Foundations for Creating a Distributed Adaptive User Interface

Don Kemper, Larry Davis, Cali Fidopiastis, and Denise Nicholson

Institute for Simulation and Training
3100 Technology Drive
Orlando, FL 32826
USA
407.882.1300
`{dkemper, ldavis, cfidopia, dnichols}@ist.ucf.edu`

Abstract. Distributed simulation allows multiple users to develop and improve interactions without having to be collocated. To enhance such interaction, we present the foundation for a distributed, multi-modal, adaptive user interface. First, the interface concept is placed within the context of a closed-loop human system. Next, the present prototype implementation is described. Then, the concept of modifying interface elements based upon a combination of actual, physically simulated, and virtual devices is discussed. Finally, we discuss the possibility for self-adaptation, design challenges, and directions for future development.

Keywords: Multi-Modal Adaptive User Interface, Closed-Loop Human Systems.

1 Introduction

"*Between stimulus and response, man has the freedom to choose.*" [1]

The ability of an individual to choose her actions is a fundamental characteristic of humanity. In having the freedom to choose, humans also have the ability to adapt. Humans adapt to internal and external changes on a continual basis, often without conscious awareness.

Another important aspect of humanity is individuality. In identical circumstances, two people may respond differently when presented with the same stimuli. Also, there are known effects of individual personality traits and the emotional and cognitive state of a person on the ability to process information [12].

An ideal computer interface should account for the individuality and adaptability of the human in order to provide optimal human computer interaction. An information system that deals with each user uniquely or treats users displaying certain traits as part of the same group can be considered an adaptive system [3]. A self-adaptive interface is defined as a human-computer interface that changes automatically in response to its experience with users [2].

D.D. Schmorrow, L.M. Reeves (Eds.): Augmented Cognition, HCII 2007, LNAI 4565, pp. 251–257, 2007.

Within the context of training, adaptive system designs can accelerate the development of expertise. However, good design remains a challenge; user intent must be translated to the computer in one form or another. A previous survey of adaptive human-computer interfaces [8] states that a major factor of HCI inadequacy is that “the design of effective interfaces is a difficult problem with sparse theoretical foundations.” Since the publishing of that research, there have been several theoretical frameworks proposed for static user interface [7] [10] as well as for adaptive user interface [4].

Distributed, multi-user simulation offers a unique opportunity for exploring adaptive user interfaces. In some instances, users participate within the simulation using a heterogeneous mix of simulators. The different simulators require interfaces that must communicate information to one another while providing an optimal experience for the user. In addition, the simulators may possess different interface devices to enable application-specific functionality. For example, a 3D simulator may have a head-mounted display (HMD) interface. The possibility of heterogeneous simulators and/or a range of interface hardware require(s) the application of an adaptive user interface.

The ultimate goal of a distributed simulation is to enable multiple users to share an environment without the requirement of being physically co-located. In this manner, the simulation connects the participants in a form of human-to-human contact. By designing the interface to apply multiple modalities (e.g. sound, motion, touch), the interaction among participants can be closer to that of normal contact and the interaction can be more robust [9]. An adaptive, multi-modal user interface could be used to increase the sense of realism within a simulation. A self-adaptive interface could be used to enhance the situational awareness of the user or mitigate the occurrence of stimuli within the environment so as to not overwhelm or under-task the user.

In remainder of this paper, we present the foundations for the creation of a distributed, adaptive, multi-modal user interface in the context of training within a distributed simulation. We then describe a prototype adaptive interface where the interface elements are modified based upon the combination of actual, simulated, and virtual devices used. The interface adaptation is currently user-driven and will be expanded to include self-adaptive interface elements that mitigate workload requirements within the application environment. Finally, we discuss modifications, improvements, and challenges related to the interface design and implementation.

2 Adaptive User Interfaces

The need for adaptive user interfaces is driven in part by the trend of work environments requiring users to do more with less [6]. In addition, as system complexity increases, system based mitigation efforts on behalf of users can become paramount, the alternative being task overload and possibly task failure. One approach to handling this is via an Augmented Cognition Closed Loop Human System (CLHS), presented by [6]. It is an iterative process which cycles through generating environment and content, presenting stimuli to the user, monitoring the effects and adapting the system according to assessments of the user’s state. Interface adaptations may range from simple visual or auditory cues to a combination of multimodal approaches [11].

2.1 The Cycle of Adaptation

One method of dealing with the cycles of adaptation is presented in the CLHS diagram shown in Figure 1. Initially, application content and environment components are generated and supplied to the UI Adaptation Layer where decisions are made regarding the presentation to the user. This involves selecting visual output and user input options based on system hardware and the presence of supported input devices. The output of the UI Adaptation Layer determines the presentation to the user, which serves as input stimuli to the user. Concurrently, the Operational Neuroscience Sensing Suite (ONSS) actively monitors the user's state and generates user state information parameters which are fed back to the UI Adaptation Layer. The UI Adaptation Layer User State Mitigation component can take actions as needed, which in turn affect the content and environment on the next cycle. The centralized location of the User Interface Adaptation Layer within the cycle is essential to the adaptation process as it dictates output and processes input feedback per iteration.

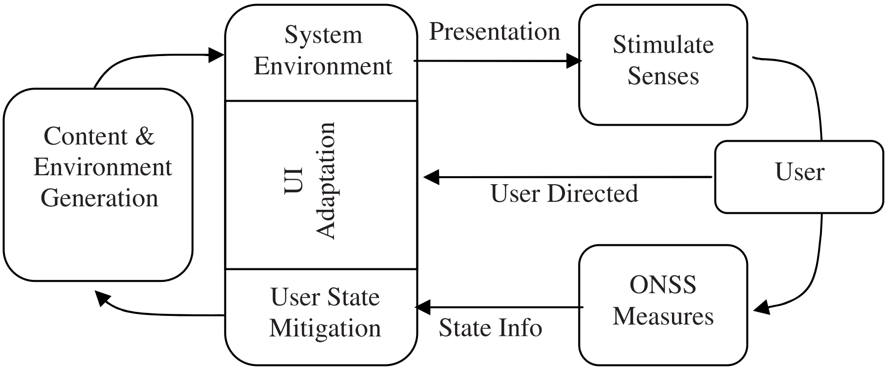

Fig. 1. Closed Loop Human System w/ UI Adaptation Layer

2.2 Our Implementation

The overarching design guidelines for the adaptive interface were to increase the sense of immersion while maintaining compatibility with the original simulation platform. The goal was to have one simulation that adapts to the hardware and the user in order to create the most immersive experience possible with the available components. The baseline simulation uses a typical 2D application style dashboard interface overlaid on a 3D virtual environment. The dashboard includes menu selections and virtual device components used within the system. The user navigates via keyboard and mouse interactions; movement in the virtual environment is accomplished via typical mouse and keyboard actions and the dashboard is point and click to select actions.

Interface Enhancements. We have created enhancements to the interface to increase the fidelity of the simulation to the user. The modifications include support for various visual display configurations, user input and manipulation devices as well as planned support for simulated physical devices. The primary display configurations include single monitor/projector, multi-monitor/multi-projector and head mounted displays. The input options currently include the standard mouse and keyboard, wireless mouse and pointing devices, head tracker, a Nintendo® Wii™ Remote and application specific physically simulated devices such as binoculars, GPS, and compass.

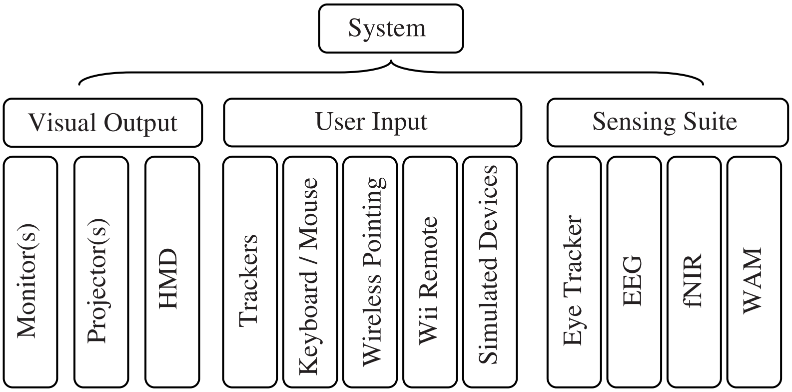

Fig. 2. System Configuration Options Overview

The primary benefit of the baseline implementation is its familiarity to users. However, with the addition of immersive environment extensions, this approach can be completely unacceptable as it significantly diminishes the benefits of the enhancements. The display of a 2D dashboard, for instance, in a multi-projector or HMD display system would diminish the sense of immersion in addition to creating a potentially awkward method of interaction. Therefore, the dashboard was replaced with an on-demand menu system and separate virtual device components. This provides a default view consisting only of the virtual environment, maximizing the immersion for the given hardware configuration.

System Environment UI Adaptation. The system environment adaptation component of the UI Adaptation Layer configures the output display and the user input devices. The process is generally automatic for standard devices such as keyboard, mouse and single displays. The physical hardware configuration for multiple displays, projectors and specialized input devices is separate from this process, with only the knowledge of their presence being of any importance to this component.

This component primarily manages the availability and location of the UI components within the environment. The UI display is adjusted in a manner that is consistent across all supported configurations based on the hardware present. For example, the on-demand menu system is always presented in same relative position with respect to the user's field of view. Additionally, alternative input devices such as the Nintendo Wii Remote perform in similar fashion as those in the baseline system for basic tasks like point and select. However, they add to the experience through the introduction of more natural navigation by virtue of their position and movement sensing capabilities. Finally, three degree-of-freedom (3DOF) tracking devices are used to provide head orientation input for the visual display.

The planned introduction of application-specific physically simulated devices (PSDs) will also be handled within this component. Each PSD will have a virtual analogue in the application and only one should be visible to the user at a time to avoid confusion. For example, the application supports a compass PSD and a virtual analog within the environment. The user will have access to the virtual compass as long as the PSD compass is not detected. The adaptation is dynamic; therefore, if a PSD compass is removed or fails, the system will detect this and make the virtual compass available. There is also conflict resolution built in to handle cases that cannot physically exist or otherwise work. If the display device being used is an immersive HMD, for example, then the user cannot be expected to interact with the PSDs in the normal fashion. Therefore, the virtual analogues will be available.

User State Mitigation UI Adaptation. This component will implement mitigation strategies as intervention techniques in the form of adaptive interactions and performance support techniques to improve human performance [6]. These will include multi-modal adaptations and attention management schemes designed to keep the user from being over or under tasked.

This assessment is made largely based on data provided by the Operational Neuroscience Sensing Suite (ONSS). This suite includes an eye tracker, EEG, functional Near Infrared (fNIR) and Wireless Arousal Meter (WAM). Each component will provide specific user state data that will be integrated by the User State Mitigation component of the UI Adaptation Layer to produce corrective action strategies based on task state knowledge in the system.

The initial mitigation strategies will include selective de-cluttering and UI support mechanisms to manage the user's task level. As ONSS data is fed into the system a decision will be made regarding whether any action is warranted. In the case of a user becoming overloaded, perhaps detected through excessive eye movement and/or increased arousal per the WAM, the system may employ a UI support strategy of highlighting environmental components relevant to the task state. During successive iterations it may be determined that the initial strategy is insufficient and that additional measures are required such as de-cluttering. Once strategies are added into the cycle, they are removed in a step-down manner based on ONSS parameters suggesting reduced workload etc. as well as when the user accomplishes tasks at hand.

3 Discussion

The prototype interface currently allows users to customize the simulator experience through a selection of different input devices and graphical controls. We now expand the discussion to include modifications, improvements, and challenges related to the interface design and implementation. Self-adaptation and current design challenges to direct future development are discussed in the following sections.

3.1 Self-adaptive Interface Elements

The interface adaptation is currently user-driven and will be expanded to include self-adaptive interface elements. These changes will allow the interface to mitigate difficulties the user may have within the application environment or provide additional stimulus if needed. Devices from the ONSS will indicate the need to provide mitigation to the interface. In this way, the interface can be tailored to meet the information processing needs of an individual within the simulation.

The concept of using neurophysiological devices to trigger mitigation is not new. Research in the area of augmented cognition encompasses a wide variety of strategies for applying mitigation based upon user state. Moreover, it is important to note that human-adaptive information research predates augmented cognition. In [5], the authors compare and contrast efforts from associate systems to that of augmented cognition systems. Although the present interface is not involved with the live control of vehicles, the lessons learned expressed in [5] (particularly, keeping the user "in charge" and the importance of co-development and progressive testing) will be leveraged within development of the adaptive interface.

3.2 Design Challenges

The interface design is intended to conform to the requirements given in [9]. In this effort, we attempt to maximize cognitive and physical ability by allowing users multiple modalities to receive information from the simulation. For example, in the case of using binoculars within a simulation, the PSD gives the advantage of physical familiarity. Both the physical and virtual modalities are integrated within the context of simulation and normal usage of the device. Usability consistency across the interface is maintained and the interface is adaptive by design.

The challenges in conforming to the requirements center on feedback and visual consistency in 3D. We are presently researching acceptable, intra-interface feedback methods to mitigate incorrect usage of PSDs. Another challenge is maintaining interface consistency in the case of a 3D simulator. For correct visual stimulus, visual interface elements must be presented at the correct depth with proper cues. Moreover, the perspective of the 3D elements must be correct with regard to the display device

Another design challenge is informing the distributed simulation of interface changes. Any devices used, mitigations, or error conditions must be provided to the distributed network to notify participants of changes in potential interactions. Through the use of the High-Level Architecture (HLA), some of the communication difficulties can be eliminated while others are created. We are presently researching a network communication paradigm using HLA to convey the interface state across the simulation.

Acknowledgements. The authors thank the members of the Applied Cognition and Training in Immersive Virtual Environments (ACTIVE) Laboratory who contributed to the writing and research presented. The results presented were funded by the Office of Naval Research as part of the Virtual Technologies and Environments (VIRTE) program and through a Presidential Equipment Grant from the University of Central Florida. The authors regret the inability to publish pictures of the interface due to export control restrictions.

References

1. Covey, S.R.: Principles of Personal Vision. In: The Seven Habits of Highly Effective People. Simon & Schuster, pp. 66–94, New York, (1990)
2. Edmonds, E.A.: Adaptive Man-Computer Interfaces. In: Coombs, M.J., Alty, J.L. (eds.) Computing Skills and the User Interface, Academic Press, Orlando (1981)
3. Feeney, W., Hood, J.: Adaptive Man/Computer interfaces: information systems which take account of user style. J SIGCPR Comput. Pers. 6, 4–10 (1977)
4. Schneider-Hufschmidt, M., Malinowski, U., Kuhme, T. (eds.): Adaptive User Interfaces: Principles and Practices. Elsiever, New York (1993)
5. Miller, C.A., Dorneich, M.C.: From Associate Systems to Augmented Cognition: 25 Years of User Adaptation in High Criticality Systems. In: Proc Aug Cog, vol. 2, pp. 344–353 (2006)
6. Nicholson, D., Stanney, K., Fiore, S., Davis, L., Fidopiastis, C., Finkelstein, N., Arnold.: An Adaptive System for Improving and Augmenting Human Performance. In: Proc Aug Cog, vol. 2 (2006)
7. Nielsen, J.: Heuristic Evaluation. In: Nielsen, J., Mack, R.L. (eds.) Usability Inspection Methods, John Wiley & Sons, New York (1994)
8. Norico, A.F., Stanley, J.: Adaptive Human-Computer Interfaces: A Literature Survey and Perspective. IEEE Trans. Sys. Man, Cyb. 19, 399–408 (1989)
9. Reeves, L.M., Lai, J., Larson, J.A., Oviatt, S., Balaji, T.S., Buisine, S., Collings, P., Cohen, P., Kraal, B., Martin, J., McTear, M., Raman, T.V., Stanney, K.M., Su, H., Wang, Q.Y.: Guidelines for Multimodal User Interface Design. Commun ACM 47, 57–59 (2004)
10. Shneiderman, B.: Designing the User Interface: Strategies for Effective Human-Computer Interaction, 3rd edn. Addison-Wesley, London (1998)
11. Stanney, K., Samman, S., Reeves, L., Hale, K., Buff, W., Bowers, C., Goldiez, B., Nicholson, D., Lackey, S.: A Paradigm Shift in Interactive Computing: Deriving Multimodal Design Principles from Behavioral and Neurological Foundations. Int J Hum Comp. Inter. 17, 229–257 (2004)
12. Szlama, J.L., Hancock, P.A.: Individual Differences in Information Processing.: In: McBride, D., Schmorrow, D. (eds.) Quantifying Human Information Processing. Lexington Books, pp. 177–193, Oxford, UK (2005)