A cognitive architecture for emergency response

(Extended Abstract)

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ABSTRACT

Plan recognition, cognitive workload estimation and human assistance have been extensively studied in the AI and human factors communities, but have seldom been integrated and evaluated as complete systems. In this paper, we develop an assistant agent architecture integrating plan recognition, current and future user information needs, workload estimation and adaptive information presentation to aid an emergency response manager in making high quality decisions under time stress, while avoiding cognitive overload. We describe its main components as well as results for en experiment simulating various possible executions of the emergency response plans used in the real world, comparing reaction time of an assisted versus an unassisted human.

Categories and Subject Descriptors

H.4 [**Information Systems Applications**]: Miscellaneous

General Terms

Human Factors, Management

Keywords

Agent-based system development, Innovative Applications

1. INTRODUCTION

Planning for complex activities often involves consulting multiple information sources in order to reduce uncertainty associated with decision making. As humans interleave planning, execution and re-planning, managing information to meet the changing requirements becomes a cognitively demanding task. Consequently, users who must make time-critical decisions are cognitively overloaded due not only to the planning activities but also to the information requirements of the planning and re-planning. In this context, we develop the *Anytime Cognition* (ANTICO) concept to assist cognitively overloaded users through an assistant agent.

Appears in: *Proceedings of the 11th International Conference on Autonomous Agents and Multiagent Systems – Innovative Applications Track (AAMAS 2012)*, Conitzer, Winikoff, Padgham, and van der Hoek (eds.), 4-8 June 2012, Valencia, Spain.

Our approach consists of recognizing a user's plan for future activities, allowing the agent to act proactively to help the user balance her workload over time. ANTICO uses predicted future plans for proactive information gathering and subsequent presentation in a suitable form that takes into consideration a user's cognitive workload available time.

We transition ANTICO to real-world scenario through a proof of concept application to assist a disaster response manager, which must deal with a chemical attack against a civilian facility in a major city, facing uncertainty throughout the response. Uncertainty stems primarily in the diagnosis and determination of the chemical used, and later from the various second-order effects. The agent assists the manager in making decisions under time-pressure, analyzing a stream of information arriving from various localized sources while keeping track of the big picture in order to coordinate multiple agencies performing activities around the affected areas. Information needed for decision making must be presented in ways that facilitate quick action, as response managers must make decisions within tight deadlines. Our contributions are threefold: first, we extend prior work on a proactive assistive agent architecture [4]; second, we deploy it in a concrete application domain; and third, we provide a simulation-based evaluation highlighting the circumstances in which gains could be obtained by our approach. We develop an emergency response scenario based on the standard disaster scenarios planning document [1], and present an application of ANTICO using this scenario, which has been fully implemented. Since potential gains from using ANTICO are closely associated to the accuracy of the agent in presenting relevant information, we evaluate the potential effectiveness of the approach through simulations of the assistance under various success rates for both intention prediction and information presentation.[1]

2. AGENT ARCHITECTURE

ANTICO architecture comprises multiple AI components including probabilistic plan recognition and intelligent information management, more details of which can be found in our previous work at [4]. Figure 1 shows a modularized view of the ANTICO components and how those components are interconnected. The rectangles represent the main components; the third-party components are drawn in dot-

[1] ANTICO demo video: `http://goo.gl/o186E`

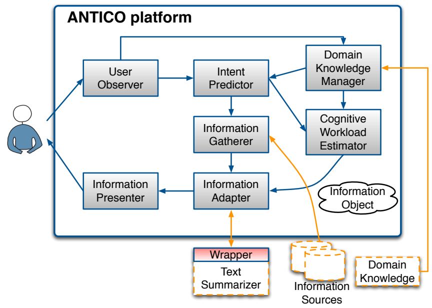

Figure 1: Architecture Overview

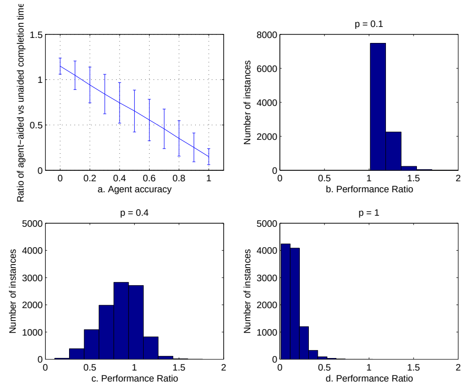

Figure 2: Simulation analysis

ted lines; a problem domain specification is provided as an input to the system; and the information object is the communication medium representing a user's information needs. Here, we specifically focus on the following two desiderata for the assistant agent. First, the agent must be able to recognize a user's activities. Second, the agent's interaction with the user must be unobtrusive and adaptive to user cognitive workload. The User Observer module is responsible for monitoring various parameters indicating a user's current activities and her environment. When a change is observed, the Intent Predictor module analyzes the new observation to identify the user's intention and makes predictions for the user's future activities according to a workflow model. Subsequently, the Information Gatherer communicates with a set of information sources to meet the information requirements relevant to the predicted future user activities. Concurrently, the agent maintains an estimated user cognitive workload based on observed temporal parameters in order to determine the appropriate level of detail in presentation.

3. EVALUATION

To demonstrate the applicability of the ANTICO approach to the real world, we developed a scenario [3] based on the National Planning Scenarios created by the Department of Homeland Security (DHS)[1].[2]In real disaster scenarios within the United States, emergency management is conducted by following an *Emergency Operations Plan* (EOP), and major urban centers in the US have them available to disaster managers. Intuitively, if the agent correctly infers the user's current intention and presents the right information in summarized form, a human user should see gains in terms of reaction time. Otherwise, if the agent displays incorrect information, a user must refer to the EOP document and suffer the time penalty of reading the irrelevant information. Given the difficulty in obtaining access to trained emergency management personnel, we have devised a simulation of a user managing an emergency scenario to evaluate the potential effectiveness of the ANTICO concept under various hypothetical error rates by the agent. The simulation consists of random walks through the workflow, following its transition probabilities, while accumulating the time taken by a human user to read the information needed to complete the task. Since we consider the amount of information actually read by the user during emergency management to be the main driver for the time spent carrying out a task, the main parameters of each step in the simulation are the best and worst-case scenario for the number of pages required to be read to complete an activity. Each activity in the workflow is associated with a particular section (or chapter) within the EOP document[3], and the amount of information needed at each task varied from none (for tasks where the emergency manager is expected to know the information) to six pages. In order to estimate the expected time spent by a human user reading this information, we took the standard measures of reading rates obtained from the human factors literature [2]. Using the resulting times of our simulations, we calculated the performance ratio between the agent-assisted and the unaided user. These results are illustrated in the graph of Figure 2.a, which shows the various accuracy values along the X axis, as well as the performance ratios (with standard deviation) along the Y axis. Furthermore, we illustrate in more detail the specific number of samples associated with each performance ratio in the histograms of Figure 2.b-2.d for p equal to 0, 0.4 and 1. Bars to the left side of each histogram show samples in which the agent led to improved performance. Notice that at $p = 0.1$ the user's performance tends to be worse than the unaided user, but already at $p = 0.4$, most of the samples indicate an improvement in user performance.

Acknowledgement: This research was sponsored by the U.S. Army Research Laboratory (ARL) and the U.K. Ministry of Defence (MoD) and was accomplished under Agreement Number W911NF-06-3-0001. The views and conclusions contained in this document are those of the author(s) and should not be interpreted as representing the official policies, either expressed or implied, of the ARL, the U.S. Government, the MoD or the U.K. Government. The U.S. and U.K. governments are authorized to reproduce and distribute reprints for government purposes notwithstanding any copyright notation hereon.

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[2]http://goo.gl/YtQfq

[3]We had access to the table of contents of the EOP for a major US city, from which data size estimates were derived.