine Learning, Abstraction in Machine Learning, Reinforcement Learning, Hierarchical Learning Architectures, Developmental Models of Learning, Model Minimization, Relational Learning, Knowledge Representation and Generalization.

EDUCATION

Doctor of Philosophy **(expected) February 2004**
Department of Computer Science
University of Massachusetts, Amherst, MA.
Adviser: Andrew G. Barto

Master of Science (Engineering) **April 1996**
Department of Computer Science and Automation
Indian Institute of Science, Bangalore, Karnataka, India.
Adviser: S. Sathiya Keerthi

Bachelor of Engineering **April 1993**
Department of Electronics and Communication Engineering
Thiagarajar College of Engineering
Madurai-Kamaraj University, Madurai, Tamil Nadu, India.

RESEARCH EXPERIENCE

Research Assistant, University of Massachusetts, Amherst **September 2002 - August 2003**
Project Title: Dynamic Abstractions in Hierarchical Reinforcement Learning.

It is frequently the case that certain independence assumptions hold for brief periods during the execution of a large complex task. We can abstract out unnecessary information for the duration of the sub-task at hand while these assumptions hold. Such abstractions are called dynamic abstractions, since they change during the course of the problem. My work in this project involves developing an algebraic abstraction framework that supports dynamic abstraction.

Research Assistant, University of Massachusetts, Amherst **September 1999 - August 2002**
Project Title: Temporal Abstraction in Reinforcement Learning

This project investigated reinforcement learning approaches to learning, planning and representing knowledge at multiple temporal resolutions, with special reference to the options framework. We also developed additional mathematical theory and studied the validity of various models of animal behavior related to this approach. My contribution consisted of investigating various formulations of utility of given sets of options and developing an algebraic framework suitable for abstraction at multiple scales of temporal resolution.

Research Assistant, University of Massachusetts, Amherst **September 1996 - August 1999**
Project Title: Application of Reinforcement Learning to Combinatorial Optimization Problems.

Approximate solution techniques are often employed to solve combinatorial optimization problems that are NP hard. This project investigated combining reinforcement learning with approximate solution techniques to derive better solutions for such problems. My work included investigating the use of reinforcement learning to solve dynamic optimization problems, especially single and multiple uninhabited air vehicle routing and planning problems.

Research Project, University of Massachusetts, Amherst **Fall 1998**
Project Title: An Adaptive approach to Information Filtering

We developed an information filtering algorithm that adapts a user profile by extracting useful features from judged documents. The algorithm uses incremental clustering with some modifications to accommodate a growing feature set. We demonstrated the performance of the algorithm on a test bed of news stories and compared the performance with that of a standard information filtering algorithm.

Consultant, Satyam Computer Systems Limited, Bangalore, India **May 1996 - July 1996**
Project Title: Search Pad

I was part of the team that developed **Search Pad**, an intelligent, personalizable search agent.
The product hit the markets in summer of 1997.

Research Assistant, Indian Institute of Science, Bangalore, India **January 1996 - May 1996**
Project Title: Search Pad

I collaborated in developing the learning component of Search Pad.

TEACHING EXPERIENCE

Teaching Assistant, University of Massachusetts, Amherst **Fall 2003**
Course: Introduction to Reinforcement Learning (Instructor: Andrew G. Barto)

Duties included developing new material, lecturing, grading homeworks and tests, and designing and grading laboratory exercises.

Teaching Assistant, University of Massachusetts, Amherst **Fall 2000**
Course: Introduction to Reinforcement Learning (Instructor: Andrew G. Barto)

Duties included grading homeworks and tests, handling certain lectures, and designing and grading laboratory exercises.

Grader and part-time teaching assistant, University of Massachusetts, Amherst **Fall 1997**
Course: Introduction to Advanced Algorithms (Instructor: Arnold Rosenberg)

Duties included grading homeworks and answering students' questions.

Instructor, Satyam Computer Systems Limited, Bangalore, India **June 1996**
Course: Introduction to Programming with PERL

Designed and co-taught a one month course on programming with Perl for employees of SCSL.

Teaching Assistant, Indian Institute of Science, Bangalore **Summer 1995**
Course: Summer School on Neural Networks for Engineering Teachers (Instructor: S. Sathiya Keerthi)

Taught classes on reinforcement learning. Designed and conducted the laboratory sections of the course, based on the Matlab neural network toolbox.

HONORS AND AWARDS

Research Fellowship, Indian Institute of Science, Bangalore, India - August 1993 - December 1995.

Scored in the top 3 percentile in the country in the Graduate Aptitude Test in Engineering (GATE), 1993. This is the equivalent of the subject GRE in engineering in India.

PUBLICATIONS

Ravindran, B. and Barto, A. G. (2003) “Relativized Options: Choosing the Right Transformation”. In the Proceedings of the Twentieth International Conference on Machine Learning (ICML 2003), pp. 608-615. AAAI Press.

Ravindran, B. and Barto, A. G. (2003) “SMDP Homomorphisms: An Algebraic Approach to Abstraction in Semi Markov Decision Processes”. In the Proceedings of the Eighteenth International Joint Conference on Artificial Intelligence (IJCAI 03), pp. 1011-1016. AAAI Press.

Ravindran, B. and Barto, A. G. (2003) “An Algebraic Approach to Abstraction in Reinforcement Learning”. In the Proceedings of the Twelfth Yale Workshop on Adaptive and Learning Systems, pp. 109-114.

Ravindran, B. and Barto, A. G. (2002) “Model Minimization in Hierarchical Reinforcement Learning”. In the Proceedings of the Fifth Symposium on Abstraction, Reformulation and Approximation (SARA 2002), pp.196-211, LNCS, Springer Verlag.

Ravindran, B. and Barto, A. G. (2001) “Symmetries and Model Minimization of Markov Decision Processes”. Computer Science Technical Report 01-43, University of Massachusetts, Amherst, MA.

Sutton, R. S., Singh, S. P., Precup, D. and Ravindran, B. (1999) “Improved Switching among Temporally Abstract Actions”. In Advances in Neural Information Processing Systems 11 (Proceedings of NIPS’98), pp.1066-1072. MIT Press.

McGovern, E. A., Precup, D., Ravindran, B., Singh, S. P. and Sutton, Richard S. (1998) “ Hierarchical Optimal Control of MDPs”, Proceedings of the Tenth Yale Workshop on Adaptive and Learning Systems, pp.186-191.

Ravindran, B. (1996) “Solution of Delayed Reinforcement Learning Problems having Continuous Action Spaces”, Master’s Thesis, Department of Computer Science and Automation, Indian Institute of Science, Bangalore, India.

Keerthi, S. S. and Ravindran, B. (1996) “C3: Reinforcement Learning”. In Handbook Of Neural Computation, E. Fiesler and R. Beale, Editors, Oxford University Press, U. K.

Keerthi, S. S. and Ravindran, B. (1994) “A Tutorial Survey Of Reinforcement Learning”. In Sadhana (Proceedings of the Indian Academy of Sciences), Vol. 19, Dec. 1994, pp. 851-889.

OTHER PRESENTATIONS

Ravindran, B. (2002) “Relativized Options”. In State-Action Reward Day in New England (SARDINE), a workshop on recent advances in reinforcement learning, May 2002, University of Massachusetts, Amherst, MA.

Ravindran, B. and Perkins, T. J. (1999) "Learning to Decompose". Poster presentation at the AT & T student poster competition, Oct. 1999, AT & T Research Labs, Florham Park, NJ.

THESES

Ph. D. Thesis
Title: An Algebraic Approach to Abstraction in Reinforcement Learning
Adviser: Andrew G. Barto

Abstract: To operate effectively in complex environments learning agents require the ability to form useful abstractions, that is, the ability to selectively ignore irrelevant details. Stated in general terms this is a very difficult problem. Much of the work in this field is specialized to specific modeling paradigms or classes of problems. In this thesis we introduce an abstraction framework for Markov decision processes (MDPs) based on homomorphisms relating MDPs. We build on classical finite-state automata literature and develop a minimization framework for MDPs that can exploit structure and symmetries to derive smaller equivalent models of the problem. Because employing homomorphisms for minimization requires that the resulting abstractions be exact, we introduce approximate and partial homomorphisms and develop bounds in loss while employing relaxed abstraction criteria.

Our MDP minimization results can be readily employed by reinforcement learning (RL) methods for forming abstractions. We extend our abstraction approach to hierarchical RL, specifically using the options framework. We introduce relativized options, a generalization of Markov sub-goal options, that allow us to define options without an absolute frame of reference. We introduce an extension to the options framework, based on relativized options, that allows us to learn simultaneously at multiple levels of the hierarchy and also employ hierarchy-specific abstractions. We provide certain theoretical guarantees regarding the performance of hierarchical systems that employ approximate abstraction. We empirically demonstrate the utility of relativized options in several test-beds.

Relativized options can also be interpreted as behavioral schemas. We demonstrate that such schemas can be profitably employed in a hierarchical RL setting. We also develop algorithms that learn the appropriate parameter binding to a given schema. We empirically demonstrate the validity and utility of these algorithms. Relativized options allow us to model certain aspects of deictic or indexical representations. We develop a modification of our parameter binding algorithm suited to hierarchical RL architectures that employ deictic representations.

Master's Thesis
Title: Solution of Delayed Reinforcement Learning Problems having Continuous Action Spaces.
Adviser: S. Sathiya Keerthi

Abstract: This work concerns the solution of delayed Reinforcement Learning problems having continuous action spaces. We first discuss the problems associated with continuous action spaces and present various existing algorithms for solving the problem. We then propose an extension of Q–learning for solving delayed RL problems having continuous action spaces which overcomes drawbacks associated with existing methods. We present simulation results to demonstrate the feasibility of the proposed algorithm.

GRADUATE COURSES

Advanced Algorithms, Data Structures and Algorithms, Theory of Computation, Artificial Intelligence, Neural Networks, Learning Automata, Reinforcement Learning, Distributed Operating Systems, Information Retrieval, Topics in Information Retrieval, Topics in Game Theory, Combinatorial Optimization, Linear Algebra, Empirical Methods in Computer Science.

Audited: Machine Learning, Advanced Topics in Reinforcement Learning, Hierarchical Probabilistic Models for AI, Statistical Pattern Recognition and Applications.

SERVICE AND ADMINISTRATIVE RESPONSIBILITIES

Reviewed papers for IEEE transactions on Systems, Man and Cybernetics, and International Conference on Machine Learning 2002 and 2003.

Web and System Administrator **September 1996 - August 2002**
Adaptive Networks Laboratory/Autonomous Learning Laboratory
Department of Computer Science
University of Massachusetts, Amherst.

Manager, Computer Science Educational Laboratory **Fall 2000**
University of Massachusetts, Amherst
Duties included managing a group of 12 monitors and ensuring smooth day to day operation of the Education Laboratory catering to the undergraduate and graduate students' computing needs.

Web and System Administrator **August 1993 - April 1996**
Intelligent Systems Laboratory
Department of Computer Science and Automation
Indian Institute of Science, Bangalore, India.

OTHER INTERESTS

Coordinator, Volunteers in Service to Education in India, Amherst Chapter (1999 - 2001). VSEI is a non-profit organization working to fund education related projects in India, focusing on women and handicapped education.

Co-Founder and administrator of two popular web sites, www.tfmpage.com (founded 1996) and www.forumhub.com (founded 1998), that together attract more than a 100,000 hits a month.

REFERENCES

Prof. Andrew G. Barto
Department of Computer Science
140 Governor's Drive
University of Massachusetts
Amherst, MA 01003
U. S. A.
Tel: +1 (413) 545-2109
Fax: +1 (413) 545-1249
Email: barto@cs.umass.edu

Prof. Sridhar Mahadevan
Department of Computer Science
140 governor's Drive
University of Massachusetts
Amherst, MA 01003
U. S. A.
Tel: +1 (413) 545-3140
Tel: +1 (413) 545-1249
Email: mahadeva@cs.umass.edu

Prof. Roderic A. Grupen
Department of Computer Science
140 Governor's Drive
University of Massachusetts
Amherst, MA 01003
U. S. A.
Tel: +1 (413) 545-3280
Fax: +1 (413) 545-1249
Email: grupen@cs.umass.edu

Prof. S. Sathiya Keerthi
Department of Mechanical Engineering
National University of Singapore
10 Kent Ridge Crescent
Singapore 119260
Republic of Singapore
Tel: +65 6874-4684
Fax: +65 6779-1459
Email: mpessk@nus.edu.sg