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A Study on User-Centered Approach to Design an Augmented Reality Maintenance Support System in Nuclear Power Plant

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1. Introduction

In nuclear power plants (NPPs), as the plants become more reliable and complex, their inspection, maintenance and repair become increasingly challenging problems, and this requires many well-experienced and well trained maintenance crew. On the other hands, reduction of lifecycle costs of the plants is strongly required, and many crews are required to take charge of various kinds of devices, including their unfamiliar ones. Their task must be done under the strong time pressure of rigid maintenance schedule. This may cause human errors even by even the well-experienced crews.

Maintenance processes are both very important to guarantee quality for safety and often quite cumbersome. In the case of nuclear power plants, such processes usually demand access to documentation such as technical manuals, either in traditional paper form or electronic form. This is especially important where & when the procedures are performed infrequently [6]. These considerations lead to considering Augmented Reality (AR) systems as an alternative to paper-based systems.

2. Maintenance in nuclear power plants

The maintenance of nuclear power plants is expensive. The complexity of nuclear power plants results into a voluminous design and procedural documentation. Economic factors force operators to minimize down time, putting pressure on time required for maintenance. Safe regulations require operators to perform periodic maintenance for critical subsystems as well as account for the outcome of these activities. To address these issues, maintenance is dictated by a rigid collection of procedures that describe every step the technician need to perform. The detail level of each procedure minimizes the probability of errors. Nuclear power plant maintenance is typically supported by a paper-based system. A technician assigned to a procedure receives a paper checklist describing the steps to perform. As the technician executes a step and observes the result, he marks the check list accordingly. The technician must go back and forth between his work and the checklist, thus interrupting the workflow. The available to the technician is restricted to the checklists and manuals that he brought with him [8].

3. Augmented Reality

3.1. General

Augmented Reality is a novel approach to the interaction between humans and machines, in which information is displayed in the field of vision of the human operator [1]. This technology used to implement assistance to the user, which consists in giving users all information, called augmentations, necessary to carry out safely and efficiently complex maintenance procedures. This information is provided directly in the working environment by the use of optical see-through Head Mounded Display (HMD). Augmented Reality can guide users step by step through difficult maintenance procedures, thereby increasing the reliability and the safety of the operations [6].

3.2. Effectiveness and efficiency

There has been some speculation on the potential of Augmented Reality to assist technician' work, i.e. facilitating technicians' informational access during diagnosis and repair, reducing the error likelihood by introducing "virtual reminder", enhancing motivation, reducing the volume of paper-based technical documentation and introducing the possibility of on-the-job-training [2]. The appropriate information has to be selected automatically out of the existing information system (normally text and graphics with reference to 3D models). The user interaction has to be supported in an easy-to-use way. New multimedia content (especially video and 3D models) has to be created and edited. The multimedia information has to be brought into a spatial relationship with the object (e.g. equipment) [5].

Augmented Reality applications are mainly effective at supporting skill- and rule-based behavior. Less attention is paid to supporting knowledge-based behavior and problem solving in a complex and dynamic context.

Also, the use of Augmented Reality generated using a wearable can be highly beneficial for the particular maintenance task. A study [3] indicated assembly performance benefits by using Augmented Reality in terms of task completion times and decrease of errors. They postulated that displaying the assembly instructions in the subject's work field-of-view may

reduce the amounted of information the operator needed to store in working memory and may also reduce the time needed to store maintenance instructions in working memory. Due to the decrease assembly requirements associated with projecting the assembly instructions directly in the subject's work field-of-view and with the general ease of performing the task when the instructions were readily available, the number of errors for the Augmented Reality condition can be reduced [3].

In the cognitive point of view, a study [4] indicated that there was a less cognitive activity with the Augmented Reality system in comparison with the paper instructions. The cognitive load is reduced with the Augmented Reality system providing pertinent information regarding the co-ordination of the activity. In that case, however, the paper instructions were faster than the augmented reality condition due the problems associated with the system. The problems with the augmented reality system are indicative of the technology. The accuracy of the software and hardware are improving and this will provide speed for Augmented Reality application [4].

3.3. Issues in AR system design

Current Augmented Reality research focuses on exploring basic principles of Augmented Reality technology and to overcome technology problems, like optimizing tracking algorithms, computer graphics and visualizing issues, or the problems of transferring Augmented Reality to new devices or platforms. There is little research on developing user-centered guidelines or presenting results from formal user-centered studies. Therefore there is a need for more user-centered and usability research in the field of Augmented Reality.

Traditional HCI methods, such as domain analysis, user needs, task analysis, as well as use case development, can be successfully applied in Augmented Reality to determine what information should be presented to users. What these approaches do not appear, to date has not been researched, is how information should be presented to user [7]. It is necessary for user-centered approaches to design a usable and useful Augmented Reality system.

3.4. A concept of AR system in NPP Maintenance

Maintenance personnel are equipped with a wearable computer with a head-mounted display (HMD). The HMD is used for displaying rich information items for maintenance tasks and the wearable computer has a second display. A camera is attached to the technician's head and captures what the technician see. The wearable computers (mobile clients) are connected to central servers via a wireless network. The server stores al the information necessary for the maintenance of the power plants, while the mobile clients retrieve individual information on demand. The maintenance procedures or manuals are then executed on the mobile client. An Augmented Reality component tracks the user's position and displays the augmentations in the HMD as a function of the current maintenance manual step and of the user preference [8].

4. Conclusion and Future work

Augmented Reality applications can provide potential benefits with respect to cognitive and performance in nuclear power plant maintenance. Several researches indicated that the Augmented Reality applications are effective at supporting particular tasks and reduced cognitive load with providing pertinent information.

We have directed our attention to application of Augmented Reality in nuclear power plant. Our research will focus on the usability and evaluation of effectiveness of an Augmented Reality to develop a maintenance support system in nuclear power plants.

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