Enhancing Situation Awareness with Visual Aids on Cognitively-inspired Agent Systems

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ABSTRACT

This paper describes the strengths of two types of visual aids: VADS (Visualization of Agent Decision Space) and ADT (Agent Decision Table). The VADS is a newly developed visual aid that intuitively represents complicated target attributes in a graphical form, whereas the ADT shows such things in a traditional tabular form. The strengths of each visual aid have been obtained through the analysis of real-time situational awareness queries. Graphical icons expressing multiple attributes are useful in achieving overall situation awareness in most cases. However, there are cases where presentation by a simple text is better in recognition than that by a

graphical notation. We discuss the recognition of the ethnic affiliation of crowds as an example at the end.

Keywords: Decision aid, Situation awareness, Knowledge visualization, Decision Support, Cognitively-inspired agent

INTRODUCTION

The information age has brought enormous changes to modern combat operations. In an information technology perspective, network-centric warfare (Cebrowski and Garstka 1998), a military doctrine of war, can be viewed as a concept of operations for increasing combat power through the use of networking sensors, decision-makers, strategies to achieve a shared situation awareness and so on (Fan, Sun et al. 2005). As effective teamwork plays a key role in the doctrine, and the teamwork can be accomplished by the use of intelligent agents, *Three-Block Challenge* has been proposed to study and evaluate agent-aided teamwork in C2CUT (command and control in complex urban terrain) environment where operations officers must react to a constant flow of event reports and make timely decisions for many tasks including combat, peacekeeping and humanitarian missions (Fan, Sun et al. 2006).

We previously developed a human-centered agent architecture for supporting decision making of the armed forces especially when they need to work together in teams with the requirement to analyze a large amount of dynamic information in order to eliminate potential threats from targets. The goal of the past research on this topic was to find a way of enhancing team collaboration and performance; it could be done by modeling a cognitively-inspired agent architecture. The architecture is suitable for proactive seeking, linking, and sharing information through the use of knowledge databases. The collaborative RPD (Recognition-Primed Decision) model has been adopted into the agent architecture for team-based decision making (Airy, Chen et al. 2006).

However, when there are too many targets to deal with and when decisions are made under time pressure, it is hard for the commander to keep track of them and predict what they will likely to behave. The Visualization of Agent Decision Space (VADS) has been introduced for ensuring better situation awareness of the subject (Yen, Strater et al. 2009). The VADS shows prior knowledge for making right decisions. The VADS maps a collection of the past experiences called common historical cases (CHCs) and current targets as icons on the display based on their relative similarities. If a new event occurs, the VADS finds several CHCs that are similar to the current event, and shows it as small bubbles on the left-hand side of the display. Each small bubble indicates one common historical case. Also, the VADS places another bubble, which indicates the current event, among the CHC bubbles. The nearest CHC bubble from the current event bubble in distance is much likely to contain the most appropriate information for dealing with the current target.

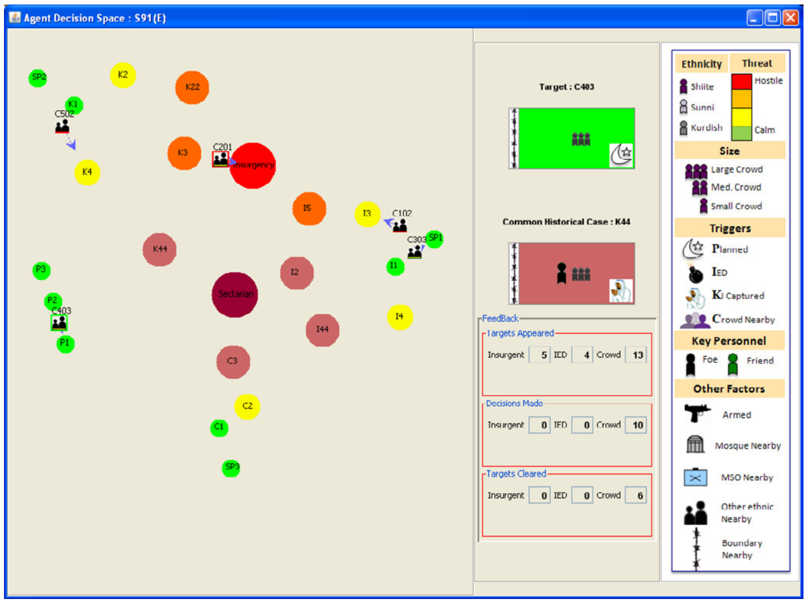
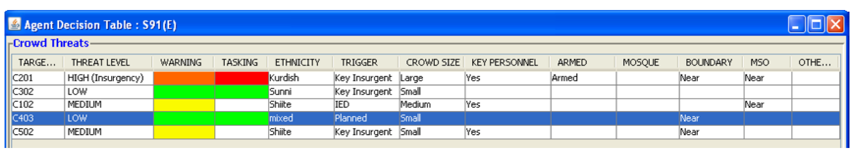


Figure 1: Visualization of Agent Decision Space (VADS)



Agent Decision Table : S91(E)

Crowd Threats

TARGE...	THREAT LEVEL	WARNING	TASKING	ETHNICITY	TRIGGER	CROWD SIZE	KEY PERSONNEL	ARMED	MOSQUE	BOUNDARY	MSO	OTHE...
C201	HIGH (Insurgency)			Kurdish	Key Insurgent	Large	Yes	Armed		Near	Near	
C302	LOW			Sunni	Key Insurgent	Small						
C102	MEDIUM			Shiite	IED	Medium	Yes				Near	
C403	LOW			mixed	Planned	Small				Near		
C502	MEDIUM			Shiite	Key Insurgent	Small	Yes			Near		

Figure 2: Agent Decision Table (ADT)

METHOD

In this experiment, participants interacted as command officer with an urban combat simulation. There were three types of targets with limited number of units on the simulation. The participants were supposed to assign their units to remove the targets and give an answer to a situation awareness (SA) query. The subject's goal was to achieve high scores in both the simulation and SA queries. Each participant was randomly assigned to either the control group or the experimental group. Each group had a different kind of secondary visual-aid; the control group was assisted by a tabular form situation display whereas the experimental group was assisted by visualized situation display. Their performance was evaluated in terms of their game scores as well as SA scores.

PARTICIPANTS

32 U.S. Army ROTC (Reserve Officer Training Corps) students from Pennsylvania State University, 3 female students and 29 male students, were recruited for this experiment. The participants ranged in age from 18 to 22 (Mean: 20.15, Standard Deviation: 1.48) years. Most of them described themselves as ones familiar with video games. On average, at the time of the experiment, they had been playing video games for 10 years, and 4 hours a week. Each participant was compensated with $20.

APPARATUS

The experiment took place in the Laboratory for Intelligent Agents at Penn State. Each human subject was seated in front of two 21 inch (1680x1050 pixels) computer monitors. The urban combat simulation environment on R-CAST, a multi-agent framework, was used with four different scenarios based on the *Three-Block Challenge* (Fan, Sun et al. 2006) where three types of operations are carried out: peacekeeping, combat, and humanitarian operations.

For the apparatus in the simulation, a limited number of units (5 police units, 6 combat units and 1 explosive ordnance disposal unit) are given to the human subject to conduct operations. The peacekeeping operation is to disperse violent crowds with a combination of police and combat units according to the threat level of the crowds. A crowd target is a moving target representing a group of people that may contain activists who are either friends or foes, and has an ethnic affiliation. Also, its threat level may change over time from low to very high. The combat operation is to capture a key insurgent, also a moving target, with two combat units. The humanitarian operation is to remove IEDs, or improvised explosive devices, for the protection of logistic routes; they are stationary targets that cause damage to nearby objects if exploded. Static objects of interest include MSRs, or main supply routes, checkpoints and key buildings such as religious buildings, schools, and hospitals. These objects may affect the movement of crowd targets.

Target		Police	Combat	EOD	Total
IED		0	1	1	2
Key Insurgent		0	2	0	2
Crowd	Low Threat Level	1	0	0	1
	Medium Threat Level	1	1	0	2
	High (Insurgency)	1	2	0	3
	High (Sectarian)	2	1	0	3
	Very High (Insurgency)	1	3	0	4
	Very High (Sectarian)	3	1	0	4

Table 1: Required units for each type of targets

EXPERIMENTAL TASKS

The subjects were asked to assign appropriate types and numbers of units to a particular location in response to terroristic event information received from other agents, maximizing the utility of the human resource. Decision making in target selection and resource allocation requires the officer to consider tradeoffs among multiple factors such as target type, threat level, the unit-target distance, etc. The type and the threat level of a target determine how many units will be necessary to deal with the target. For the purpose of a situation awareness measurement, subjects were also asked to answer a situation-related question, or a Real-time Situation Awareness Questions (RTSA), each time when they assigned their units to a target.

EXPERIMENTAL DESIGN

The experiment was a 2x2x2 mixed factorial design with one between-group variable (visual-aid) and two within-group variables, crowd size and fast burner ratio. The size of crowd was included to determine whether the usage of knowledge visualization was differently influenced by the workload.

Participants first completed an informed consent form and took a demographic survey, and were randomly assigned to one of two conditions (experimental and control). Each participant then watched a 20-minute training video. After the training, the participants had played with a 5-min practice trial until they became familiar with the whole rules in the simulation. And then they proceeded to four 10-minute simulation trials that were given in a random order.

RESULTS AND CONCLUSION

A previous study showed that the group with the VADS achieved a 20 percent improvement over the group with the ADT in terms of task performance, the product of game score and the degree of RTSA (Yen et al. 2009, Hanratty et al. 2009). Even though the task performance implicates overall situation awareness and the VADS helps commanders make right decisions as a result, it is important to understand what type of visual aids is good for recognizing a certain attribute of events (e.g. ethnicity of crowds) when designing a visual aid for decision support system.

This study analyzes the advantages of the two types of visual-aid: the VADS and the ADT. The VADS is good for representing multiple objects with many attributes on a limited space in an intuitive way, and for showing the likely future behaviors of crowd targets predicted by the agent. However tabular forms are also good in some cases. The following table shows the RTSA queries that the control group got better scores than the experimental group did (left-hand side), and vice versa (right-hand side).

Control group with ADT	**Experimental group with VADS**
(Q1) What was the affiliation of the last crowd target that you assigned units to? { Shiite, Sunni, Kurdish, Mixed } (Q2) Did the last crowd target you assigned units to require more police units or more combat units? { more police units, more combat units, same number of police and combat units }	(Q3) How many active crowd targets contain escalating elements? { 0-1, 2-3, 4-5, 6-7, 8-10 } (Q4) In the last crowd target you assigned units to more likely to become an insurgency event or a sectarian event? { Insurgency, Sectarian } (Q5) What has been most frequent trigger event for crowd targets in this scenario? { IED exploded, Key insurgent captured, Nearby crowd, Planned Event }

Table 2: Selected RTSA queries (Q1 – Q5 mean RTSA query numbers)

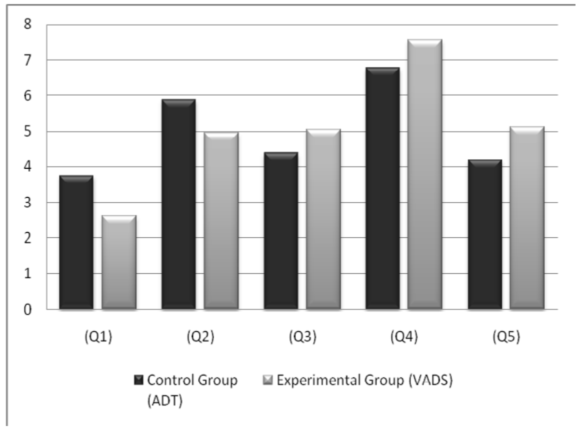


Figure 3: Average scores for selected RTSA queries
(Y-axis: Average score, X-axis: RTSA query numbers)

The ethnic affiliation of crowd targets was shown as texts in the ADT, and as a result, the subjects could easily recognize it and recall it after unit assignments. The VADS also graphically represented it in its display, but it was not as good as the ADT in terms of the average RTSA score. The ADT was shown to be good for recognizing how many police and combat units were required for the previous target. On the other hand, the VADS turned out to be useful in showing whether a crowd event would be more likely to become a sectarian event or an insurgency event, and it is important to assign the appropriate number of units to the target in advance before the threat becomes more dangerous; it may be too late if the subject tries to deal with targets after they reach to such states.

The following is the table of the RTSA queries that both groups got similar degree.

Both Groups
• What was the trigger event for the last crowd target you assigned units to? • How many high or very high threat crowd targets are currently on your display? • Will you need to assign additional units to any crowd target that you've already assigned units to? • What is the intent of the last crowd you assigned units to? • How many of the active key insurgent targets will your units capture before they appear?

Table 3: RTSA queries that did not distinguish the groups

The VADS and the ADT have different strengths in ensuring situation awareness. In particular, a simple text can be better than a graphical icon if there is something to be memorized for precise operation planning. However, an intuitive graphical notation implying many attributes can be useful in achieving better task performance.

ACKNOWLEDGEMENT

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REFERENCES

Airy, G., P. Chen, et al. (2006). Collaborative RPD Agents Assisting Decision Making in Active Decision Spaces, IEEE Computer Society Washington, DC, USA.

Cebrowski, A., J. Garstka (1998). Network-centric warfare: Its origin and future, Proceedings in US Naval Institute 124(1): 28-35.

Endsley, M., Garland, D. (2000). Situation awareness: analysis and measurement, Lawrence Erlbaum Associates.

Fan, X., S. Oh, et al. (2008). The influence of agent reliability on trust in human-agent collaboration, ACM New York, NY, USA.

Fan, X., Sun, B., Sun, S., McNeese, M., Yen, J. (2006). RPD-enabled agents teaming with humans for multi-context decision making, The 5th International Joint Conference on Autonomous Agents and Multi-Agent Systems (AAMAS).

Fan, X., S. Sun, et al. (2005). Collaborative RPD-enabled agents assisting the three-block challenge in command and control in complex and urban terrain, Conference on Behavior Representation in Modeling and Simulation (BRIMS)

Hanratty, T., Hammell II, et al. (2009). Knowledge Visualization to Enhance Human-Agent Situation Awareness Within a Computational Recognition-Primed Decision System, The 5th IEEE Workshop on Situation Management (SIMA).

Yen, J., L. Strater, et al. (2009). “Cognitively-inspired Agents as Teammates and Decision Aids”, in: Advanced Decision Architectures for the Warfighter: Foundations and Technology, McDermott, P., Allender, L (Ed.). pp. 219-236.