Grand Challenges Conference Application

Robot-Assisted Search and Rescue: A Grand Challenge Problem for Computing Systems

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On Sept 11, 2001 CRASAR, under the direction of John Blitch at SAIC, responded with its diverse cache of rescue robots within 6 hours to the WTC disaster with teams from Foster-Miller led by Arnis Mangolds, iRobot led by Tom Frost, SPAWAR (Navy) led by Bart Everett, and the University of South Florida led by Robin Murphy. Center personnel remained on-site through Oct. 2. The first two weeks focused on searching the rubble pile and neighboring buildings, while the second two weeks concentrated on inspection of the basement and slurry wall structure. The robots assisted FDNY and FEMA teams in finding the bodies of at least five victims in the first 10 days, essentially the same number as found by manual search teams but in half the time and in places that humans and dogs could not physically enter or could not enter safely. A good summary of the first two weeks can be found in this New York Times article: http://archives.nytimes.com/2001/09/27/technology/circuits/27ROBO.html.

While on one hand the use of robots can be considered a success, on the other hand it is painfully clear that the robots were far below the true state of the art. Artificial intelligence algorithms were available but only compatible for robots that were too large or fragile to be deployed on the rubble pile. The software wouldn't accept the addition of new sensors. User interfaces were laughable. Simple software solutions had been ignored. This might have been understandable if the robots were prototypical platforms snatched from a mechanical engineering department, but most of these robots are commercially available, with their roots in computer science departments at MIT, CMU, Georgia Tech, and the University of South Florida. The robots showed the gap between computing theory and practice, a gap that we believe stems both from a lack of understanding of the complexity of such systems and from weaknesses in the educational system that reinforce a piecemeal approach to a systems problem.

We believe that this failure of transferring computer science advances to such a meaningful domain illustrates a grand challenge in computing systems. Rescue robotics forces computer scientists to apply everything they know to make a truly useful system, while working in a domain that has an unequivocal humanitarian contribution to society. The robots are not intended to replace USAR workers but rather to augment them, so it avoids the Luddite response. Also, we believe that the use of humanitarian domains will help attract talented women and minorities who are often turned off by more traditional computer domains. To this end, rescue robotics can be used as a motivating example in computer science education.

Here is only a partial list of the diversity of issues that have to be resolved in order to make a truly successful search and rescue robot:

Distributed Computing, Networking, and Communications. The current trend in robot manufacturers is "proxy processing," where the robot is essentially a thin client getting computational resources for control in real-time from a remote workstation. This solution makes it easier to work around the limitations of having a computer on wheels and can exploit the distributed computing vogue. However, this assumes near perfect, high bandwidth data (such as in a laboratory). Data from the WTC shows that close to 25% of the communications between wireless robots and their control unit were so noisy as to be useless or simply missing. The loss in communications and lack of onboard embedded processing resulted in the loss of a $35K robot at the WTC response. Clearly, this is a domain where networking, bandwidth, intermittent communications, and embedded processing cannot be ignored.

Software Engineering and Interoperability. Many algorithms that were developed for USAR or could have been easily applied to USAR were not used at the WTC. They weren't used because of a lack of interoperability between components, a shocking amount of spaghetti code written with no clear use of fundamental software engineering principles, and a lack of software testing procedures (and confidence in those procedures) that could allow new software to be written for a complex system and tested in less than 24 hours.

Real-time multi-threaded control. One reason why robot manufacturers (and research labs) prefer to do control computing off-board is that the computations are often massive and require multi-threading. If you have a larger processor and faster clock, you can avoid addressing these issues. Essentially, the hard problems like design and the tedious problems like optimization get swept under the Bigger, Faster Computer rug.

User interfaces and Human-Robot Interaction. As a system, the robot must be designed with the task in mind, including the end user. In USAR, the end user is not a teenager spending hours playing a sophisticated game or a business person searching the web, instead it is a person until extreme cognitive and physical fatigue racing against the clock in a life-and-death endeavor. We have seen FEMA teams walk away from useful robots that were the most powerful in terms of computing and AI for want of a reasonable user interface. However, it is not just the lack of user interfaces, but rather a fundamental lack of conception about how humans and agents, software or physical, can divide responsibilities and cooperate to get a task done. USAR is characterized by the fact that the robot is merely a source of information, the operator is not the end, or only, user. The information collected has to be distributed to different people with different objectives in different time spans.

BIO:

Dr. Robin R. Murphy Associate Professor, Department of Computer Science and Engineering & Cognitive and Neural Sciences, Department of Psychology, University of South Florida.

I am on a journey of the soul
one that searches the very
boundaries of my mind
in a land of believe and make
where those who care pay a toll
--Regis McKenna

Robin Roberson Murphy received a B.M.E. in mechanical engineering, a M.S. and Ph.D in computer science (minor: Computer Integrated Manufacturing Systems) in 1980, 1989, and 1992, respectively, from Georgia Tech, where she was a Rockwell International Doctoral Fellow. From 1992 to 1998, she was an assistant professor in the Department of Mathematical and Computer Sciences at the Colorado School of Mines. Since 1998, she has been an associate professor in the Computer Science and Engineering Department at the University of South Florida with a joint appointment in Cognitive and Neural Sciences in the Department of Psychology.

Dr. Murphy has concentrated her research on sensor fusion, distributed sensing, and fault tolerant perception for mobile robots. Her work has realized the first autonomous implementation of a class of heterogeneous mobile robot teams known as marsupial robots, creating a low computational complexity, biomimetic docking behavior. These efforts are/have been funded by DoE (RIM), DARPA (including the Tactical Mobile Robots, Unmanned Ground Combat Vehicle, PerceptOR and Synergistic Cyber-Forces programs), ONR, NASA, NSF and industry, and have led to over 70 publications in the field, including the textbook Introduction to AI Robotics (MIT Press). Her preferred test domain is Urban Search and Rescue (USAR), leading to her participation in the first known use of robots for urban search and rescue at the WTC disaster. Her USAR robotics work has earned a NIUSR Eagle award, and she serves on the NIUSR Executive Board as well as Deputy Director of Research for the NIUSR Center for Robot-Assisted Search and Rescue.

Dr. Murphy is active in the robotics research and applications communities. She is currently co-chairing a DARPA/NSF Study on Human-Robot Interaction (with Dr. Erika Rogers, Cal Poly) and a CVPR workshop on Robot Vision: Real-Time Vision in Outdoor Terrains (with LTC John Blitch), an associate editor for IEEE Intelligent Systems, an IEEE Computer Society Distinguished Visitor Program speaker, and is the first woman to serve on the Executive Committee of the IEEE Robotics and Automation Society (her post is RAS Society Secretary). Dr. Murphy was a member of the 1998-9 Defense Science Study Group, and is currently serving on the National Research Council Committee on Army Unmanned Vehicle Technology and the USAF Scientific Advisory Board. She is a member of the Board of Directors for Continential Divide Robotics, which provides GPS and intelligent agent software for tracking parolees. Prior to graduate work, Dr. Murphy worked in the process control industry as a software project engineer.

Dr. Murphy directs the Perceptual Robotics Laboratory at USF, which has recently won the Nils Nilsson Technical Achievement Award at the 2000 AAAI Mobile Robot Competition. In addition, she has received two teaching awards and a Colorado Institute Gender Equity Excellence Award for her efforts at the college and K-12 levels in encouraging women and minorities to pursue careers in the sciences.

Introduction to AI Robotics

I have written a textbook, Introduction to AI Robotics, 2000, MIT Press, aimed at upper level undergraduates and first year graduate students. An instructor's manual and powerpoint slides are available upon request to MIT Press (they filter students trying to get answers to the test...). I also recommend Behavior-Based Robotics by Ron Arkin (my PhD advisor and the reference for most of my book) for an advanced treatment of the same material.

The MIT Press release reads:

This text covers all the material needed to understand the principles behind the AI approach to robotics and to
program an artificially intelligent robot for applications involving sensing, navigation, planning, and uncertainty.
Robin Murphy is extremely effective at combining theoretical and practical rigor with a light narrative touch. In the
overview, for example, she touches upon anthropomorphic robots from classic films and science fiction stories before
delving into the nuts and bolts of organizing intelligence in robots.

Following the overview, Murphy contrasts AI and engineering approaches and discusses what she calls the three
paradigms of AI robotics: hierarchical, reactive, and hybrid deliberative/reactive. Later chapters explore multiagent
scenarios, navigation and path-planning for mobile robots, and the basics of computer vision and range sensing. Each
chapter includes objectives, review questions, and exercises. Many chapters contain one or more case studies showing
how the concepts were implemented on real robots. Murphy, who is well known for her classroom teaching, conveys
the intellectual adventure of mastering complex theoretical and technical material.