Thomas M. Howard

Curriculum Vitae

Current Position

Title
Research Scientist
Robust Robotics Group

Address
Massachusetts Institute of Technology
Computer Science and Artificial Intelligence Laboratory
32 Vassar Street Room 32-332
Cambridge, MA 02139

Contact
Email: tmhoward@csail.mit.edu
Office: (617) 324-8250

Website
Personal: http://people.csail.mit.edu/tmhoward/www/
Google Scholar: http://scholar.google.com/citations?user=IvuuU14AAAAJ&hl=en

Education

Carnegie Mellon University, Pittsburgh, PA, USA
Robotics Institute, School of Computer Science

Ph.D. in Robotics — August 2009
Advisors: Prof. Alonzo Kelly and Prof. Red Whittaker
Thesis: Adaptive Model-Predictive Motion Planning for Navigation in Complex Environments

M.S. in Robotics — May 2006
Advisors: Prof. Alonzo Kelly and Prof. Red Whittaker

University of Rochester, Rochester, NY, USA
Hajim School of Engineering and Applied Science

B.S. in Mechanical Engineering with High Distinction — May 2004
B.S. in Electrical and Computer Engineering with High Distinction — May 2004

Research Experience

Research Scientist (October 2013 - now)
Postdoctoral Associate (October 2012 - September 2013)
Computer Science and Artificial Intelligence Laboratory, Massachusetts Institute of Technology, Cambridge, MA, USA

Developed algorithms for human-robot interaction and natural language understanding with mobile robots. Key innovations include a novel approach for inferring planning constraints from natural language using probabilistic graphical models. Led the integration of this framework for natural language understanding of robot instructions in the autonomy architecture of the United States Army Research Laboratory's (ARL) Robotics Collaborative Technology Alliance (RCTA).

Research Technologist II (September 2009 - September 2012)
Robotic Software Systems Group, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA

Researched and developed technologies for motion planning, navigation, control, pose estimation, and simulation of mobile robots and redundant manipulators as a member of the Robotic Software Systems group. Led research tasks investigating planetary rover search space design, perception and pose estimation for small unmanned ground vehicles in poorly illuminated environments, and adaptive vehicle simulation for mobile robot navigation. Worked on autonomous navigation for the Mars Science Laboratory (MSL) as a member of the flight software team and led development of motion planning algorithms for the Jet Propulsion Laboratory (JPL) and California Institute of Technology team on the Defense Advanced Research Projects Agency (DARPA) Autonomous Robotic Manipulation (ARM) program.

Graduate Research Assistant (August 2004 - August 2009)
Robotics Institute, School of Computer Science, Carnegie Mellon University, Pittsburgh, PA, USA

Researched and developed model-predictive motion planning, navigation, and control algorithms for terrestrial mobile robots operating in complex environments. Key innovations include a real-time trajectory generation algorithm that compensates for arbitrary models of vehicle mobility and terrain interaction, a generalizable constraint-space sampling search space generation method for navigation in off-road and urban environments, and the Adaptive State Lattice technique for improving the relative optimality of feasible motion planning search spaces. Contributed to research tasks for sponsors including JPL, DARPA, and the Office of Naval Research (ONR) and as a team member of Tartan Racing, winner of the 2007 DARPA Urban Challenge.

Teaching Experience

Lecturer in Mechanical Engineering

Advanced Robotics: Navigation and Vision	California Institute of Technology	Winter/Spring 2012
Advanced Robotics: Navigation and Vision	California Institute of Technology	Winter/Spring 2011

Guest Lecturer

Introduction to Robotics	Arts Center College of Design	Spring 2011
Mobile Robots	Carnegie Mellon University	Spring 2009

Teaching Assistant

Advanced Mobile Robot Development	Carnegie Mellon University	Spring 2005
Applied Fourier Series and Boundary Value Problems	University of Rochester	Fall 2003
Engineering Mechanics II: Dynamics	University of Rochester	Fall 2002

Publications

Journal Articles

[1] **T.M. Howard**, M. Pivtoriako, R. A. Knepper, and A. Kelly, "Model-Predictive Motion Planning," *IEEE Robotics and Automation Magazine*, vol. 21, no. 1, pp. 64-73, March 2014.

[2] N. Hudson, J. Ma, P. Hebert, A. Jain, M. Bajracharya, T. Allen, R. Sharan, M. Horowitz, C. Kuo, **T.M. Howard**, L. Matthies, P. Backes, and J. Burdick, "Model-Based Autonomous System for Performing Dexterous, Human-Level Manipulation Tasks," *Autonomous Robots*, vol. 36, no. 1-2, pp. 31-49, January 2014.

[3] D. Ferguson, **T.M. Howard**, and M. Likhachev, "Motion Planning in Urban Environments," *Journal of Field Robotics*, vol. 25, no. 11-12, pp. 939-960, November-December 2008.

[4] C. Urmson, J. Anhalt, H. Bae, J. Bagnell, C. Baker, R.E. Bittner, T. Brown, M.N. Clark, M. Darms, D. Demitrish, J. Dolan, D. Duggins, D. Ferguson, T. Galatali, C.M. Geyer, M. Gittleman, S. Harbaugh, M. Hebert, **T.M. Howard**, S. Kolski, M. Likhachev, B. Litkouhi, A. Kelly, M. McNaughton, N. Miller, J. Nickolaou, K. Peterson, B. Pilnick, R. Rajkumar, P. Rybski, V. Sadekar, B. Salesky, Y. Seo, S. Singh, J.M. Snider, J.C. Struble, A. Stentz, M. Taylor, W.L. Whittaker, Z. Wolkowicki, W. Zhang, and J. Ziglar, "Autonomous Driving in Urban Environments: Boss and the Urban Challenge," *Journal of Field Robotics*, vol. 25, no. 8, pp. 425-466, June 2008.

[5] **T.M. Howard**, C. Green, D. Ferguson, and A. Kelly, "State Space Sampling of Feasible Motions for High Performance Mobile Robot Navigation in Complex Environments," *Journal of Field Robotics*, vol. 25, no. 6-7, pp. 325-345, June-July 2008.

[6] **T.M. Howard** and A. Kelly, "Optimal Rough Terrain Trajectory Generation for Wheeled Mobile Robots," *International Journal of Robotics Research*, vol. 26, no. 2, pp. 141-166, February 2007.

Conference Papers

[7] R. Mukherjee, **T.M. Howard**, S. Myint, J. Chang, and J. Craft, "Vehicle Dynamics Models for Onboard Motion Planning", to appear in the *Proceedings of the ASME 2014 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference*, 2014.

[8] F. Duvallet, M. Walter, **T.M. Howard**, S. Hemachandra, J. Oh, S. Teller, N. Roy, and A. Stentz, "A Probabilistic Framework for Inferring Maps and Behaviors from Natural Language", to appear in the *Proceedings of the 14th International Symposium on Experimental Robotics*, 2014.

[9] **T.M. Howard**, S. Tellex, and N. Roy, "A Natural Language Planner Interface for Mobile Manipulators," to appear in the *Proceedings of the 2014 International Conference on Robotics and Automation*, 2014.

[10] N. Hudson, **T.M. Howard**, J. Ma, A. Jain, M. Bajracharya, S. Myint, C. Kuo, L. Matthies, P. Backes, P. Hebert, T. Fuchs, and J. Burdick, "End-to-End Dexterous Manipulation with Deliberate Interactive Estimation," in *Proceedings of the 2012 International Conference on Robotics and Automation*, 2012, pp. 2371-2378.

[11] P. Hebert, N. Hudson, J. Ma, **T.M. Howard**, T. Fuchs, M. Bajracharya, and J. Burdick,"Combined Shape, Appearance and Silhouette for Simultaneous Manipulator and Object Tracking," in *Proceedings of the 2012 International Conference on Robotics and Automation*, 2012, pp. 2405-2412.

[12] **T.M. Howard**, A. Morfopolous, J. Morrison, C. Villalpando, L. Matthies, and M. McHenry, "Enabling Continuous Planetary Rover Traverse through FPGA Stereo and Visual Odometry," in *Proceedings of the 2012 IEEE Aerospace Conference*, 2012, pp. 1-9.

[13] **T.M. Howard**, J. Cameron, S. Myint, H. Nayar, and A. Jain, "A KML Interface for Dynamic Simulation of Robotic Planetary Exploration," in *Proceedings of the 2011 IEEE Aerospace Conference*, 2011, pp. 1-8.

[14] H. Nayar, A. Jain, J. Balaram, J. Cameron, M. DiCicco, **T.M. Howard**, Y. Kuwata, C. Lim, R. Mukherjee, S. Myint, A. Palkovic, M. Pomerantz, and S. Wall, "Surface Operations Analyses for Lunar Missions," in *Proceedings of the AIAA Space 2010 Conference and Exposition*, 2010.

[15] P. Krusi, M. Pivtoraiko, A. Kelly, **T.M. Howard**, and R. Siegwart, "Path Set Relaxation for Mobile Robot Navigation," presented at the *10th International Symposium on Artificial Intelligence, Robotics, and Automation in Space*, 2010.

[16] **T.M. Howard**, C.J. Green, and A. Kelly, "Receding Horizon Model-Predictive Control for Mobile Robot Navigation of Intricate Paths," in *Proceedings of the 7th International Symposium on Field and Service Robotics*, 2009, pp. 69-78.

[17] P.M. Furlong, **T.M. Howard**, and D. Wettergreen, "Model Predictive Control for Mobile Robots with Actively Articulating Chassis," in *Proceedings of the 7th International Symposium on Field and Service Robotics*, 2009, pp. 469-478.

[18] D. Ferguson, **T.M. Howard**, and M. Likhachev, "Motion Planning in Urban Environments: Part I," in *Proceedings of the 2008 IEEE/RSJ International Conference on Intelligent Robots and Systems*, 2008, pp. 1063-1069.

[19] D. Ferguson, **T.M. Howard**, and M. Likhachev, "Motion Planning in Urban Environments: Part II," in *Proceedings of the 2008 IEEE/RSJ International Conference on Intelligent Robots and Systems*, 2008, pp. 1070-1076.

[20] D. Anderson, **T.M. Howard**, D. Apfelbaum, H. Herman, and A. Kelly, "Coordinated Control and Range Imaging for Mobile Manipulation," in *Proceedings of the 11th International Symposium on Experimental Robotics*, 2008, pp. 547-556.

[21] M. Pivtoraiko, **T.M. Howard**, I. Nesnas, and A. Kelly, "Field Experiments in Rover Navigation via Model-Based Trajectory Generation and Nonholonomic Motion Planning in State Lattices," presented at the *9th International Symposium on Artificial Intelligence, Robotics, and Automation in Space*, 2008.

[22] **T.M. Howard**, C. Green, and A. Kelly, "State Space Sampling of Feasible Motions for High Performance Mobile Robot Navigation in Highly Constrained Environments," in *Proceedings of the 6th International Conference on Field and Service Robotics*, 2007, pp. 585-593.

[23] A. Kelly and **T.M. Howard**, "Terrain Aware Inversion of Predictive Models for Planetary Rovers," presented at the *NASA Science and Technology Conference*, 2007.

[24] A. Kelly, **T.M. Howard** and C. Green, "Terrain Aware Inversion of Predictive Models for High Performance UGVs," presented at the *SPIE Defense and Security Symposium*, 2007.

[25] **T.M. Howard** and A. Kelly, "Trajectory and Spline Generation for All-Wheel Steering Mobile Robots," in *Proceedings of the 2006 IEEE/RSJ International Conference on Intelligent Robots and Systems*, 2006, pp. 4827-4832.

[26] **T.M. Howard**, R.A. Knepper, and A. Kelly, "Constrained Optimization Path Following of Wheeled Robots in Natural Terrain," in *Proceedings of the 10th International Symposium on Experimental Robotics*, 2006, pp. 343-352.

[27] **T.M. Howard** and A. Kelly, "Terrain-Adaptive Generation of Optimal Continuous Trajectories for Mobile Robots," presented at the *8th International Symposium on Artificial Intelligence, Robotics, and Automation in Space*, 2005.

[28] **T.M. Howard** and A. Kelly, "Trajectory Generation on Rough Terrain Considering Actuator Dynamics," in *Proceedings of the 5th International Conference on Field and Service Robotics*, 2005, pp. 479-490.

Book Chapters

[29] Th. Fraichard and **T.M. Howard**, "Iterative Motion Planning and Safety Issues," In A. Eskandarian, editor, *Handbook of Intelligent Vehicles*. Springer, pp. 1433-1458, 2012.

Workshop Papers

[30] **T.M. Howard**, I. Chung, O. Propp, M.R. Walter, and N. Roy, "Efficient Natural Language Interfaces for Assistive Robots", to be presented in the *Workshop on Rehabilitation and Assistive Robotics* at *2014 IEEE/RSJ International Conference on Intelligent Robots and Systems*, 2014.

[31] **T.M. Howard**, S. Tellex and N. Roy, "A Natural Language Planner Interface for Mobile Manipulators," presented in the *Workshop on Robot Learning* at the *International Conference on Machine Learning*, 2013.

[32] S. Tellex, R.A. Knepper, A. Li, **T.M. Howard**, D. Rus and N. Roy, "Asking for Help: Assembling Furniture by Asking for Help from a Human Partner," presented in the *Collaborative Manipulation Workshop* at *Human-Robot Interaction*, 2013.

[33] P. Hebert, J. Burdick, **T.M. Howard**, N. Hudson, and J. Ma, "Action Inference: The Next Best Touch," presented in the *Mobile Manipulation Workshop* at *Robotics Science and Systems*, 2012.

[34] Y. Kuwata, A. Elfes, M. Maimone, A. Howard, M. Pivtoraiko, **T.M. Howard**, and A. Stoica, "Path Planning Challenges for Planetary Robots," presented in the *2nd Workshop on Planning, Perception, and Navigation for Intelligent Vehicles* at the *2008 IEEE/RSJ International Conference on Intelligent Robots and Systems*, 2008.

Theses

[35] **T.M. Howard**, "Adaptive Model-Predictive Motion Planning for Navigation in Complex Environments," Ph.D. Dissertation, Robotics Institute, Carnegie Mellon University, Pittsburgh, PA, 2009.

Invited Talks

The George Washington University, Computer Science Colloquium	July 2014
Cornell University, Artificial Intelligence Seminar	March 2014
University of Rochester, Electrical and Computer Engineering / Computer Science Colloquium	February 2014
Massachusetts Institute of Technology, CSAIL Seminar	June 2012
Carnegie Mellon University, National Robotics Engineering Center Seminar	February 2009
Jet Propulsion Laboratory, Mobility and Robotics Systems Section Seminar	December 2008
University of Rochester, Mechanical Engineering Seminar	December 2008
Jet Propulsion Laboratory, Mobility and Robotics Systems Section Seminar	June 2007
Jet Propulsion Laboratory, Mobility and Robotics Systems Section Seminar	August 2006
Carnegie Mellon University, Field Robotics Center Seminar	April 2006
Jet Propulsion Laboratory, Mobility and Robotics Systems Section Seminar	August 2005

Professional Service

Associate Editor

IEEE International Conference on Robotics and Automation	2014

Reviewer

International Journal of Robotics Research	2010, 2012
Journal of Field Robotics	2008, 2009, 2012
IEEE Transactions on Robotics	2010
Robotics, Science and Systems	2013
IEEE International Conference on Robotics and Automation	2007, 2008, 2010, 2011, 2012
IEEE International Conference on Intelligent Robots and Systems	2010, 2011, 2014
IEEE International Conference on Automation Science and Engineering	2010
International Conference on Field and Service Robotics	2007, 2009
Workshop on the Algorithmic Foundations of Robotics	2012

Ph.D. Research Qualifier Committee Member

Robotics Institute, Carnegie Mellon University, Pittsburgh, PA, USA

Colin Green	2008

M.S. Thesis Committee Member

Robotics Institute, Carnegie Mellon University, Pittsburgh, PA, USA

Forrest Rogers-Marcovitz	2010
Michael Furlong	2009
Michael Bode	2007
Jason Ziglar	2007
Josh Struble	2006
Josh Johnston	2006

MIT Program for Research in Mathematics, Engineering and Science (PRIMES) Mentor
Massachusetts Institute of Technology, Cambridge, MA, USA

Istvan Chung	2014
Oron Propp	2014

Honors and Awards

NASA Group Achievement Award (MSL Project Operations Team)	2014
NASA Group Achievement Award (Autonomous Robotic Manipulation Software Team)	2012
JPL Bonus Team Award	2012
Finalist, International Conference on Robotics and Automation Best Manipulation Paper Award	2012
JPL Spot Award	2010
First Place, Urban Grand Challenge (Team Award)	2007
International Foundation of Robotics Research Student Travel Fellowship	2006
Carnegie Mellon University Graduate Student Research Fellowship	2004 - 2009
University of Rochester Mechanical Engineering Emil L. Kuichling Prize	2003