Development of an Evaluation Method for the Design Complexity of Computer-Based Displays

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1. Introduction

The importance of the design of human machine interfaces (HMIs) for human performance and the safety of process industries has long been continuously recognized for many decades. Especially, in the case of nuclear power plants (NPPs), HMIs have significant implications for the safety of the NPPs because poor HMIs can impair the decision making ability of human operators.

In order to support and increase the decision making ability of human operators, advanced HMIs based on the up-to-date computer technology are provided. Human operators in advanced main control room (MCR) acquire information through video display units (VDUs) and large display panel (LDP), which is required for the operation of NPPs. These computer-based displays contain a huge amount of information and present it with a variety of formats compared to those of a conventional MCR. For example, these displays contain more display elements such as abbreviations, labels, icons, symbols, coding, etc.

As computer-based displays contain more information, the complexity of advanced displays becomes greater due to less distinctiveness of each display element. A greater understanding is emerging about the effectiveness of designs of computer-based displays, including how distinctively display elements should be designed [1].

This study covers the early phase in the development of an evaluation method for the design complexity of computer-based displays. To this end, a series of existing studies were reviewed to suggest an appropriate concept that is serviceable to unravel this problem.

2. Literature Reviews

According to Gestalt theory, 'distinctiveness' can be expressed by 'similarity.' For example, more similarity between two elements can be explained as less distinctiveness between them [2]. Based on this consideration, literature reviews for quantifying the similarity were performed to figure out how to represent distinctiveness. These reviews cover existing studies from 1960s to present.

As shown in Table 1, an effort to evaluate the concept of similarity was pervasive especially for two main elements: Image and Text. Particularly with evaluating the similarity of an image, three categories are divided in detail.

Table 1. Review of evaluation methods for similarity

		~1990	~2000	~Present
Text	Text Segment	[7]	[8-10]	[11]
Image	Image Segment	[15]	[3-4]	[12]
	Two Dimensional Shape		[5]	[16]
	Three Dimensional Shape		[6]	[13-14]

Many similarity measurements have been proposed, such as *information content* [9], *mutual information* [8], *dice coefficient* [10], *cosine coefficient* [10], and *feature contrast model* [15].

A method called *dice coefficient*, shown in Eq. 1, is a representative evaluation method for text similarity [10]. This concept is to evaluate similarity between A and B with a ratio between the amount of information needed to state the commonality of A and B.

$$SIM(A,B) = \frac{2 \times P(A \cap B)}{\log P(A) + \log P(B)} \quad (1)$$

$$I(S) = -\sum \log P(f) \quad (2)$$

where $P(f)$ is the probability of feature f and it is estimated by the percentage of words among the set of words. And $I(S)$ is the amount of information contained in the set of feature S.

Feature	Noun1	Noun2	$I(f_i)$
f_1	√	√	3.15
f_2	√		5.43
f_3	√	√	5.88
f_4		√	4.99
f_5	√	√	4.97

Table 2. Features of 'Noun1' and 'Noun2'

Feature f_1 to f_8 express the relationship between 'Noun1 and Noun2' and their adjective modifier or their determiner. From Table 2, the similarity between 'Noun1' and 'Noun2' is 0.729.

$$SIM(A,B) = \frac{2 \times I(f_1, f_3, f_5)}{I(f_1, f_2, f_3, f_5) + I(f_1, f_3, f_4, f_5)} = 0.729$$

3. Result and Discussion

Various kinds of evaluation methods have been proposed for characterizing the similarity of image and text segment. However, it seems that most of these methods have a problem to be adopted in evaluating the complexity of computer-based displays. That is, these methods evaluate the similarity based on single perspective, either image or text segment. However, computer-based displays contain many elements, which make it difficult to adopt a single perspective for measuring its similarity. In other words, since these methods evaluate the similarity only when the elements have commonality, it is not easy to measure the similarity of elements containing different shapes and text segments, etc. For this reason, the concept of excess entropy which was introduced by Crutchfield and Packard [17] is introduced to evaluate the similarity of elements included in computer-based displays.

Fig. 1 well expresses the concept of excess entropy by Venn diagram. Because $H(A\cap B)$ that denotes the amount of excess entropy corresponds to the amount of shared information between *A* and *B*, a large value of excess entropy means that *A* and *B* have more dependence on each other, that is, they have low distinctiveness value.

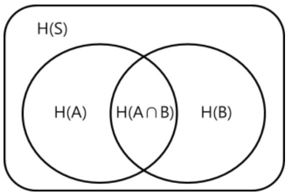

Fig 1. The concept of excess entropy

In this regard, if a computer-based display system *S* is constructed with two display elements *A* and *B*, then information contained in *S* can be defined by the entropy function shown in *Eq.(3)*. This means that the excess entropy of *S*, *C(S)*, is given by *Eq.(3)* where the entropy value of A and B, *H(A)* and *H(B)*, can be represented by *Eq. (4)*.

$$C(S) = H(A) + H(B) - H(S) \tag{3}$$

$$H = -\sum_{i=1}^{h} p(A_i)\log_2 p(A_i) \tag{4}$$

Also, construction of data structure graph is required. Through the data structure graph, shown in Fig. 2, entropy value as well as excess entropy can be calculated.

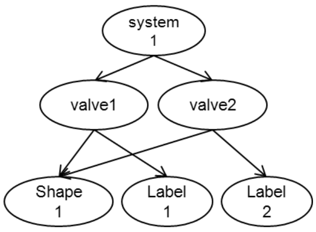

Fig 2. The data structure graph in system 1

Event though, more theoretical backgrounds and experimental studies are needed to apply excess entropy to actual use, it seems possible to evaluate the similarity of design elements contained in computer-based displays in aspect of multiple perspectives.

4. Conclusion

In this study, various kinds of methods for measuring the similarity are reviewed. Based on review results, it was revealed that there is a critical problem for measuring the design complexity of computer-based displays. For this reason, the concept of excess entropy is suggested because it has advantages of evaluating the similarity in multiple display elements. Although further theoretical and experimental studies are indispensable for clarifying the feasibility of the suggested concept in this study, it seems to be evident that the suggested concept would be a good starting point to scrutinize the design complexity of computer-based displays.

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