Aesthetical Design and Human Factor Evaluation for the Totally Digitalized MCR in Korea Next Generation Nuclear Power Plant

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ABSTRACT

The analog or partly digital typed interface of main control room in nuclear power plant (NPP) is gradually being replaced to the totally digitalized interface suitable for the digital environment. SKN 3,4 Nuclear Power Plant is currently developed in such a way to employ advanced displays and controls such as computerized procedure system(CPS), large display panel(LDP), and Soft control. The main control room (MCR) of the SKN3,4 was aesthetically designed based on a design concept of the health and sustainability and technically evaluated with human factors guidelines, which somehow lack of the confidence on the evaluation for the rapidly changing digital environment. The suitable review guideline for the digitalized interface and the environment was developed such as the guideline for Interior design, Illumination, Workplace color and Information displays on VDU. For the guideline development, tremendous guidelines and technical papers related to evaluation issues of digital environment has been collected, analyzed and transformed to electric database forms and then built on database management system, called Design Review Supporting System to retrieve the appropriate issues for the practical usage of evaluators-in-field.

Keyword: Guideline, Digital environment, Human factor evaluation, Information Display, VDU, Nuclear power plant, MCR

INTRODUCTION

As the computer technology is highly developed, the complex human machine system such as nuclear power plant or avionic system tends to employ the computer-based system, for examples, computer based procedure (CBP) or information display panel using software control to help the users make an operational decision more efficiently.

The analog or partly digital typed interface of main control room in nuclear power plant (NPP) is gradually being replaced to the totally digitalized interface suitable for the digital environment. SKN 3,4 NPP in Korea(Figure 1) is currently developed in such a way to employ the concept of the totally digitalized environment.

Figure 1. SKN 3,4 NPP Graphic simulation mockup

The suitability of the computer based system interface is mostly evaluated and aesthetically validated through human factors review guidelines which are somehow lack of digitalized concept or conception. In fact, the more the computerized devices and procedures are employed in the system, the mental model of computer users has been more changed from analogue stereotype to digitalized one[Cha, 2002]. Therefore, it is necessary and confident to consider the evaluation issues which are suitable for the aesthetical design of the digitalized system environment.

METHODOLOGY

Some researches has been performed for providing an updated and expanded set of user-interface guidelines that meet the needs of designing and/or evaluating information display on VDT by integrating the generic guidelines involving information display design issues as much as possible[Cha, 2007]. The design issues and resolutions from the finding provided the cues for the designers and evaluators of the specific man machine interfaces of the system environment using digitalized devices.

Guidelines Selection

In order to derive the design review issues of human machine system environment, many guidelines and technical papers were collected, transformed guidelines to electric database forms and then built on database management system which employs intelligent search algorithm based on keyword mapping to each guideline

for retrieving the appropriate issues for information display on VDT.

The numbers of VDT display related guidelines from collected 14 documents are shown in Table 1. From the DBMS, the relevant evaluation issues and its hierarchy have been developed.

Table 1. Selected guidelines

Categories	Guideline Documents
Nuclear Guidelines	HF 010
	NUREG 0700 Rev.2
	IEEE 1289-1998
Government Guidelines	DOT/FAA/CT-01/08
	NASA-STD-3000
	MIL-STD-1472F
Non-government Guidelines	ANSI/HFS 100
	ANSI/HFS 100 Rev.1
	ISO 9241 Part 3
	ISO13406
	Display Measurement Standard(VESA)
	Display Measurement Standard(TCO)
	Motif 2.1 & CDE 2.1 Style Guide
	X-Windows & Motif Programming

Guidelines Integration

The selected guideline items for evaluating information display on VDT were classified and integrated by 5 components: 3 physical issues and 2 cognitive issues. Physical issues include Display elements, Display format and Windows. Cognitive issues include Information coding and Interaction. And environment issues are also collected and integrated from 3 categories: Hardware, Workstation and Environment

Although evaluation items from major human factor guidelines have too many issues to control the evaluation process, the total number of suggested evaluation items from integrated guidelines for information display was finally reduced to 222 items on 5 categories and digital environment to 66 on 3 categories. The summary tables of evaluation issues of referenced guidelines corresponding to the suggested evaluation items are shown at Table 2 and Table 3.

Guidelines Validation

For the validation of the collected issues for information display on VDT, the experiments were performed. The relationship among issues was discovered by AHP(Analytic Hierarchy Process) which employed subjective measure of guidelines users such as display developer, evaluator, human factors specialists.

For the validation of the collected issues for information display on CRT, the experiments were performed. The relationship among issues was discovered by AHP(Analytic Hierarchy Process) which employed subjective measure of guidelines users such as display developer, evaluator, human factors specialists [Cha & Jang, 2004].

The result of these researches has been applied to human factor verification and validation (V/V) process for official approval of the collected issues. For examples, the correctness of collection of CBP(Computer Based Procedure) issues were validated on CPS (Computerized Procedure System) on Korea Next Generation Reactor

(APR1400), and VDT issues on PMAS (Plant Monitoring and Alarm System).

Design Review Supporting System

The guidelines evaluation support system prototype, called DReSS-AID(Design Review Supporting System-Advanced Information Display) shown at Figure 2, was developed in order to perform evaluation process efficiently. The system consists of two mode: display mode with keymapper function, and evaluation mode with checklist function.

Figure 2 Design Support system interface

MCR ENVIRONMENT DESIGN ISSUES

For the evaluation of the human factor design for the totally digitalized main control room of nuclear power plant, Shingori 3,4 NPP, 287 item from 34 categories in 5 design were selected and evaluated. 5 design categories are general design, illumination design, interior design, color design and VDU information design. Details are as follows.

□ General design: 8 categories, 36 items

- ✓ Facility Accessibility(2)
- ✓ Task consistency(3)
- ✓ Layout(7)
- ✓ Documentation(6)
- ✓ Tools maintenance(6)
- ✓ Supervisor Accessibility(2)
- ✓ Communication (7)
- ✓ Comfort(1)

□ Illumination design: 7 categories, 14 items

- ✓ Illumination level(3)
- ✓ Task area luminance ratio(1)
- ✓ Ambient illumination(4)
- ✓ Material reflectance(1)
- ✓ Reflective glare(1)
- ✓ Surface color(1)
- ✓ Luminaries(3)

□ Interior design: 6 categories, 27 items

- ✓ Consoles ergonomics(7)

- ✓ VDU layouts(3)
- ✓ Furniture(7)
- ✓ Interior design(3)
- ✓ Ambient noise(6)
- ✓ Thermal & humidity (2)
- ✓ Ventilation(2)

- Colors Design: 2 categories, 4 items
 - ✓ Color coding(2)
 - ✓ Colored illumination(2)

- VDU information display : 10 categories, 206 items
 - ✓ Character & Symbol size
 - ✓ Number of colors
 - ✓ Information flow
 - ✓ Contrast
 - ✓ Luminance Uniformity
 - ✓ Color Uniformity
 - ✓ Background Color
 - ✓ Color Coding
 - ✓ Symbol coding
 - ✓ Alarm sound

CONCLUSION REMARKS

In order to evaluate the appropriate number of HCI issues on information display on VDT and its environment, tremendous guidelines and technical papers related to evaluation issues of information display has been collected, analyzed and transformed to electric database forms and then built on database management system to retrieve the appropriate issues for information display on VDT.

From the DBMS system, the relevant evaluation issues and its hierarchy has been finally developed and validated through guideline integration based on the concept of human cognitive model process.

It is necessary and confident to consider the result of the suggested evaluation issues which are suitable for the design of the system with advanced information displays such as Computer Based Procedure (CBP) and information on Large Display Panel (LDP).

The design issues and resolutions from the finding may provide the cues for the designers and evaluators of the specific man machine interfaces of the system environment using digitalized devices.

In fact, as for the human factors guidelines of CBP in KNGR (Korea Next Generation Reactor) main control room, the items related to the issues has been assigned and analyzed.

And another contribution of this research is that it would consider the new issues of VDT information display from the current Korea NPP evaluation guidelines such as Nureg0700 Rev.2 or HF010, which needs to be updated

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Table 2. Number of evaluation items for Information Display in each guideline

Structure Title	Selected guidelines for VDT information displays					
	Eval. Items	ISO 9241	FAA	ANSI Rev.1	IEEE 1289	NREG Rev.2
Display Elements	45	6	133	6	38	125
Display Format	51	0	355	0	3	434
Windows	42	0	389	0	0	110
Information Coding	29	0	32	0	32	48
Interaction	55	0	133	0	26	386
Total	222	6	1042	6	99	1103

Table 3. Number of evaluation items for digital environment in each guideline

Evaluation items		NUREG-0700 rev.2	FAA: HFDG	ANSI Rev.1	NASA-STD	MILSTD 1472F	ISO-9241	ISO-13406	TCO'03
Display Devices	29	31	112	27	9	109	25	29	42
Control Devices	13	65	99	32	52	62	45	..	..
Workstation	13	46	68	38	29	42	28	..	..
Environment	11	24	27	8	85	4	20	..	10
Total	66	166	306	105	175	217	98	29	52