The DEFACTO System for Human Omnipresence to Coordinate Agent Teams: The Future of Disaster Response *

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ABSTRACT

Enabling interactions of agent-teams and humans is a critical area of research, with encouraging progress in the past few years. However, previous work suffers from three key limitations: (i) limited human situational awareness, reducing human effectiveness in directing agent teams, (ii) the agent team's rigid interaction strategies that limit team performance, and (iii) lack of formal tools to analyze the impact of such interaction strategies. This paper presents a software prototype called DEFACTO (Demonstrating Effective Flexible Agent Coordination of Teams through Omnipresence). DEFACTO is based on a software proxy architecture and 3D visualization system, which addresses the three limitations mentioned above.

Categories and Subject Descriptors: I.2.8 [Artificial Intelligence]: Distributed Artificial Intelligence - Multiagent Systems

General Terms: Algorithms

Keywords: Teamwork, Adustable Autonomy

1. INTRODUCTION

Human interaction with agent teams is critical in a large number of current and future applications[3]. For example, current efforts emphasize humans collaboration with robot teams in space explorations, humans teaming with robots and agents for disaster rescue, as well as humans collaborating with multiple software agents for training.

This paper focuses on the challenge of improving the effectiveness of human collaboration with agent teams. Previous work has reported encouraging progress in this arena, e.g., via proxy-based integration architectures[1], adjustable autonomy[2] and agent-human dialogue. Despite this encouraging progress, previous work suffers from three key limitations. First, when interacting with agent teams acting remotely, human effectiveness is hampered by low-quality interfaces. Second, agent teams have been equipped with adjustable autonomy (AA)[3] but not the flexibility critical in such AA. Third, current systems lack tools to analyze the impact of human involvement in agent teams, yet these are key to flexible AA reasoning.

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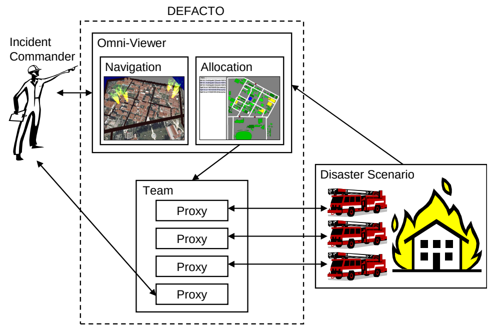

Figure 1: DEFACTO system applied to a disaster rescue.

2. DEFACTO SYSTEM DETAILS

DEFACTO consists of two major components: the Omni-Viewer and a team of proxies (see Figure 1). The Omni-Viewer allows for global and local views. The proxies allow for team coordination and communication, but more importantly also implement flexible human-agent interaction via Adjustable Autonomy. Currently, we have applied DEFACTO to a disaster rescue domain. The incident commander of the disaster acts as the *user* of DEFACTO and his goal is to extinguish fires that quickly spread to adjacent buildings if they are not quickly contained.

2.1 Omni-Viewer

The Omni-Viewer incorporates both a conventional map-like 2D view, Allocation Mode (Figure 1) and a detailed 3D viewer, Navigation Mode (Figure 1). The Allocation mode shows the global overview as events are progressing and provides a list of tasks that the agents have transfered to the human. The Navigation mode shows the same dynamic world view, but allows for more freedom to move to desired locations and views. In particular, the user can "walk" freely around the scene, observing the local logistics involved as various entities are performing their duties.

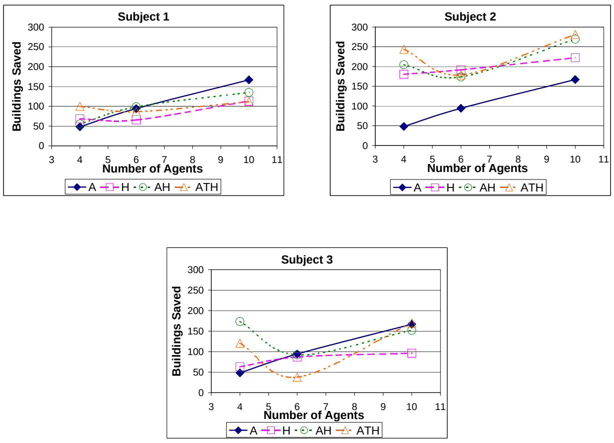

Figure 2: Performance of subjects 1, 2, and 3.

2.2 Proxy: Teamwork and Adjustable Autonomy

We have built teams based on previous proxy software [2], that is in the public domain. The proxies were extended to our domain in order to take advantage of existing methods of communication, coordination, and task allocation for the team. We focused on Adjustable autonomy which refers to an agent's ability to dynamically change its own autonomy, possibly to transfer control over a decision to a human. While previous work on adjustable autonomy could be categorized as either involving a single person interacting with a single agent, our approach allows for team-level extensions.

In our work Adjustable Autonomy is comprised of various transfer-of-control strategies. Each transfer-of-control strategy is a preplanned sequence of actions to transfer control over a decision among multiple entities, for example, an $A_T H_1 H_2$ strategy implies that a team of agents (A_T) attempts a decision and if it fails in the decision then the control over the decision is passed to a human H_1, and then if H_1 cannot reach a decision, then the control is passed to H_2. Since previous work focused on single-agent single-human interaction, strategies were individual agent strategies where only a single agent acted at a time.

3. EXPERIMENTAL EVALUATION

The results of our experiments are shown in Figure 2, which shows the results of subjects 1, 2, and 3. Each subject was confronted with the task of aiding fire engines in saving a city hit by a disaster. For each subject, we tested three strategies, specifically, H, AH and $A_T H$; their performance was compared with the completely autonomous A_T strategy. AH is an individual agent strategy, tested for comparison with $A_T H$, where agents act individually, and pass those tasks to a human user that they cannot immediately perform. Each experiment was conducted with the same initial locations of fires and building damage. For each strategy we tested, varied the number of fire engines between 4, 6 and 10. Each chart in Figure 2 shows the varying number of fire engines on the x-axis, and the team performance in terms of numbers of building saved on the y-axis. Each data point on the graph is an average of three runs.

Figure 2 enables us to conclude the following:

- *Human involvement with agent teams does not necessarily lead to improvement in team performance.* For instance, for subject 3, human involving strategies such as AH provide a somewhat higher quality than A_T for 4 agents, yet at higher numbers of agents, the strategy performance is lower than A_T.
- *Providing more agents at a human's command does not necessarily improve the agent team performance* As seen for subject 2 and subject 3, increasing agents from 4 to 6 given AH and $A_T H$ strategies is seen to degrade performance. In contrast, for the A_T strategy, the performance of the fully autonomous agent team continues to improve with additions of agents, thus indicating that the reduction in AH and $A_T H$ performance is due to human involvement.
- *No strategy dominates through all the experiments given varying numbers of agents.* For instance, at 4 agents, human-involving strategies dominate the A_T strategy. However, at 10 agents, the A_T strategy outperforms all possible strategies for subjects 1 and 3.
- *Complex team-level strategies are helpful in practice*: $A_T H$ leads to improvement over H with 4 agents for all subjects, although surprising domination of AH over $A_T H$ in some cases indicates that AH may also a useful strategy to have available in a team setting.

4. SUMMARY

This paper presents a large-scale prototype, DEFACTO, that is based on a software proxy architecture and 3D visualization system and provides three key advances over previous work. First, DEFACTO's Omni-Viewer enables the human to both improve situational awareness and assist agents, by providing a navigable 3D view along with a 2D global allocation view. Second, DEFACTO incorporates flexible AA strategies, even excluding humans from the loop in extreme circumstances. Third, analysis tools help predict the performance of (and choose among) different interaction strategies. Results from experiments using DEFACTO illustrate that an agent team must be equipped with flexible strategies for adjustable autonomy, so that they may select the appropriate strategy autonomously.

5. REFERENCES

[1] D. V. Pynadath and M. Tambe. Automated teamwork among heterogeneous software agents and humans. *Journal of Autonomous Agents and Multi-Agent Systems (JAAMAS)*, 7:71–100, 2003.

[2] P. Scerri, D. Pynadath, and M. Tambe. Towards adjustable autonomy for the real world. *Journal of Artificial Intelligence Research*, 17:171–228, 2002.

[3] P. Scerri, D. V. Pynadath, L. Johnson, P. Rosenbloom, N. Schurr, M. Si, and M. Tambe. A prototype infrastructure for distributed robot-agent-person teams. In *AAMAS*, 2003.