SCENARIOS AS A TOOL FOR DESIGN ENVISIONING: USING THE CASE OF NEW SENSOR TECHNOLOGIES FOR MILITARY URBAN OPERATIONS

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This paper describes the use of a collaborative envisioning tool to combine the goals of disparate communities concerning the role of new sensor technologies being deployed in Military Operations in Urban Terrain (MOUT). To do this, Cognitive Engineering intersects with the sensor development and military operations communities. Through the use of scenario-based design and the Topic Landscape tool, generic patterns provide seeds that help envision realistic futures of MOUT which are expressed in a narrative. These patterns provide insight on two levels: On one level they describe complexities inherent to all cognitive work, while on another level they provide insight about what makes MOUT difficult. The Topic Landscape is a collaborative tool that organizes information from a Cognitive Task Analysis of MOUT in many forms (text, graphics, video, etc.) from many contributors. This approach turns scenarios from a validation tool to an effective envisioning tool.

INTRODUCTION

Understanding the difficulties of Military Operations in Urban Terrain (MOUT) and using new technology to support these operations is particularly important in a time of asymmetric international conflicts. New technologies are being developed to allow the military to conduct urban operations more safely and effectively. One such technology is that of unattended ground sensors (UGS), which aim to be smaller, cheaper and more versatile for use in the urban environment. Part of this development process includes matching the capabilities of the technology to the real needs and constraints of MOUT. The development community is under real pressure to provide the problem holders (military personnel) new fieldable systems to improve performance. The technologists (sensor technology researchers) are advancing the capabilities of UGS: smaller, lighter, more robust sensors; multi-modal sensor packets that incorporate photosensors, acoustic sensors, magnetometers and Passive Infrared (PIR) motion sensors; ad-hoc networks of many hundreds of nodes; and new processing to detect more complex patterns in human activity individually and as a network of sensors (Taylor, et al. 2004).

As these two communities envision future urban military operations, the question is: what is the role and contribution of Cognitive Engineering? First, Cognitive Engineering is concerned with understanding the complexities and how people cope with the complexities of operational settings like MOUT. Methods like cognitive work or task analysis (Vicente, 1999) help us capture the actual constraints and avoid oversimplifications from the distant desk chairs of system developers (Woods, et al., 2004). Second, Cognitive Engineering is concerned with identifying leverage points about what would be useful in supporting cognitive work in difficult operational settings (Woods, 1998). The major challenge is the task-artifact cycle or the envisioned world problem (Carroll and Rosson, 1992; Woods and Dekker, 2000), where the introduction of new technology transforms the activities and goals that technology was designed to support. In HCI and Cognitive Engineering, researchers have been developing techniques to deal with the challenges of the envisioning process that go beyond mere acceleration of the standard prototype and test of iterative cycles. Many of these techniques are based on using scenarios and storytelling as a means for collaboration across diverse groups engaged in the development process (Carroll, 2000; Woods and Christoffersen, 2000; Feltovich et al., 2004; Roesler, Woods, and Feil, 2005).

In this project, we use Cognitive Engineering techniques to support collaboration across diverse development groups to facilitate design envisioning. The specific context is how new sensor technology can support more effective MOUT operations. The techniques are an extension of scenario-based methods and use of a shared multimedia visualization concept called Topic Landscape to support collaborative envisioning.

COGNITIVE TASK ANALYSIS RESULTS

Increasingly, the United States Military has been conducting operations in urban environments. This radically different battlefield introduces new complexities which demand the adaptation of units on the ground as well as higher echelons. Initial Cognitive Task Analysis (CTA) results are available from critical incident studies of recent urban operations such as the Tet offensive in Hue City, Vietnam 1968; the US experience in Mogadishu on October 3rd, 1993 during the Somalian Civil War; the battles for Grozny, Chechnya in 1995 and 1996; and the 2002 Israeli operation in Jenin, West Bank. Additional information is available from observation of U.S. Military training exercises and from debriefings of units returning from urban operations in the Balkans, Afghanistan and Iraq.

For this project we synthesized the available CTA results across these multiple sources (e.g., Innocenti, 2002). Briefly, critical functions needing support in urban operations that may be relevant to new sensor technologies include:

- Orientation to the environment and friendly forces (e.g., the danger of getting lost in urban environments and the need to cross reference landmarks, targets, and locations across units and echelons; the need to coordinate unit boundaries as local terrain makes this difficult and effective asymmetric foes try exploit them).
- Restrict opponent's mobility (e.g., cutting off routes of escape & approach, sealing off areas).
- Managing civilians in potential conflict areas as there is a complex mix of hostile and civilian populations (e.g., avoid alienating local populace; detecting when civilians are being used by opponents such as bait and trap).

Complicating factors in the urban environment that need to be considered in any human-technology design include:

- Urban terrain changes and is re-designable.
- Different operational tempos in different parts of the cityscape can cause mis-synchronization across units.
- Speed of decisions and situations can change unpredictably across high intensity, low intensity, crowd control, humanitarian situations.
- Varying rules of engagement and opponents who fight your rules of engagement.
- Vertical multi-tiered environment.
- Highly adaptive situations against fast-learning adversaries.
- Operations can be channeled along narrow lanes due to limited fields of view, limited fields of fire, and constricted avenues of approach.
- Risk of friendly fire is high.
- Difficult resource management tasks as urban operations burn through people and other resources rapidly.

Design Collaboration through Cognitive Engineering

The key to envisioning the future of operations given new pressures and new technological possibilities is building ways to integrate the operational, technological and cognitive system perspectives. The means to accomplish this collaborative environment is a shared and evolving story framework within which multiple detailed scenarios can be played out. The story framework creates a future operational setting and story line that can be used to express basic difficulties of urban operations and the opportunities of new technology. The story framework defines a collaborative environment in which different perspectives on a system development can be integrated.

The research base of Cognitive Engineering also provides general patterns in cognitive work that apply in this operational setting. These patterns provide a level of abstraction above the MOUT–specific complexities which describe cognitive work in any domain. Because these general patterns can apply in any domain, they represent classes of problems that play out as specific instantiations within the confines of a domain story space. Addressing complexities at their most basic level means that solutions are easily adapted to other domains, or different scenarios within the same domain.

An example of this relationship would be a commander's decision to advance through vacated buildings when it's discovered the roads have been set up for an ambush. This represents the larger class of adapting to changing constraints in pursuit of goals. Trying to analyze the decision from a domain-specific viewpoint might lead to the conclusion that streets are never safe because they might be trapped. The larger pattern is how to adapt a plan to meet the intent when impasses are encountered (Shattuck and Woods, 2000).

We have successfully used a variant on this story framework—the future incident technique—previously in multi-perspective design envisioning in the context of new air traffic management concepts (Dekker and Woods, 1999).

THE TOPIC LANDSCAPE

A Tool for Collaborative Envisioning

The tool we're using to organize and display our body of information is the Topic Landscape. A mature example of this can be seen online at the following url: *http://csel.eng.ohio-state.edu/woodscta* The Topic Landscape organizes a large amount of evolving material building on a basic principle of information design: the navigation mechanism should be a model of the topic being navigated. It consists of a multi-tiered organization based on simple concepts related to work on visual narratives (Roesler, Woods and Feil, 2005). The starting point of the Topic Landscape is a diagnosis that poses a problem and launches an exploration that takes the form of a series of challenge and response units. Under each item a variety of multimedia materials (video, maps, graphics, photos, interactive timelines, etc.) can be accessed that illustrate and expound on the diagnosis of each challenge and response unit. An example can be seen in Figure 1 which shows screen shots from a line-of-sight simulated video. To track the evolution of this Topic Landscape, it can be viewed online at: *http://csel.eng.ohio-state.edu/woods* (click on 'electronic productions').

The advantage of an effective CTA is that it allows you to see promising directions which are used to define the challenge and response units. In this case, the challenge and response units are emerging based on CTA results as the collaborative envisioning process evolves. The previous section of this paper defines some of the challenges in MOUT and provides insight for how to meet those challenges. The visual narrative ends with a synthesis and transition point that can launch new stories, and new explanations of related topics. The advantage of this orga-

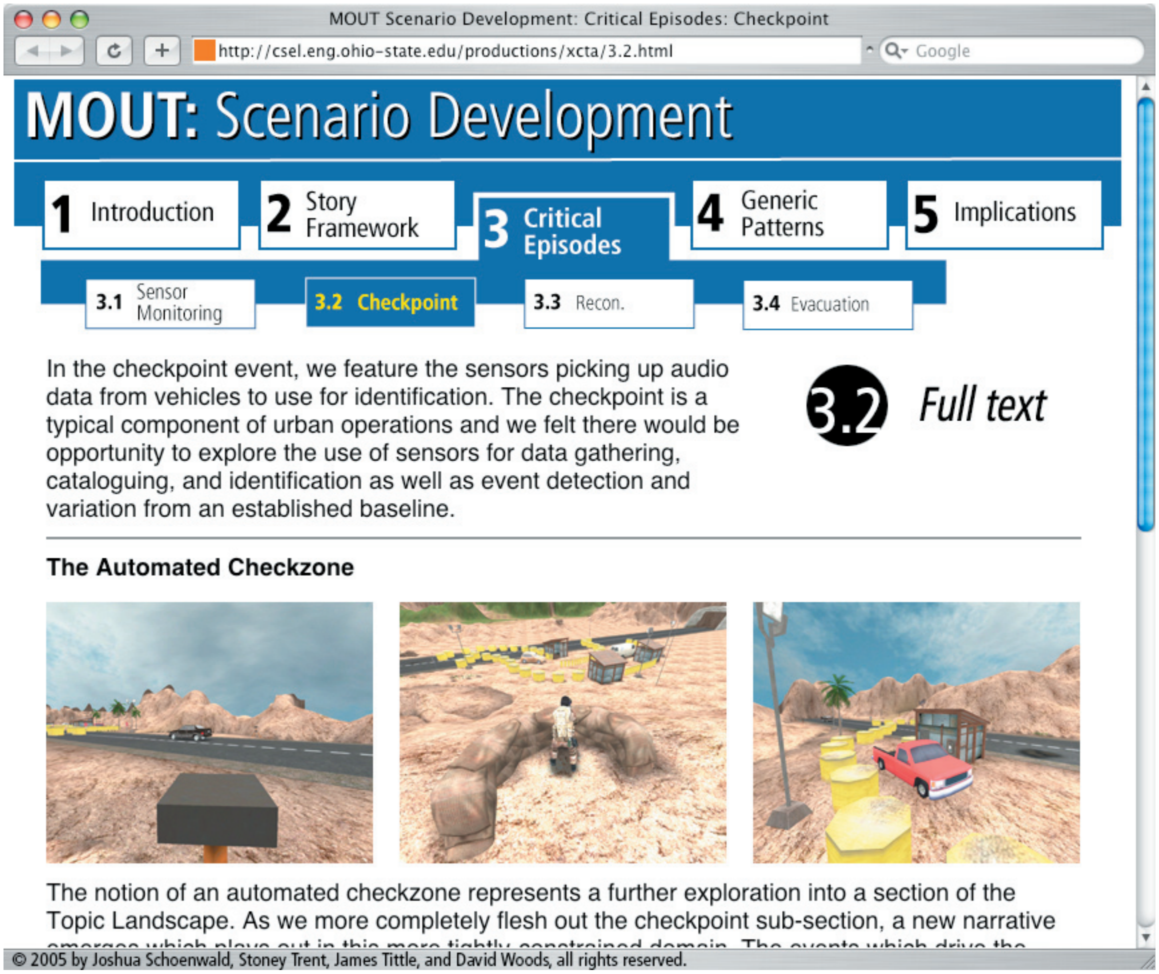

Figure 1: The Topic Landscape. Section 3 displays critical punctuating episodes supplemented with graphics and video. Section 3.2 focuses on the checkpoint episode.

nization is that it presupposes no linear path yet still retains a backbone structure which is easy to navigate, making the Topic Landscape ideal for presenting information as well as developing ideas. Because the Topic Landscape is extendable, it also becomes an ideal tool for collaboration; different sections can represent information from different contributors, and there is no risk of disrupting any pre-designed sequencing. Our Topic Landscape organizes components of a scenario-based exploration to discover what would be useful as design seeds in the MOUT domain. This includes the introduction and overview to the story of operations, the sequence of events, the critical episodes that punctuate the flow, the deeper structure of generic patterns in cognitive demands and coordinated activity built into the domain story, and lastly the implications that emerge from using the scenario to explore how the new technology supports the operations in question.

Results from the Cognitive Task Analysis of MOUT led us to establishing a military evacuation operation as the core around which we were to build the narrative. The evacuation was a good candidate to use because it is a fairly typical objective and it's broad enough to exist on its own as a mission, rather than being just a small subset of a larger operation. It also allowed us opportunities to incorporate generic cognitive systems factors in addition to MOUT-specific factors.

Section 2 of the Topic Landscape contains our initial attempt to flesh out the framework for the story. We divided this section into 5 subsections which, at a very high level, illustrate the flow of the narrative including the background establishing context, the initial decision that an evacuation is necessary, the significant events, and finally the redeployment of soldiers. The sections are divided by military-level distinctions, still independent of affordances for the use of sensors. A brief summary accompanies each subsection of the story framework which is our initial draft of how the events could play out.

Sections 3 and 4 of the Topic Landscape work hand in hand to create a detailed narrative of future operations of how new sensor technologies might be employed in MOUT. The generic patterns from the CTA results provide a base of domain-relevant information from which to draw the elements making up the narrative. The critical episodes are not meant to exhaustively define the narrative, rather they represent vignettes of activity all playing out within the larger context. Depending on technology or research needs, these episodes can be reconfigured, reorganized, or edited to highlight different elements of the framework. We chose surveillance, checkpoint, reconnaissance and evacuation as critical episodes because they offered particular advantages for exploring the use of unattended ground sensor (UGS) technology.

IMPLICATIONS

The results of our explorations with the Topic Landscape yielded three categories of implications that describe the parameters for considering the use of UGS in MOUT. These categories are rooted in the research base of Cognitive Engineering, yet they are tied to both the constraints of the MOUT domain and the continuing advances in UGS technology.

Observability and Directability

Designing the future use of emerging sensor technology in MOUT requires that the technology be both observable and directable. Observability (Christoffersen and Woods, 2002) refers to the visibility of system status and the ability to which it allows people to see things they weren't expecting. This rich understanding enables human stakeholders to fully understand the bounds of technology and reduce episodes of automation surprises (Sarter, Woods, and Billings, 1997) which usually lead to deactivation or discontinued use of relevant technology. Additionally, stakeholders will understand areas where the system is weak and strong, so that its use can be optimized and questioned as appropriate.

In addition to being observable, sensor systems must also be directable. Directability refers to being able to control the technology as necessary based on knowledge of your goals, the system, and how the system works. This demonstrates the value of observability; when as a stakeholder you need to change something, your model of why and how to do so is accurate. Simply creating observable systems with no commensurate directability does not afford stakeholders the means to make necessary changes.

The consequences of unobservable and undirectable technology have been well documented, especially in the domains of aviation (Sarter, Woods, and Billings, 1997, NTSB, 1986), health care (Cook, et. al. 1991) and navigation (Lutzhoft and Dekker, 2002). Poor observability and directability led to failures in these situations because practitioners were unable to gain a true picture of what the systems were doing or make the changes necessary to stave off disaster.

Observability and directability teach us that the issue is not the level of autonomy or authority, but rather the degree of coordination (Christoffersen and Woods, 2002). This is especially true in high-risk, fast-paced, dynamic environments such as MOUT. In this way, parallels can be drawn between previously observed domains and MOUT, showing us that the MOUT domain is equally susceptible to these types of failures. With regard to sensor technology, we must go beyond the mere availability of data and begin to provide information that helps the soldier perform his or her job. A technologist's point of view might try to indicate when sensors are triggered by activities related to people moving nearby. More informative would be integrated texture displays derived from multiple sensors which create observability allowing the soldier to see if people are converging on a point, moving a way from a point, or if some subgroups are moving towards a point of conflict while others are moving away.

Event vs. Signal Recognition

As cooperative agents, sensors must be able to communicate in a manner that has real meaning in reference to the goals of the stakeholders. These goals are complex and involve the consideration not only of the squad in question, but other squads, platoons, and enemy forces which may be geographically separate, yet critically important. In order to facilitate this communication, sensors must be designed to operate in the perspective of the soldier, not the technologist (Christoffersen, Woods, and Blike, 2001).

This means the focus and the value of sensors comes in event recognition rather than signal recognition. Sensors are designed to collect data based on a programmed set of parameters. Simply presenting this (raw) data does not tell the soldier any valuable information as it relates to real goals which are more complex than whether or not something crossed the receptive field of a sensor. Interpreting this data through algorithms into assumptions about the nature of such detections ("was the detection caused by a truck or a group of people") is not the correct way to solve this problem either. Automated assumptions are brittle when used in dynamic, fast-paced adversarial situations, where enemy tactics are constantly adapting to pose new threats.

Instead, real advances in sensor utility will come when data collected by these sensors is organized and integrated in ways that make enemy actions apparent. The key is to support rather than supplant the decisions made by the stakeholders. In other words, instead of trying to make assumptions on behalf of the soldier, these sensors should be providing information that makes the decisions easier for the soldiers to make.

Implications of Generic Patterns

Critical Support Functions. Sensors have the potential to help friendly troops orient themselves not only to the environment but to each other. An oft-unspoken difficulty in MOUT is knowing the precise whereabouts of friendly troops, both in relation to each other, the environment, and known enemy forces. Using sensors as tracking devices or waypoints could help support the need to continuously be aware of one's location as it relates to friendly and enemy forces.

Restricting opponent's mobility is another crucial MOUT function because of the relative ease with which locals can move and hide within the terrain. Sensors placed in swept areas could serve as indicators of the re-emergence of enemy combatants into secure areas. Locals will always have a more intricate understanding of the battlefield and will exploit this advantage. Understanding the need to establish boundaries should guide the use of sensors in this fashion.

Complicating Factors. One significant complicating factor of MOUT is it's instability. Situations that are benign can become hostile for a number of reasons. Often, attacks on friendly troops can be side-effects of in-fighting elsewhere in the area. Occupying forces must be wary of their use of sensors to monitor the environment. A civilian group might become hostile if they discover a hidden camera or microphone in their midst. Other important factors affecting the role of sensors in MOUT include tempo, and the physical environment which is vertically-oriented and redesignable.

CONCLUSION

These tools and processes have stimulated interactions and conversations to facilitate envisioning across the perspectives of sensor technologists, operational practitioners, and cognitive engineers. They are bridges which prevent us from getting lost in the details of the technology or the current modes of operational practice without understanding what's really beneficial for each community.

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