Application of the Decomposition Method to the Design Complexity of Computer-based Display

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1. Introduction

The importance of the design of human machine interfaces (HMIs) for human performance and safety has long been recognized in process industries. In case of nuclear power plants (NPPs), HMIs have significant implications for the safety of the NPPs since poor implementation of HMIs can impair the operators' information searching ability which is considered as one of the important aspects of human behavior.

To support and increase the efficiency of the operators' information searching behavior, advanced HMIs based on computer technology are provided. Operators in advanced main control room (MCR) acquire information through video display units (VDUs), and large display panel (LDP) required for the operation of NPPs. These computer-based displays contain a very large quantity of information and present them in a variety of formats than conventional MCR. For example, these displays contain more elements such as abbreviations, labels, icons, symbols, coding, and highlighting than conventional ones.

As computer-based displays contain more information, complexity of the elements becomes greater due to less distinctiveness of each element. A greater understanding is emerging about the effectiveness of designs of computer-based displays, including how distinctively display elements should be designed [1]. And according to Gestalt theory, people tend to group similar elements based on attributes such as shape, color or pattern based on the principle of similarity. Therefore, it is necessary to consider not only human operator's perception but the number of element consisting of computer-based display.

2. Method

Decomposition method is suggested to measure the complexity of computer-based display. The decomposition method is originally developed for reducing problems of system design. A general design problem is characterized by design components and design attributes.

Consider a design problem involving *n* components and *m* attributes. Let $\mathrm{C} = \{\mathrm{c}_1, \mathrm{c}_2, \ldots, \mathrm{c}_\mathrm{n}\}$ and $\mathrm{A} = \{\mathrm{a}_1, \mathrm{a}_2, \ldots, \mathrm{a}_\mathrm{n}\}$ be two non-empty sets of *n* components and *m* attributes, respectively. The incidence matrix of a design problem can be defined as

$$\mathrm{M} = [\mathrm{m}_{\mathrm{ij}}], (i = 1, 2, \ldots, m; j = 1, 2, \ldots, n)$$

Where m_{ij}=1 if the component c_j contains property a_i, and m_{ij}=0 if component c_j does not contain property a_i. The rows of the incidence matrix are labeled with properties and the columns of the matrix with components. This definition implies that all relationships between properties and components in the matrix are of equal importance.

	c1	c2	c3	c4	c5	c6	c7
r1	1	1	0	0	0	0	0
r2	0	0	1	0	0	1	1
r3	0	0	1	1	0	1	0
r4	1	0	1	0	1	0	0
r5	0	0	0	1	0	0	1
r6	0	1	0	0	1	0	0

Figure 1. An example of the incidence matrix.

In the context of the matrix-based decomposition, the similarities between components and between attributes are taken into consideration. The similarity measure between two columns/rows depends on the number of common elements being shared. Jaccard's resemblance coefficient is accepted to measure the strength of similarity, according to

$$r_{col\_ij} = \frac{\sum_{\mathrm{k=1}}^{\mathrm{m}} \min(m_{ki}, m_{kj})}{\sum_{\mathrm{k=1}}^{\mathrm{m}} \max(m_{ki}, m_{kj})}$$

where r_{col_ij} is the similarity coefficient for measuring the similarity between the i_{th} colomn and the j_{th} column. Also the similarity value between two rows can be estimated according to

$$r_{row\_ij} = \frac{\sum_{\mathrm{k=1}}^{\mathrm{m}} \min(m_{ki}, m_{kj})}{\sum_{\mathrm{k=1}}^{\mathrm{m}} \max(m_{ki}, m_{kj})}$$

Cluster analysis is applied to convert the incidence matrix, which is originally unorganized. Based on the similarity coefficient, the original incidence matrix is rearranged with similarity coefficient such as figure 2. And the vertical scale of the cluster tree is quantified similarity coefficient.

	c1	c2	c3	c4	c5	c6	c7
c1	0	0.33	0.25	0	0.33	0	0
c2	0.33	0	0	0	0.33	0	0
c3	0.25	0	0	0.25	0.25	0.67	0.25
c4	0	0	0.25	0	0	0.33	0.33
c5	0.33	0.33	0.25	0	0	0	0
c6	0	0	0.67	0.33	0	0	0.33
c7	0	0	0.25	0.33	0	0.33	0

Figure 2. Similarity coefficient matrix

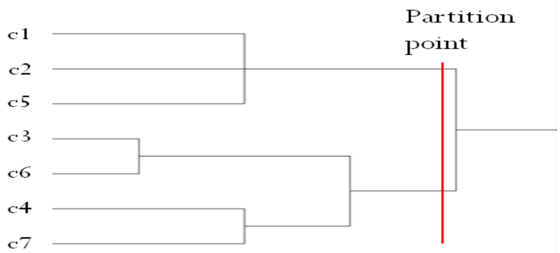

Figure 3. Cluster tree

The key feature of decomposition method is the decoupling of the function of matrix based decompose –tion. The partition analysis utilizes the information from similarity analysis to partition according to some decomposition criteria. Partition analysis transforms the diagonal matrix into a block angular matrix. The partition points replaced at the top branches which are dividing two parts of cluster tree and that point represent good locations to divide the diagonal matrix based on the similarity.

After developing block angular matrix, COM denotes the complexity for the interaction involved matrix, which can be formulated as

$$\mathrm{COM} = \mathrm{m_a} \ln 2^{\mathrm{n_a}} + \sum_{\mathrm{i}=1}^{\mathrm{n_b}} \mathrm{m_i} \ln 2^{\mathrm{n_{ci}}}$$

Let n_b be the number of blocks, m_i the number of design properties and n_{bi} the number of design components. Interaction size can be described with m_a the number of interaction rows and n_a the number of interaction columns.

3. Result and Discussion

Various methods are measuring the complexity. However, most of the methods are not consider the perceptual aspect and they only consider the number of components, or evaluate the complexity by gathering response of subjects of experiment.

We applied the decomposition method for measuring the complexity of computer-based display. Figure 4 shows that a part of LDP in NPPs. As a result of that, the complexity was

$$\mathrm{COM} = 2 \ln 2^{12} + 13 \ln 2^{9} + 6 \ln 2^{3} = 110.210$$

When the components have same property, the complexity of computer-based display was

$$\mathrm{COM} = 10 \ln 2^{12} + 7 \ln 2^{7} + 3 \ln 2^{5} = 127.539$$

in the same way with first example. COM of second example is larger than first example because components of second display have same color. Therefore we can assume that the similarity of components affect to increase the complexity.

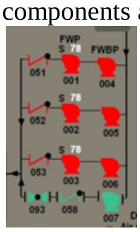
Figure 4. A part of feed-water system of LDP in KHNP

Figure 5. Block-angular matrix partitioned into two similarity matrix and interaction part

3. Conclusion

The decomposition method is applied to measure the complexity of computer-based display. With this method, the complexity is identified by properties of components. That means we can obtain the value of complexity considering not only the number of components but each properties of components. Also from the results of examples, high similarity affects to increase the complexity of computer-based display.

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