The-Abstraction-Hierarchy-based Mobile PC Display Design for NPP Maintenance

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1. Introduction

Recently, the importance of effective maintenance in nuclear power plants (NPPs) has been emphasized and research into effective maintenance by adopting mobile maintenance aids (MMAs) have been attempted. For improved and effective use of an MMA display design method based on abstraction hierarchy (AH) is proposed and its design considerations are discussed in this study. Six levels of abstraction hierarchy are proposed in this paper to classify the maintenance information. By classifying and organizing maintenance information using AH, maintenance information can be used effectively by users with either high or low levels of expertise. When information classification has been finished, the information for MMA design is selected and designed. With the considerations of MMA design analysis and guidelines, AH-based MMA is designed for the maintenance tasks.

An experiment is conducted using the AH-based MMA in order to estimate the effectiveness of the proposed method for the maintenance tasks and to identify design considerations to enhance the proposed MMAs. The result indicated that an AH-based manual was more effective than a conventional manual in terms of task completion time and number of errors. The workload for the AH-based manual was estimated less than the conventional manual for subjects with low level of expertise. As the level of expertise increases, subjects tended to follow more abstract information while the number of navigations decreased. It is believed that when mobile devices become pervasive in NPP maintenance fields, AH-model applied MMAs can be used as an effective maintenance supporting tool.

2. Application of Abstraction Hierarchy to a Maintenance Task

The Abstraction Hierarchy (AH) is a multilevel information representation framework for describing the inherent functional structure of the systems, defined by a goals-means relation between adjacent levels [1]. The AH is usually defined in five levels and a brief summary and meaning of each level are shown in Fig. 1. From the figure, it can be outlined that the higher levels in the AH are represented at a less detailed and more abstract level than lower levels are.

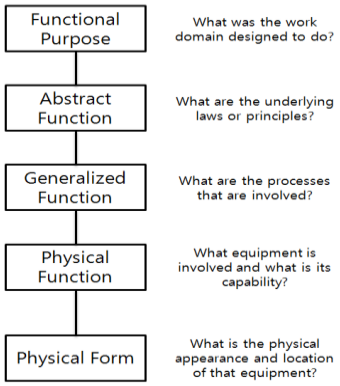

Fig. 1. The five levels of the Abstraction Hierarchy [2]

To classify the maintenance information according to the AH method, the levels that describe the hierarchy should be defined. The following six levels of the AH for maintenance information are proposed. Brief descriptions of the six levels are shown in Table I. Higher levels in the AH are represented in less detail and are more abstract than lower levels.

Table I. Six levels of the proposed abstraction hierarchy

Level	Description
General Purpose	Describes the main goal of maintenance
Functional Purpose	The topic for the maintenance
Generalized Procedure	Abstract means for the maintenance
Abstract Step	Specific steps to achieve procedure
Basic Component	What actions should performed and objects have to be dealt?
Component Material	Describes and supports how basic components actually behave and perform

Among the six hierarchy levels, the upper four levels are classified as a means of achieving goals for maintenance, while the lower two levels are classified as a means representing structure of procedure information. Many researchers believe that a goal-oriented hierarchical structure is best for presenting, comprehending, learning, and remembering procedures [3]. More levels for the structure of the maintenance manual can be suggested; however, in general, only three levels of sections are suggested in many technical manual writing materials [4, 5].

3. Experimental Validation

3.1 Experimental Procedures

The experimental procedures were as follows (Fig. 2). At the training stage, explanations about the manuals and instructions on the use of the UMPC were given to the subject. Subjects were asked to memorize every step, be accustomed to the procedure, and perform them as fast as possible.

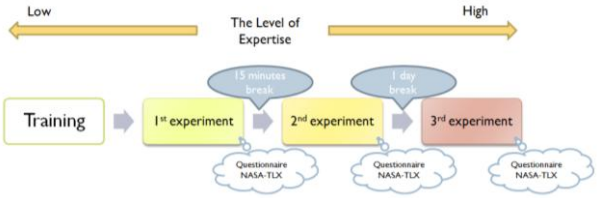

Fig. 2. The experiment procedure

In the first experiment, subjects performed the maintenance task with MMAs and were required to complete the questionnaire and NASA-TLX scale sheet. In the second experiment subjects conducted the same maintenance task as they did in the first experiment. Finally, subjects completed the third maintenance task. Subjects were asked to complete a questionnaire which examines both abstract and specific aspects of the task to determine whether subjects understood the maintenance tasks comprehensively. The abstract questions involved the structure or order of the task. Specific checkpoints, i.e. how to connect wires and test methods were also asked. Three maintenance tasks and three questionnaires were identical.

3.2 Results

For all levels of the subjects, the tasks were completed in less time when using AH-based MMA (AHM) group. The t-test result showed that the subjects who used AHM demonstrated faster performance than the Conventional MMA (CM) group. The task completion time was reduced much at the low expertise level than at the other expertise levels.

There were 27 errors from 20 subjects. Of these errors, 17 occurred with CM and 10 occurred with AHM. Subjects in CM made more errors when indicating the operation method and guiding the step order. This indicates that the use of CM is more conducive to errors in maintenance tasks compared to the AHM. However, there was no difference between the numbers of error about step proceeding without step completion.

Workload measurements with NASA-TLX were performed on each participant. Workloads were decreased as the level of expertise increases in both groups. The workload for the low expertise group was estimated to be less for AHM than CM, but as the level of expertise went up, the workloads became similar.

As result of the questionnaire evaluation, an increase of the score implies that the level of expertise of the subjects was increased as the maintenance tasks were repeated. However, the score of the two groups differed. The questionnaire scores of the CM group were higher than those of the AHM group, both in structure scores and in checkpoint scores.

The navigation path was analyzed only for the AHM group. The information was shown and the materials that were referred on the screen were recorded during their maintenance task and analyzed. To analyze the path data, a measure of average information level was defined, and the nature of the navigation was surveyed. The task completion time and the number of navigations were reduced as the level of expertise goes up. Also it confirms that the Mean navigation level (MNL) value decreased as the experiment was conducted repeatedly.

4. Conclusions

In this study, a MMA display design method based on AH was proposed and additional design considerations found from the experimental study were discussed to improve human performance and reduce human errors during maintenance tasks.

To classify the maintenance information, six levels of hierarchy were proposed in this paper, and a MMA was designed based on these classifications. To validate the proposed MMA, experimental validation was done. It turned out that the proposed AH-based MMA demonstrated better performance in completion time, occurred errors, and workload when compared to the conventional MMA. The proposed method can support maintenance workers at all levels of expertise.

Based on the experiment results, some design considerations were found and discussed in terms of the maintenance information organization, error prevention, and application to novices. These considerations would be reflected in the design of practical MMA for a better use.

Further work will concentrate on various aspects. Usability and acceptance studies should be performed in any case. Research on the specification of user and role models would be continued in order to support workers in their specific tasks even better.

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