Developing Adaptive User Interfaces Using a Game-based Simulation Environment

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ABSTRACT

In dynamic settings, user interfaces can provide more optimal support if they adapt to the context of use. Providing adaptive user interfaces to first responders may therefore be fruitful. A cognitive engineering method that incorporates development iterations in both a simulated and a real-world environment is used to develop new adaptive concepts. In a simulated 3D-world, created with the Unreal Tournament game-engine, a team of emergency personnel have to rescue people and develop an understanding of the situation. We believe a game-based simulation environment can provide an effective platform for experiments in which crisis management situations can be created under controlled circumstances. Using this simulation, support concepts based on adaptive user interfaces can be developed and evaluated before they are implemented in a real-world setting. This paper describes the work that has been done, and presents the design of the planned experiments.

Keywords

Adaptive user interfaces, cognitive engineering, game-based simulation, human factors, experimentation

INTRODUCTION

The term first responders refers to the individuals and teams that are first on the scene when a man-made or natural crisis occurs. They can be firemen, medics, or policemen, and have several important tasks to perform such as urban search and rescue, triage victims, examine the area, and inform other parties when they arrive at the crisis scene. Often, it takes a considerable time before a good situation awareness is developed because of the complexity and dynamics of crises.

Information technology can support first responders with building situation awareness. For this purpose, information systems have been built into emergency vehicles to enable better preparation while driving to the crisis area. In recent years, there has been considerable research on support for first responders by means of PDAs and intelligent cell phones (i.e., McGrath and McGrath, 2005; Wagner, Phelps, Guralnik and VanRiper, 2004). One type of support that is provided by many approaches is a GIS-application presenting a map that shows the locations of all emergency personnel in the area. Studies have shown that this helps with building good situation awareness because it provides answers to the questions: "Where am I?" and "Where are my colleagues?". Most tools provide some means of communication, for example voice, chat, or e-mail, and can show information about objects on the map.

In this study, we examine whether adaptive user interfaces can improve the support provided. We distinguish between adaptive and adaptable user interfaces. An adaptive interface changes the information content or way of dialogue (or both) in real time without the explicit control of the user. User interfaces that can be changed by the user will be referred to as adaptable interfaces. Both have their pros and cons. Adaptable interfaces leave the user in control, but adapting takes time and the user may be to absorbed with his work to think of changing to a more optimal user interface. Adaptive interfaces have the potential to improve overall human–machine system performance if properly designed; they also have a very real potential to degrade performance if they are not properly designed (Bennett, Cress, Hettinger, Stautberg and Haas, 2001). To be able to anticipate on the information needs of the users and adapt the interface appropriately, the system needs to have a good understanding of the user's capacities and preferences, his or her current tasks, and the location and characteristics of the surroundings of the user. Several user requirements can be described for effective adaptive interfaces, for example (Lindenberg, Nagata and Neerincx, 2003):

- Adaptation of dialogue: adapt the information presentation, dialogue structure, and modality to the current context of use, available cognitive resources, and emotional state of the user,

- Adaptation of content: adapt information selection based on long-term and momentary interests of the user and the current context of use,
- Pro-active scheduler: provide suggested actions based on scheduling information and current context of use,
- Continuity of interaction and content.

Goal of this paper is to study whether new adaptive concepts can be designed and tested using a simulated task environment. A cognitive engineering method that incorporates a simulated environment will be introduced in the next section. The simulation technology is described and the design of the experiments that are planned is presented.

COGNITIVE ENGINEERING METHOD

It is not feasible to test decision support technologies for first responders in real crisis situations. Training exercises can be used for testing but are expensive and generally it is hard to get domain experts. For development of innovative technologies and extensive experimentation, other approaches have to be found. A common solution is testing the concepts in exercises that are similar to crisis management. For example, the COORDINATOR tool has been evaluated in an office building where props (representing fire, obstacles, and civilians) were placed in various rooms (Wagner, Phelps, Guralnik, and VanRiper, 2004). Another alternative is simulation, which has the advantage that it is easy to create specific situations in which support can be helpful. For these reasons, we have built a simulation environment for the evaluation of our adaptive interface concepts. This simulation enables control over all factors that may make adaptive interfaces desirable and provides a challenging environment with characteristics similar to real crises.

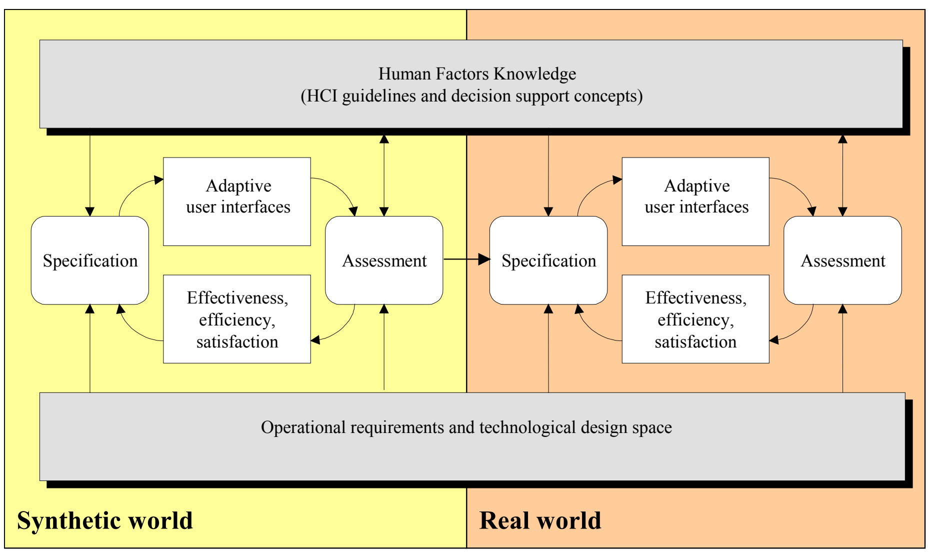

Figure 1. Cognitive engineering method (based on van Maanen, Lindenberg and Neerincx, 2005)

Figure 1 shows the cognitive engineering method that will be used in this study (based on van Maanen, Lindenberg, and Neerincx, 2005). Two phases can be distinguished in the development process: iterations in a synthetic environment, followed by development iterations in a real-world setting. The sometimes reciprocal requirements of operations and available technology on the one hand and human factors knowledge on the other hand are made explicit and are integrated in the specification and assessment process. During specification, both the human factors expertise and the operational requirements are addressed concurrently. In the assessment activity it is checked whether the specifications agree with the human factors guidelines and the operational requirements. The assessment will provide qualitative or quantitative results in terms of effectiveness, efficiency, and satisfaction, which are used to refine, adjust or extend the specification. Eventually, the process of iteration stops when the assessment shows that the adaptive user interface satisfies all requirements and is ready for evaluation in real-world settings. In a similar iterative loop the specifications are refined and evaluated in real-world settings. In some situations, it may be desirable to return to the synthetic environment for further research. When in the real-world assessment sub-optimal designs are found due to lack of fidelity of the simulation, this information must be used to make the simulation more realistic.

A GAME-BASED SIMULATION ENVIRONMENT

The interest in game engines as platforms for serious simulation has increased dramatically over the past few years. Game engines have made great advances in user interaction and visualization at low cost that have exceeded advances within the simulation community (Lewis and Jacobson, 2002). We have used the Unreal Tournament game engine (Epic Games Inc.), which makes it easy to build a multi-person simulation in 3D. This game engine has been used by others as well (McGrath and McGrath, 2005), because it is powerful, has a large support community and is inexpensive.

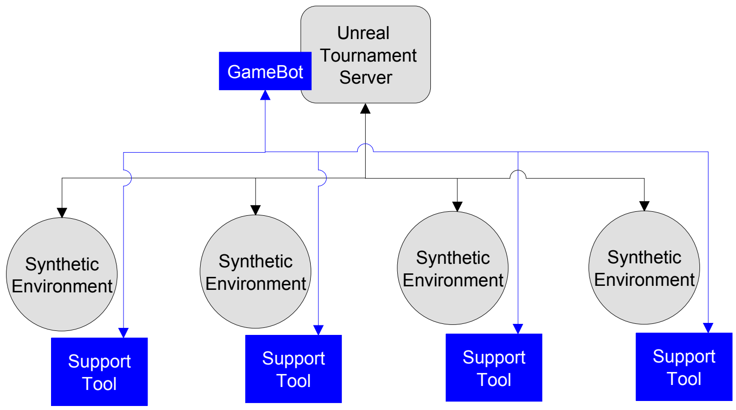

Figure 2. Architecture of the simulation environment

Figure 2 shows the architecture of the simulation platform. The central point is an Unreal Tournament game server, to which up to 32 players can connect. This figure shows four players, each having a synthetic display showing the '3D-world' provided by an Unreal game client, and a support tool that was built in Visual Studio .NET 2003. This support tool provides a GIS-application showing the location of all players, for which reason it is connected to the Unreal game server using GameBots (Kaminka, Velose, Schaffer, Sollito, Adobbati, Marshall, Scholer and Tejada, 2002). GameBots is a publicly available modification to the Unreal Tournament environment that allows artificial characters to be controlled via external programs. GameBots also provides detailed information about all other persons in the synthetic environment. The game engine does all the rendering and shows 'the world' to the users. An environment that represents the scene of the crisis was created using the Unreal Tournament editor. In this environment people must be rescued and a good understanding of the damage to the areas must be developed. Figure 3 shows an impression of the interface for the user. This setup provides the starting point for adding intelligent mobile task support for emergency personnel.

Support can be offered on a PDA, but it is also possible to present the information on a separate computer screen. On this screen, various PDAs with different screen sizes and capabilities can be simulated. Hence, more flexibility and control is available for experimentation, and focus is on the support concepts that are under examination rather than on usability of the selected PDA. In this project we are not interested in mapping a user interface to a range of different devices.

Not only first responders are part of the team, also the incident commander (IC) can be one of the participants. The IC is present just outside the disaster area and probably does not have a 3D-world perspective (although it can be desirable to mount the first responders with virtual camera's and provide these images to the IC), but may have a laptop or a PC with a large screen, more advanced support, communication tools and higher bandwidth.

The simulation environment is an excellent platform for human-in-the-loop experimentation, and provides ample opportunities for extensions. To increase the complexity and realism of the world, it is possible to model civilians or other rescue workers using intelligent cognitive autonomous agents.

Figure 3. The synthetic 3D-world presenting an urban task environment to the first responders. Novel adaptive interface concepts can be implemented on a PDA to support the first responders .

DESIGN OF THE EXPERIMENTS

Because trained and experienced first responders are not generally available, we will use naive subjects for experiments in the simulated environment. Therefore, the tasks in the simulation will focus on generic collaboration and communication tasks that are similar to crisis management, such that no deep domain knowledge is required.

The first responders have to rescue victims and develop an understanding of the situation. The game does not restrict them, nor suggests correct actions according to emergency plans, as might be desired in training exercises where the participants learn how they must act in specific situations. They are free to walk around, communicate, and collaborate as they see fit. However, it is possible that the subjects want to have information that they consider to be relevant for their task or desire to take actions that were not foreseen by the designers of the system. We do not expect this to happen often, but if it happens the simulation should be extended or improved.

A pilot study to check the platform for clarity, stability, effectiveness, ease of navigation, learning effects, et cetera, is planned for early 2006. In the next months, focus will be on developing adaptive interface concepts. In the first experiment, we will examine the costs and benefits of adaptivity to organizational changes. When first responders arrive at the scene, no central command is present. Therefore, the team members have to coordinate their actions themselves. Command can be taken in turn (depending on workload or safety of the location) or a team member can be made responsible for coordination. The user interface for the commander will provide information about all team members, enabling him or her to allocate tasks to the others. The group may also increase in size, requiring redistribution of tasks and transfer of information. Later, when an emergency operations center is installed, actions will be coordinated by the incident commander. This shift from distributed decision making to a more centralized form also means a change in organization and tasks, and can be reflected in the user interface. Adaptivity to location and tasks will be examined in later experiments, as well as user preferences to adaptivity.

Metrics that are used to determine the efficacy and efficiency of the proposed concepts will be both objective, such as the time used, distance traveled, number of victims rescued, and subjective, based on a SAGAT questionnaire (Endsley and Garland, 2000) that can be taken both during the test and afterwards. During the exercise all movements, actions, and communication will be logged for analysis.

DISCUSSION AND CONCLUSIONS

Training is the most common application of 3D-simulation, but we think that a synthetic 3D-world can also provide a good environment to develop and scrutinize new user interface concepts. The game-engine of Unreal Tournament is suited for building the simulation, and has proven to be easy to use in scientific experiments. Using the Unreal editor, an urban environment has been built in which different team members can work together on a set of tasks. In 2006, a series of experiments are planned, focussing on adaptive interfaces and team coordination. These experiments will show for which interface design questions simulated environments are suitable, and whether there are limits to the questions that can be answered this way. One question that can be raised is whether a human referee is required that deals with situations that were unforeseen by the designers of the simulation. We expect that the environment is suited for both individual trials with users to elicit comments and suggestions early in the development, as well as controlled experiments to measure efficacy and efficiency of user interfaces. An interesting question is whether higher fidelity of the urban environment implies better results. This issues is important because it is strongly related to the development costs.

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