A Task Complexity Assessment Tool for Single-Operator Multi-Robot Control Scenarios

(Demonstration)

A. Tuna Özgelen[1] and Elizabeth Sklar[1,2]
[1]The Graduate Center and [2]Brooklyn College
The City University of New York, New York, USA
aozgelen@gc.cuny.edu,sklar@sci.brooklyn.cuny.edu

ABSTRACT

One important aspect of research in multi-robot team applications focuses on integrating humans in the control loop to perform collaborative tasks. Human operators are expected to assume many different roles in these systems. So far, the research in this domain mainly considers situations where tasks are independent from one another. In contrast, the work demonstrated here describes a methodology and software system for studying human behavior in multi-robot control scenarios where tasks are complex and have different types of dependencies.

Categories and Subject Descriptors

I.2.9 [**Robotics**]: Miscellaneous; H.1.2 [**Models and Principles**]: User/Machine Systems—*Human factors*

Keywords

Human-Robot Interaction, Multi-Robot Systems

1. INTRODUCTION

Utilization of multi-robot teams has been one center of attention for research concerning future approaches to disaster recovery and military operations. Teamwork and coordination aspects have been investigated by the multiagent systems community, mostly focusing on computational complexity and scalability of algorithms. Due to the critical nature of missions in the possible application domains, human operators and/or experts are expected to be integral players in the control loop of these teams in the near future. Various approaches in the literature (see [5]) state that in practice, one of the main limitations to deployment of agents for decision support or collaborative control is *cognitive* on the part of the human operator. Plans devised by state-of-the-art multiagent systems are often discarded by human experts if the plans are not understood or conflict with their expectations.

The work presented here focuses on *Single-Operator Multi-Robot (SOMR)* control in domains where tasks are dependent on one another and/or constrained by the environment or mission specifications. Our approach includes integration of agent technology to assist human operators during planning and resource allocation problems which arise particularly when an operator assumes a supervisory mode of control. We have devised a *human-centric taxonomy* which allows us to classify weaknesses and behavioral patterns of human operators in complex task assignment situations. In order to identify circumstances where agents might improve performance, we have developed the *Task Complexity Assessment Tool (TCAT)*, which presents a set of scenarios to human subjects—encompassing points across our taxonomy—and evaluates users' performance with respect to each scenario.

Appears in: *Proceedings of the 12th International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2013)*, Ito, Jonker, Gini, and Shehory (eds.), May, 6–10, 2013, Saint Paul, Minnesota, USA.

2. RELATED WORK

A widely-cited *robot-centric* taxonomy for multi-robot task allocation was introduced by Gerkey and Matarić [2], to enable researchers to compare their results in terms of algorithmic efficiency and complexity. The authors categorized task allocation problems into a classification of task environment composed of three dimensions: (i) number of tasks that the robots can handle simultaneously (*Single-task vs. Multi-task*); (ii) resource requirements of tasks (*Single-robot vs. Multi-robot*); and (iii) available information during task assignment (*Instantaneous vs. Time-extended*). Landen et al., [4], extended Gerkey and Matarić's work, by introducing several new dimensions, two of which describe dependencies: (iv) *Independent vs. Constrained* tasks; and (v) relationship between the utilities of tasks (*Unrelated vs. Interrelated*).

3. SYSTEM

Our work studies task allocation problems from the human operator's standpoint. Our task representation is classified based on two of the dimensions mentioned above: (ii) required platforms: *multi-robot (MR) vs. single-robot (SR)* [2]; and (iv) constraints: *independent (ID) vs. constrained (CN)* [4]. The latter property represents the constraints imposed on the task either by definition or by the domain. A constraint on a task can be one of the following:

- Temporal, such as a completion deadline;
- Explicit dependencies on other tasks, such as $t_i \ \{before, after, during, ...\} \ t_j$ (e.g., scanning a room with sonar (t_i) should be performed simultaneously with scanning the same room with a camera (t_j));

- Implicit dependencies imposed by the spatial constraints of the environment (e.g., debris (t_i) must be cleared before accessing to a room where a fire has broken out (t_j)).

To assess human behavior for coping with complex task allocation scenarios, the TCAT system was developed. Human subjects who interact with the system are first presented with some test scenarios, in order to get accustomed to the interface. After training, the human subjects are presented with scenarios (similar to the ones shown in training) and are asked to assign robots to tasks as quickly as possible. They have to assign the required number of robots for each task in order to complete a scenario. Users receive a score, based on the speed with which they completed their assignment and the effectiveness of the allocation as compared to a near-optimal solution (computed off-line).

3.1 Scenario

Scenarios are inspired from the RoboCup Rescue Simulation domain [3] where heterogenous groups of agents attend to victims, fires and road blocks in the aftermath of an earthquake in an urban environment. In our scenarios, a fixed number of robots (homogenous and single-task) and tasks are scattered in a simulated office-like environment. The tasks can either be a *sensor-sweep* task, where a robot is expected to go to a specific location and send back sensor information (e.g., camera feed), or response tasks resulting from two different events, namely *fires* and structural collapses creating *debris*. Fire extinguishing and debris removal tasks may require multiple robots to execute, and they block any access to the areas in which they appear. Sensor-sweep tasks can be executed by a single robot and do not block access. For the demonstration, a scenario is considered complete as soon as a plan is generated by the user where each task in the scenario is assigned (execution is not required).

3.2 Interface

The TCAT interface (developed in C++, using Qt and OpenGL) users employ to generate a plan consists of two components (Figure 1). The *map* panel displays the positions of the robots, tasks, other environmental features and the anticipated paths from robots to their assigned tasks. The *allocation* panel is the main component where users can assign tasks to robots. It displays robots, assignments, tasks and additional information such as the remaining number of robots required per task and dependencies between tasks. Users can delete assignments and re-plan at will.

3.3 Evaluation

The quality of users' allocations are scored based on several factors, such as the anticipated total distance which would be traveled by the robots if the robots executed the plan, the number of task constraints that would be violated, and the total time it took for devising the plan. The perceived complexity of an allocation problem instance may differ from one person to another. Our complexity analysis is based on the positions of tasks and robots and accessibility of one to another. In addition, the NASA Task Load Index (NASA-Tlx) [1] is used for subjective assessment of the complexity of an allocation problem. Together with the user's subjective ratings, the complexity factors listed above allow us to map particular task instances to our derived task complexity landscape.

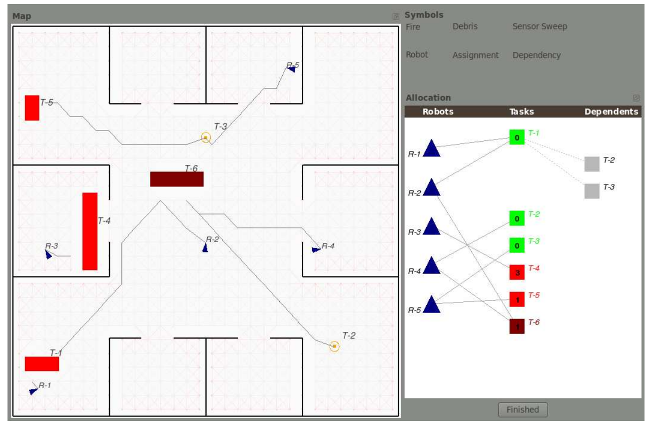

Figure 1: *TCAT Interface, Map component (on the left) and Allocation component (on the right).*

4. SUMMARY

The demonstration described here presents an empirical approach to classifying the complexity of task allocation problems, as perceived by human users. Our aim is to provide researchers with a more informed interaction design for supervisory control of multi-robot systems and a methodology to analyze particular circumstances in a formal manner. Our long term research hypothesis is that the TCAT system will help in identifying behavioral patterns and possible situations where users might require assistance or benefit from delegating some task assignments to an autonomous (or semi-autonomous) planning agent. Future direction of this work include extending the task assessment model for real-time assignment scenarios.

Acknowledgments

This work was supported by National Science Foundation under grant #IIS-11-170.

5. REFERENCES

[1] NASA Task Load Index (TLX). NASA Ames Research Center, Moffet field, California, v.1.0.

[2] Brian P. Gerkey and Maja J. Matarić. A Formal Analysis and Taxonomy of Task Allocation in Multi-Robot Systems. *The International Journal of Robotics Research*, 23(9):939–954, September 2004.

[3] Hiroaki Kitano, Satoshi Tadokoro, Itsuki Noda, Hitoshi Matsubara, Tomoichi Takahashi, Atsuhi Shinjou, and Susumu Shimada. RoboCup Rescue: Search and Rescue in Large-Scale Disasters as a Domain for Autonomous Agents Research. In *IEEE International Conference on Systems, Man, and Cybernetics*, pages 739–746, 1999.

[4] David Landén, Fredrik Heintz, and Patrick Doherty. Complex Task Allocation in Mixed-Initiative Delegation: A UAV Case Study (Early Innovation). In *Principles and Practice of Multi-Agent Systems Lecture Notes in Computer Science*, volume 7057/2012, pages 288–303, 2010.

[5] Arif Tuna Özgelen. Real-Time Supervision of Human Multi-Robot Teams in Complex Task Domains. PhD. Proposal, 2012.