Appeared in *Journal of the Robotics Society of Japan*, Special issue on women in robotics, 25 (5-6): 431-447, 2006.

Review Article

Why Autonomous Robotics and Artificial Intelligence?

One Researcher's Perspective

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1. Motivation for Studying Robotics and AI

Scientists and technologists have many reasons for choosing the field they work in. For me, fascination with how the human mind works to solve problems, combined with the satisfaction of creating working systems that solve problems, led me to my interest in artificial intelligence and autonomous robotics. I have always been intrigued with the question of how we, as humans, survive in what seems to be a very complex environment and society. If you consider the world we live in, and our ability to cope (and even thrive) in our complex world, many questions come to mind. For example, how do we make sense of the flood of information we process on a moment-by-moment basis? How do we decide what is important, what is not important, and what actions to take to achieve our objectives? How do we work together to help each other or to understand each other's needs and capabilities without requiring the exchange of detailed personal information on our philosophies, reasoning approaches, perspectives on the world, plans, goals, and dreams? How do we learn from experience, so that we can be more efficient at what we do, and can avoid making the same mistakes twice? Developing answers to these big questions requires many generations of study in philosophy of mind, cognitive science, neuroscience, psychology, sociology, and behavioral science.

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Keywords: cooperative robotics, multi-robot systems, distributed robotics, autonomous robotics women roboticists

But for me, these questions are much too big for one person's life pursuit. I like knowing the answer to problems, and these questions are too complex to be answered easily. Instead, what if we study a "simpler" life form – a robot – and try to answer these questions in that context? How can we give robots the capability to solve problems in a way that is as "natural" for the robot as it seems to be for us as humans? And, why not develop these answers by applying robots to real-world problems that can help make our complex human lives a bit easier (and perhaps even more interesting)? Then, we can have answers to these fascinating questions while at the same time applying our work to benefit human society. To me, this is a great motivation for my research in artificial intelligence and autonomous robotics, and what makes this work very satisfying to me.

2. Research Studies in Cooperative Robotics

Introspectively, it seems that much of how we survive in the world is intuitive, not requiring conscious planning, thoughtful deliberation, and detailed negotiations with others, but rather involving quick choices that, somehow, are usually best in the end. I began studying these issues in my Ph.D. research in the Artificial Intelligence Laboratory at the Massachusetts Institute of Technology. While negotiation-based protocols had been previously developed for multi-agent cooperation, I wanted to take a different approach, to see if the task allocation problem could be solved without assuming the use of negotiation. These developments led me to my Ph.D. dissertation work,

which was the development of ALLIANCE [1] -- a behavior-based approach to action selection in cooperative robotics that incorporates models of motivations to enable robots to cooperate without explicitly negotiating with each other. This work was one of the first to address the multi-robot task allocation problem; much work has been done more recently following the more traditional negotiation approach. However, comparative studies have shown that the ALLIANCE approach is strongly competitive with more traditional negotiation approaches, and deals with the assignment of sequences of tasks, rather than the simpler instantaneous assignment problem. I believe the ALLIANCE approach matches how we as humans cooperate on teams with "familiar" members – we do not have to discuss which person will perform which task every time we go to work. Instead, team members silently gravite toward the subtasks in their job that they know the team has implicitly agreed they should perform.

Since this first work of mine in cooperative robotics, I have studied many other issues in multi-robot team control. For example, in the ALLIANCE work, attention was focused on "loosely coupled" tasks (also known as "single robot" or "weakly cooperative" tasks), which are tasks that can be independently solved by individual robots. A question arises, though, in how robots can cooperatively solve more tightly coupled (or multi-robot) tasks, which require the close interaction of multiple robots working simultaneously. I was interested in extending the task allocation techniques to tasks that are strongly cooperative, meaning that the proper actions of a robot are at all times dependent upon the current actions of team members. To study this problem, I formulated the "CMOMMT" (Cooperative Multi-robot Observation of Multiple Moving Targets) benchmark [2], which required robot teams to move cooperatively so as to maximize the observation of multiple targets moving through the environment.

More recently, we have been studying the issue of multi-robot coalition formation, which enables heterogeneous robots to share sensory resources to solve tighly coupled, multi-robot tasks. Our approach is called ASyMTRe [3] (pronounced "Asymmetry"), which is an autonomous reasoning system that can automatically configure the interconnections of low-level schema building blocks to generate coalescent task solutions. The connections are determined based upon the required information flow needed for the task. We have shown this approach to be able to significantly extend the repertoire and flexibility of problem solutions in heterogeneous multi-robot teams.

This work on ASyMTRe was motivated by our prior research on a large-scale multi-robot teaming application involving the deployment of up to 80 simple sensor robots into an acoustic sensor network [4]. In this work, we realized that the software solutions for deployment were very strongly tied to the sensory capabilities of the robots, leading to minimal code reuse. Rather than requiring the human designer to rewrite application code for each robot hardware configuration, our objective was to provide an automated approach that could automatically be configured by the robot team members. ASyMTRe provides this capability.

Certainly, there are many other interesting topics in multi-robot teaming that I, and many others, have explored and continue to explore, including learning, multi-robot path planning, multi-robot localization and mapping, fault tolerance, and so forth [5]. This field is full of compelling questions that will keep us busy for many years to come.

3. How to Increase Numbers of Female Roboticists

Because I have found this field of research to be so satisfying, I would like to see more women join this field. For this special journal issue on "Women in Robotics", I

would like to offer my thoughts on how to encourage more women to join the field.

As we are all aware, the field of robotics currently has very few women, with the percentage currently hovering around 10%. The reasons for this low representation are debatable, but I conjecture that two key reasons for the low representation of women in robotics are: (1) how we teach computer science and engineering (which are the fields in which robotics is normally studied), and (2) low numbers of female role models in the field. From personal experience, I believe that, on average, females are most interested in fields that give practical benefits to society. Without question, the field of robotics has this characteristic, with applications in areas such as household service, elder care, surgery, medicine, agriculture, manufacturing, and security. But perhaps, as a community, we are not communicating and teaching these practical benefits of robotics as clearly as we could. We need to work harder on this.

Having female role models and colleagues is also very important to increasing the comfort level of new women students in the field. I happened to be fortunate in my own Ph.D. studies to have several female colleagues also doing robotics graduate work at the same time in the same research group at MIT. Additionally, I feel privileged to currently advise four female Ph.D. students who are studying to be the next generation of roboticists. However, I recognize that these are anomalous experiences, and most other women robotics students are not so fortunate. For me, being female never entered the equation for deciding the career I would pursue, since I just pursued what fascinated me. I hope that other females will not be deterred from pursuing their interests, regardless of how many women are currently in the field.

Eventually, if enough women follow their research interests in robotics, a critical mass of women will be reached, hopefully encouraging other women to follow. The field of robotics, and indeed society itself, can only benefit from this increased participation of women in the field.

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