Transactions of the Korean Nuclear Society Autumn Meeting
PyeongChang, Korea, October 30-31, 2008

Ecological Interface Design of Augmented Reality Display for Nuclear Power Plant Maintenance

In Kim, Poong Hyun Seong *
Dept. of Nuclear and Quantum Engineering, Korea Advanced Institute of Science and Technology, Daejeon 305-701
**Corresponding author: phseong@kaist.ac.kr*

1. Introduction

The importance of maintenance in nuclear power plants (NPPs) has been emphasized through many researches. The goals of maintenance in nuclear power plants are not only to reduce the number of shutdowns which directly affects to the profit, but also to prevent accidents or incidents hence improves nuclear safety [1].

It is known that reduction of the rate of human error in maintenance tasks can be achieved if maintenance personnel are properly supported by maintenance support systems. Among many proposed maintenance support system, the use of augmented reality (AR) has been proposed [2].

2. Designing Maintenance Support System Using Augmented Reality 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 [3].

2.1 Augmented Reality for Maintenance Support System

Augmented reality can be defined as the enhancement of the real world by a virtual world. The basic goal of an AR system is to enhance the user's perception of and interaction with the real world by supplementing the real world with virtual objects [4]. Maintenance personnel can be provided appropriate information overlaid onto the object they are investigating by equipping with a head-mounted display (HMD) and a wearable computer with the help of AR technology. Hence, they can concentrate on their tasks without having to refer to separate media, as in conventional working procedures [1].

2.2 Information Display for Maintenance

By adopting AR technology during the maintenance, maintenance personnel can refer various resources such as text manuals, graphics, 3D models, and video instructions. But due to limited field-of-view of a HMD and the possibility of sight obstruction, the information which is to be provided through HMD should be managed not to interfere with maintenance tasks.

TMI-2 accident shows that inadequately designed displays often impose unnecessary burdens on the user that results in failures. On the other hand, well-designed display can help maintenance personnel reducing errors and workloads and overcoming the complexity of dynamic systems [5]. How can the maintenance support system enhanced by AR be designed to meet the requirement in the guidelines that the maintenance personnel must perform the maintenance achieving the goals in NPPs? 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 [6].

2.3 The Abstraction Hierarchy and Ecological Interface Design Methodology

Abstraction hierarchy is a theoretical framework for representing working domain semantics in terms of nested hierarchy of functional constraints [6]. Such a hierarchy describes bottom-up what components and functions can be used for, how they may serve higher-level purposes, and top-down, how purposes can be implemented by functions and components. The analyzed abstraction hierarchy is reflected in the interface display design. The following table provides a description of the five levels of representation in the abstraction hierarchy:

Table 1: The Abstraction Hierarchy

Levels	
Functional Purpose	System objectives, constraints, etc.
Abstract Function	Causal structures: mass, energy, and information flow topology, etc.
Generalized Function	Standard functions and processes
Physical Function	Electrical, mechanical, chemical processes of component and equipment
Physical Form	Physical appearances and anatomy; material and form; locations, etc.

Ecological interface design (EID), proposed by Vicente and Rasmussen, is a methodology that describes

human behaviors with three different modes – skill based, rule based, and knowledge based behavior.

- Skill-based behavior: the personnel act on what he observes.
- Rule-based behavior: the personnel use rules or procedures to act on what he observes.
- Knowledge-based behavior: The operator must interpret what he observe and take a decision based on his knowledge.

The purpose of EID is to change the knowledge-based behavior into skill-based or rule-based behavior, and EID framework provides a general principle, not a guidance of how to implement in a concrete case [7].

3. Design Criteria for Maintenance Support System

3.1 Extraction of Information Requirements

Ecological interface design requires overall analysis of work space of maintenance personnel. In the Park's work, characteristics of maintenance, general maintenance procedures, categorization of maintenance information, and cognitive task analysis for maintenance personnel are studied [8]. Based on this research, the work domain analysis for the maintenance can be performed by defining the system boundary, gathering information, and modeling an abstraction hierarchy of work domain. By analyzing the work domain model for the maintenance in NPPs based on the abstraction hierarchy, information requirements in aspects of ecological interface design method for the maintenance can be obtained.

3.2 Display Design Criteria for AR Maintenance System in Ecological Interface Design Aspects

Maintenance personnel create highly located information in the abstraction hierarchy by collecting low-level information and inferring. If maintenance personnel could provide high-level information, then it is expected to reduce cognitive load for maintenance personnel by displaying information required to performing maintenance. We want to categorize these requirements and find specific criteria or principles in the design of AR maintenance support system. Furthermore, display in the AR maintenance support system could be designed more effective to maintenance personnel.

4. Conclusions

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 augmented reality technology, the need of guidelines for the effective display design arose. The requirements can be categorized according to the ecological interface design methodology proposed by Vicente and Rasmussen. We want to categorize these requirements and find specific criteria or principles in the design of AR maintenance support system. We also expect that an effective display for maintenance personnel in the maintenance support system could be designed according to the design criteria.

REFERENCES

[1] International Atomic Energy Agency, Modern Instrumentation and Control for NPPs: A Guidebook, Technical Report Series No. 387, IAEA, Vienna, pp. 202-203, 1999.
[2] J. J. Koo, I. Kim, and P. H. Seong, Design and Evaluation of AR for NPP Maintenance based on Cognitive Activity Analysis, Proceedings of International Symposium on Symbiotic Nuclear Power Systems for 21st Century (ISSNP-2008), Sep. 8-10, 2008, Harbin, China.
[3] C. D. Wickens, J. Lee, Y. Liu, and S. Gordon Becker, An Introduction to Human Factors Engineering Second Edition, Pearson Prentice Hall, 2004.
[4] R. Azuma, Y. Baillot, R. Behringer, S. Feiner, S. Julier, and B. MacIntyre, Recent advances in augmented reality, IEEE Computer Graphics and Application, Vol. 21, No. 6, pp. 34-47, 2001.
[5] D. D. Woods, The cognitive engineering of problem representations, in J. Alty and G. Weir, eds., Human-Computer Interaction and Complex Systems, Academic Press, London, 1991.
[6] G. Salvendy, Handbook of human factors and ergonomics, 3rd ed., John Wiley & Sons, Inc., Hoboken, New Jersey, 2006.
[7] K. J. Vicente and J. Rasmussen, Ecological interface design: theoretical foundations, IEEE Trans. Syst. Man, Cybernat, Vol. 122, No. 4, pp. 589-606, 1992.
[8] Y. H. Park, Human Cognitive Task Distribution Model for Maintenance Support System of a Nuclear Power Plant, Master's Thesis, Korea Advanced Institute of Science and Technology, 2007.
[9] S. M. Ko and R. Myung, Ecological Interface Design for Air Traffic Control Display, Journal of the Ergonomics Society of Korea, Vol. 25, No. 4, pp. 103-113, 2006.