Merging of Next Generation VR and Ambient Intelligence – From Retrospective to Prospective User Interfaces

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Abstract. In this paper we present current and future approaches to merge intelligent interfaces with immersive Virtual Environments (VEs). The aim of this paper is to substantiate the introductory presentation in the session "Facing Virtual Environments with innovative interaction techniques" at HCI 2007. Although VEs and multimodal interfaces tried to make Human-Computer-Interaction as natural as possible, they have shown serious usability problems. We describe concepts to aid users in supporting their personal cognitive and perceptual capabilities, where the Virtual Environment will adapt dynamically and in real-time to the users' physiological constitution, previous behaviour and desires. With our concept, human performance can be significantly enhanced by adapting interfaces and environments to the users' mental condition and their information management capacity. Health and usability problems caused by stress, workload and fatigue will be avoided. We intend to encourage discussions on this topic among the experts, which are gathered this session.

Keywords: Virtual Reality, Sensors, Ambient Intelligence, Adaptive interfaces.

1 Introduction

1.1 Adaptive Interfaces

One of the main aims of Virtual Reality is to make interaction with computers less difficult. New interaction approaches and techniques are continually being produced and modified - with important consequences on the interaction with computers. Taking also into consideration the recent efforts to provide computer-based interactive applications that are accessible by a broad end user population, including people with disabilities, one can conclude that the design of the User Interface

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requires the revision of currently prevailing HCI assumptions, such as designing for the “average” user in a desktop environment. These assumptions need to be replaced incrementally by the more challenging objective of designing for the diversity in the end user population, the access media and devices, the contexts of use, etc. Depending on their characteristics, systems that adapt to users are contemplated as adaptive interfaces, user modelling systems, software agents or intelligent agents. The term “user-adaptive” system is often used for describing the entire family of the aforementioned systems.

Another approach to cater for diversity in the end user population is based on providing users with the opportunity to explicitly specify desired properties of the user interface. Systems offering such functionality are known as user-adaptable systems. The main advantage of such systems is that they allow the user to decide how the system will be displayed. One frequent objection to such an approach is that, in many cases, it is not possible for the user to know the best configuration settings for his/her requirements. Thus, the adaptability of such a system is under-utilised, since it is a time-consuming and complicated task. The main difference between the user-adaptive and the user-adaptable systems can be summarised in that user-adaptive systems adapt their behaviour to individual users on the basis of processes of user model acquisition and application, that involve some form of automated learning, inference, or decision making; while user-adaptable systems allow the individual user to explicitly tailor the user interface, by choosing options that determine, for example, the appearance of the system.

The emerging field of “Augmented Cognition” aims at revolutionizing the way humans interact with computer-based systems by coupling traditional electromechanical interaction devices (e.g., mouse, joystick) with psychophysiological methods (e.g., respiration, heart rate, EEG, functional optical imaging), where human physiological indicators can be used in real time to drive system adaptation. [1]

1.2 Multimodal Interfaces

Multimodal interfaces include more than the traditional keyboard and mouse. Natural input modes are used such as voice, gestures, haptic interaction and facial expressions. As described in [2], multimodal interfaces should follow several guiding principles, e.g. to be predictable and not unnecessarily complex and they should provide for modality switching. Multimodal interfaces should adapt to user’s needs, abilities and the environment. Our approach will base its developments on the generation of new user-adaptive interfaces, fusing information from various modalities by measuring continuously both, the physiological and the behavioural status of the user.

1.3 Physiological Sensing

Using real-time neurophysiologic techniques within a virtual environment in the form of a closed-loop-system is relatively new. The general feasibility has already been demonstrated within the EU co-funded project VIEW of the Future (IST-2000-26089). A possible undesired health impact of these combined technologies was investigated thoroughly in the course of the EU co-funded project AGILE (QLK6-CT-2002-00118; target group: Elderly people). In the EU co-funded project RESPECT (QLRT-2000-00038) the question whether users might suffer health-related symptoms caused by the assessment tools themselves (the physiological measurement equipment) was addressed. It has been shown that the modular test-battery developed by COAT-Basel, which measures various physiological parameters, is a valid and valuable new test instrument of satisfactory acceptance by the targeted test population.

2 The Problem

Several existing interface technologies offer users various modes of interaction within a VE (speech, gestures, spatial motion, etc.). They are supported by traditional interaction devices like joysticks or tracking devices. Users are able to listen to spoken prompts and audio, to view information on high end graphical displays and to get tactile and haptic feedback from their interaction devices. They can talk, move and use force input to interact with the virtual world. Nevertheless, many 3-D input devices (e.g. data gloves) have shown usability problems [3]. The rapid decrease of prices for hardware, such as PCs and digital video projectors, leaded to an increasing spread of VEs to industries, SME's, hospitals, universities and soon to private homes.

There was a public demonstration of an immersive VR-System at the International Conference of Human Computer Interaction, 2003, in Crete, where visitors (delegates of the Human Factors and Ergonomics community) gave expert feedback on the design, usability and utility of the system exhibited. Many participants found the technology still difficult to use and had various problems to interact with the environment. There were many responses of how the technology should be improved, including the comment to "link technology with brain/mind/hand research." [4]

Interaction within VEs has many user specific parameters that affect the usability of the VE. The parameters are defined using calibration processes for devices and by explicit settings, using user preferences. In the last case it is hard for inexperienced users to identify and set their preferences within a VE [5]. However, it might be possible for the system to identify the user preferences by observing the psycho-physical and behavioural condition of the users, while practicing in the VE. In addition, although immersive virtual environments and multimodal interfaces try to make Human-Computer-Interaction as natural and effective as possible, it still lags far behind the much more natural and efficient human interpersonal communication and interaction. One major reason for this is that humans are able to adapt to each other, in order to maximise efficiency of communication and interaction, whereas artificial worlds and interfaces expect the "ideal" user. Another major problem when designing and developing new interaction techniques for 3-D environments is the lack of specific best practice guidelines [6]. Furthermore, accurate interaction with complex virtual environments has been shown to fail when a stressful situation is encountered. Efficient interaction can not be guaranteed if workload and fatigue is too high. Simulator sickness, information overload, dizziness and severe health problems have already been investigated in several research activities.

3 The Challenge

We aim, by measuring the mental and physical condition of the user and his/her behaviour, to adapt and personalise the multimodal virtual environment in real-time, to avoid health problems caused by anxiety, stress, workload and fatigue, as well as to enhance the user's satisfaction and comprehension of the VE. In this way, human performance while interacting with virtual multimodal environments could be tremendously enhanced, within an Ambient Intelligence Environment, where the interface and VE adapt to the users mental and physical condition, level of expertise, individual preferences, needs and wants.

New multimodal and adaptive interfaces and virtual environments could improve the usability of VEs by providing natural, intuitive and efficient interfaces for all kinds of users. They could increase the sense of realism, enrich the experience and the sense of presence, protect the users' health and manage his/her stress and fatigue levels in the VE. Interfaces and environments developed would adapt to the user, based on psycho-physiological, behavioural and personal preferences and related parameters, which would be derived from a multimodal measurement system. The multimodal measurement system would monitor the user regarding his/her physiological state (measuring autonomic body functions and EEG) and psychological state (monitoring behaviour, mimics and gestures), taking also into account explicit user profile parameters and preferences. The challenge is also to adapt multimodal interfaces (i.e. change from visual feedback to acoustic feedback or vice versa), according to the user's mental condition and his/her information management capacity; to identify mental workload and fatigue to prevent usability and health problems; to increase the sense of realism and to enrich the experience and the sense of presence of a user in a Virtual Environment and to improve the usability of VEs by providing natural, intuitive and efficient interfaces.

4 Potential Applications

4.1 Product Design and Engineering

Immersive Product Design and Engineering applications are complex human-machine interactive environments that have been shown to fail, due to stressful situations, to information overload and cyber sickness. Validation of geometry is the most common use of immersive virtual reality. Inspection of integrity, interferences between parts, accuracy and functionality are complex tasks to be performed by the operator. Depending on the user's individual workload, visual, audio or haptic feedback could be given to the user, in order to operate in the environment most efficiently. Additionally, the system could identify which senses of the user suffer from an information overload and provide alternative modalities to transfer the information more ergonomically to the user. Self adapting applications and interfaces will empower the user's ability to successfully accomplish the task. Cyber sickness can be detected before the user will get seriously sick.

4.2 Health and Medicine

Surveys estimate that fear of flying exists in 10-20% of the population. To treat the fear of flying, heights, tight spaces, etc. VR exposure therapy is a safe and successful procedure. Its popularity is justified by its lower costs than in vivo exposure, its ability to have total control of the environment, the repeatability of any phobic stimuli and its safety. In controlled stages patients can be exposed to virtual environments using stereoscopic displays as HMDs, where the virtual environment elicits progressively higher levels of anxiety. Each stage can be repeated until the patients anxiety has lessened and they feel ready to move to a higher level.

Adaptive VEs could refine and sustain medical treatments of anxieties. An individualized level of anxiety can be generated by the VR-system, based on the patients' level of fear, which can be derived from the objective physiological measurement system. A real-time evaluation kit can be used to monitor the physiology of the patient. He/she will be monitored during all phases of therapy, to ensure that the client is not becoming too anxious. At the same time, the environment should not be too boring for the patient. If the patients' anxiety becomes overwhelming, he/she will always be able to return to a less stressful level or exit the environment completely. The closed loop computational system, in which the computer adapts to the state of the patient would significantly improve the success of the treatment.

4.3 Training and Education

After unpredictable events, like earthquakes, terrorist attacks, etc, procedural knowledge is often unusable for a first aid. In these particular circumstances, strategic knowledge is the key for taking quick and effective decisions. Several organisational psychologists have shown how the human capability to deal and to utilise strategic knowledge is directly connected to the personal capability of the subject to cope with anxious situations. A pragmatic case for these considerations is represented by people operating in the civil protection organisations. Their skills are put in action mainly in unstructured situations, where procedures wouldn't help much to face such complex and multi-differentiated circumstances. A system able to perform adaptations, based on psychophysiological feedback parameters coming from the user, can be of big advantage in a variety of applications for the civil protection operators. Psychophysiological feedback parameters coming from the students during the training sessions using the VR will be utilised for adapting the VR training scenarios, strategies and system parameters accordingly. The approach of utilizing the students' emotional relevance, provided by the multimodal measurement system developed in the project, will be beneficial for the training of unpredictable and risky events, because it will be able to adapt the involvement level of the training scenario, in order not to be too scary for the trainees and monitor the trainees awareness level, in order to provide them real-time feedback during critical situations (self-consciousness during the performance of safety related tasks).

5 Future Work

We intend to develop/enhance and integrate micro- and nanosensors into Virtual Environments which are capable of sensing user-related input (i.e. physiology) and behavioural input/data from the user, as well as from the VE system. Development of knowledge-based (semi)-automated systems, capable of processing behavioural data in real time and actuating the integrated VE proactively (user pattern recognition leading to predictive behaviour estimations by the system) will therefore be needed. Furthermore a feasible user and decision model and a sensor fusion model (to extract higher level user state and behaviour) will be developed. Reasonable adaptation mechanisms to support user needs in complex VE's need to be provided.

6 Conclusion

We presented state of the art approaches to integrate multimodal interfaces, adaptive interfaces and immersive Virtual Environments. We discussed current barriers and problems with interaction in virtual environments. The challenge to be tackled and promising applications which could benefit from this approach are described in detail. We provide concepts to aid users in supporting their personal cognitive and perceptual capabilities, where the Virtual Environment will adapt dynamically and in real-time to the users' physiological constitution, previous behaviour and desires. The intention of this paper is to substantiate our introductory talk and to encourage further discussions on this topic.

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