Design of Mobile Device Display for Nuclear Power Plant Maintenance Considering the Level of Expertise

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1. Introduction

Maintaining and repairing complex technical facilities such as nuclear power plants requires comprehensive knowledge on a broad range of the system, as well as on operational and safety procedures by the performing maintenance personnel. There exists the need to have access to instruction sheets and parameter tables at the worksite. This may not be practicable with printed manuals simply due to their increasing bulk. To cope with this situation, fully mobile wirelessly connected (FMWC) information and communication technologies (ICT) are thought to have high potential for improving field maintenance through increased accessibility and availability of critical information needed in on-site reference or decision making [1]. Among many up-to-date technologies, the mobile application to the maintenance support system will be proposed in this paper.

2. Designing Maintenance Support System Using Mobile Technology

The main purpose of maintenance support systems is to prevent human error and reduce the time required to complete maintenance tasks. It is considered more efficient to allow people to access information while they are doing a task rather than to try to teach them a large amount of knowledge. Maintenance support is the process of providing a set of information and learning activities in a context-specific fashion during the maintenance tasks [2], and maintenance concept which benefits from the emerging information and communication technologies (ICT) to implement cooperative and distributed multi-user environment is introduced [3].

2.1 Mobile Devices in Maintenance

Displaying manuals as interactive content on a computer mainly offers greater versatility than paper. Graphical features such as 2-dimensional or even 3-dimensional representations, keyword searches for specific contents or past maintenance history, and context-based filters will be available.

With the ongoing pervasion of mobile devices like PDAs or PMPs, interactive digital manuals can be run on readily available, commonplace hardware. Nowadays, the technology enabled mobile devices to display colorful graphical features, provide sound or video clips, and even perform complex computation. If the maintenance information is distributed from a central repository and the network is accessible with LAN or wireless LAN, it also mitigates the problems of keeping parts of the maintenance material up to date.

2.2 Information Display on Mobile Devices

Kristoffersen and Ljungberg pointed out four general characteristics of mobile interaction – task hierarchy, visual attention, hand manipulations, and mobility [4]. Task hierarchy asserts that while interacting with a mobile device, tasks external to operating the device are central, whereas the tasks taking place in the computer are supplementary. Visual attention of the user is largely directed to events occurring outside the computer, to avoid danger or to monitor the progress of the primary task. Regarding hand manipulations, the user's hands are commonly engaged with a variety of physical objects unrelated to the interaction with the mobile device during the interaction. Mobility means that some users may be required to remain highly mobile during the task.

On the other hand, the very important aspects that must be considered in designing the interface of mobile devices are their limited input and output functionalities. The information presented should be immediately useful in the context of the task and appropriately displayed. The navigation process should be well-organized so that interactive access to the required information is easy. Furthermore, due to limited size of the display restricts the amount of information.

These features may affect to task hierarchy, visual attention, and hand manipulation, and finally, human cognition during maintenance tasks. Various design method for information extraction and display is considered and proposed, and recently, a number of research groups have recognized that effective interface design should describe the fundamental mappings between the person, the interface, and the working domain, not on information-processing characteristics, graphical forms, events, trajectories, tasks, or procedures per se [5].

3. Selective Display Interface for Maintenance Novice/Expert

3.1 Cognitive differences between novice and expert

The differences between novices and experts are introduced and analyzed in many researches [6-9]. Research from Hmelo-Silver and Pfeffer indicates that among structures, behaviors, and functions, structures are the most cognitively available level of a complex system for novices, and the behavioral and functional levels serve as the deep principles that organize their knowledge of the system for the experts [6].

Another description about the behavior differences between two groups is widely accepted. The Decision Making Model and SRK Taxonomy, suggested by J. Rasmussen, also describe cognitive control and process differences between novices and experts [10, 11]. According to these models, human behaviors are distinguished into three modes – skill-based, rule-based, and knowledge-based behavior – and novices act based on knowledge, whereas experts act based on skill or rule.

In addition to these frameworks, Reason proposed the generic error modeling system (GEMS), which represents an integrated picture of the error mechanisms operating at all three levels of cognitive control [12]. It is based heavily on Rasmussen's three major categories of errors: skill-based slips and lapses, rule-based mistakes, and knowledge-based mistakes. GEMS is a more general description of the cognitive "black box", which can be used to address the mechanisms of both slips and mistakes. GEMS taxonomy of error types is a useful method to assess cognitive determinants in complex technological environments.

3.2 Display Methodology for Mobile Devices in Maintenance

As mentioned above, the amount of contents furnished for maintenance tasks are restricted. Furthermore, the information display should be controlled and properly organized according to the skill level of the personnel since novices require structural knowledge whereas experts require reminders for mechanisms or functional aspects of a system. We expect that information requirements in aspects of ecological interface design method for the maintenance can be studied by performing researches such as work domain analysis for the maintenance. We want to categorize some requirements and find principles in the design of mobile maintenance support system. Furthermore, display in the mobile maintenance support system could be designed more effective to maintenance personnel.

4. Conclusions

In this paper, we have discussed about the mobile computing environment and outlined our strategy to manage the display to support maintenance. Because of the importance of maintenance in nuclear power plants, possible human errors should be minimized by enhancing perception of maintenance personnel and reducing their cognitive load. In designing a display of maintenance support system applied with mobile technology, the need of guidelines and methodologies for the effective display design arose. The requirements can be categorized according to the characteristics of mobile devices and ecological interface design methodology. We want to categorize these requirements and find principles in the design of mobile device to support nuclear power plant maintenance considering the skill level of maintenance personnel.

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