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Supporting Human Supervision of Multiple Robots

Julie A. Adams* *Vanderbilt University

1. Introduction

Practical applications for unmanned mobile robotic vehicles (UMV) has exploded in recent years. UMVs are deployed for emergency response and military conflicts. Most current UMV missions require human-in-the-loop control of a single UMV. Long-term objectives include deploying multiple autonomous UMVs that require a single human to supervise their activities. My research focus is the development of human interaction for multiple UMV systems that incorporate intelligent decision support capabilities via distributed artificial intelligence.

An undergraduate Artificial Intelligence (AI) course and Rosie, the robotic maid from the television show The Jetsons peaked my interest in robotics. This interest led to graduate studies in a number of AI related courses, which then lead to my Ph.D. research. This research [1] permitted a focus on many areas of interest: robotics, computer vision, sensory fusion, and artificial intelligence while requiring the development of a human interface to four semi-autonomous mobile robots.

There were few industrial robotics opportunities available when I finished my Ph.D. I then embarked to improve my human factors skills via industry. I held industrial positions for over five years in Human Factors focusing on aviation, commercial imaging, and chemical processing. This work honed my Human Factors skills but the desire to focus on UMVs persisted. My current university position permits my research focused on human-robot interaction (HRI) for multiple UMV systems.

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*VU Station B #351824, Nashville, TN 37235-1824, USA

2. Method

As the desire to remove humans from dangerous situations, such as exposure to harmful chemicals, increases, so does the need to develop UMV systems. Current bomb squad and urban search and rescue response systems [3] rely on a human to teleoperate the UMV. These systems are very demanding on the human, which limits the overall system performance. There is also a desire to increase the number of deployed UMVs while limiting the number of humans. Ideally, UMV systems would be autonomous, however the reliable technology is not yet available. Therefore, human interaction capabilities that permit a single human to supervise a number of semi-autonomous UMVs is required.

The HRI is only one element in achieving such systems. The underlying UMV technology must be intelligent and achieve complex reasoning that reduces the reliance on the human's cognitive reasoning capabilities. Improving individual and team UMV intelligence along with improved HRIs should increase the number of UMVs that a single human can simultaneously supervise.

One research focus has been the development of autonomous coalition formation [7]. Coalition formation partitions a set of UMVs into different coalitions where each coalition is assigned a task and executes that task. The optimal solution to the coalition problem is NP-hard [6], however, solutions to similar problems have been developed [2] [5]. Our coalition formation algorithm provides solutions for the Multiple Robot-Multiple Task problem (MR-MT) [4] where the objective is to assign a robot team to a task in order to maximize that the system's overall utility.

Our algorithm determines coalitions based upon the UMV's capabilities (i.e. sensors and actuators) while considering the balance and fault tolerance of the re-

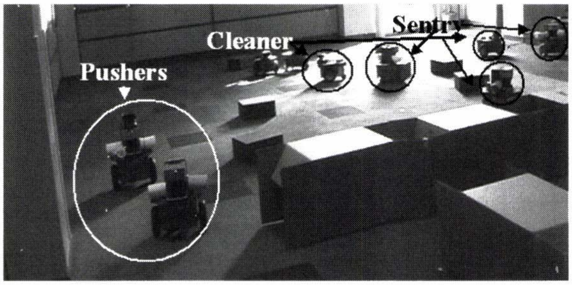

Fig. 1 Four coalitions assigned to four tasks

sulting coalition. The UMVs evaluate possible coalitions and determine the coalition assignments. A more balanced coalition is composed of multiple UMVs with limited capabilities thus making it easier to replace a UMV over UMVs with a large number of capabilities. The algorithm also considers the coalition's fault tolerance level.

The coalition formation algorithm has been evaluated with up to forty simulated UMVs and with up to fourteen actual UMVs [7]. **Fig. 1** demonstrates four UMV coalitions completing three different tasks. Two UMVs are preparing to push a box. Two coalitions of two UMVs each are moving into position to complete two sentry duty tasks while the remaining robots are assigned a clean-up task. This work has also evaluated how coalition balance can affect coalition task performance and how coalition performance can be improved by substituting better performing coalition members for poorly performing members in less balanced teams [8].

The coalition formation algorithm is an autonomous algorithm, however coalition formation represents a highly demanding cognitive task for humans. The assignment of UMVs to multiple coalitions from a large set of possible UMVs is quite involved in the best of circumstances, i.e. low workload demands, little time or environmental stress, and good decision making. However, Human Factors research has shown that as the demands placed on the human and environmental stressors increase, human decision-making accuracy decreases. Therefore, a next step for this research is to incorporate the coalition formation algorithm with our HRI.

It is common when humans interact with complex systems to automate the tasks that are easy to automate; unfortunately, this includes the tasks that are easiest for the human. Additionally, there tends to be a higher level of automation when the demands placed on the human are low, and very few automated capabilities when the human is placed in demanding situations such as abnormal system functioning. The integration of the coalition formation, a cognitively demanding task, will consider how best to integrate it with the human information requirements. Another known problem with providing highly autonomous capabilities is that as the human is removed from the activity, the human looses an awareness of the activity. Therefore, while the coalition formation has the capacity to greatly simplify a difficult task, the human must be able to maintain an understanding of the process and the coalition assignments.

Additional coalition formation extensions include the incorporation of unmanned aerial and underwater vehicles; dynamic coalition formation and reformation as new tasks appear or system faults occur; and the formation of overlapping coalitions that share UMVs across coalitions.

3. Conclusion

The UMV research area is changing rapidly as the technology progresses and more real world applications become available. This is a domain that requires the cooperation of individuals across research areas such as electrical, computer, and mechanical engineering; computer science; psychology; and cognitive science. A single course and television show peaked my interest in this field, one that changes daily and is always exciting! One day perhaps we will have robots as capable as the Jetsons' maid, Rosie.

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Julie A. Adams

Julie A. Adams received the B.S. (1989) and B.B.A. (1990) in Computer Science and Accounting, respectively from Siena College and her M.S.E (1993) and Ph.D. (1995) in Computer and Information Sciences from the University of Pennsylvania. Since 2003 she has been an Assistant Professor in the Electrical Engineering and Computer Science Department at Vanderbilt University. She worked in Human Factors for Honeywell, Inc. and the Eastman Kodak Company from 1995 to 2000. She was an Assistant Professor of Computer Science at Rochester Institute of Technology from 2000 until 2003. She conducts research in human-robotic interaction and distributed algorithms for multiple robotic systems. She is a member of the IEEE, HFES, ACM, and AAAI.