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Application of fuzzy measures and fuzzy integrals model to evaluation of human interface

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Abstracts: This paper proposes a method which selects essential elements in a human evaluation model using the Choquet integral based on fuzzy measures, and applies the model to the evaluation of human interface. Three kinds of concepts are defined to select essential elements. *Increment Degree* implies the increment degree from fuzzy measures of composed elements to the fuzzy measure of a combined element. *Average of Increment Degree* of an element means the relative possibility of superadditivity of the fuzzy measure of each combined element. *Necessity Degree* means the selection degree of each combined element as a result of the human evaluation.

A task experiment, which consists of a static work and two dynamic works, is performed by the use of some human interfaces. In the experiment, (1) a warning sound which gives an attention to subjects, (2) a color vision which can be distinguished easily or not, (3) the size of working area and (4) a response of confirmation that is given from an interface, are considered as human interface elements. Subjects answer the questionnaire after the experiment. From the data of the questionnaire, fuzzy measures are identified and are applied to the proposed model. Effectiveness of the proposed model is confirmed by the comparison of human interface elements extracted from the proposed model and those from the questionnaire.

Keywords: Fuzzy measures, Evaluation, Human interface

1 INTRODUCTION

Recently, we can accomplish hard work more correctly, safely and simply with a highly developed system [1]. On the other hand, we need technical capability and knowledge for the operating of that system[6]. From the above point of view, the importance of a human interface has been recognized again. Especially, a computer system is fairly wide spread recently. Then users levels for a computer system become wide, that is, from beginners levels to experts levels, and users favorite interface elements are various and many. It is an important problem to evaluate users favorite elements in a design of a human interface from not only the objective point of view but also the subjective point of view.

There have been applications of fuzzy measures and fuzzy integrals to a model of human subjective evaluation [2-5,7,8]. In the human evaluation model it becomes necessary to find out essential elements for evaluation [2].

In this paper fuzzy measures and fuzzy integrals [8] are applied to the evaluation of a human interface. Three kinds of concepts are defined to select essential human interface elements for the evaluation. The validity of proposed method is confirmed by the use of interfaces in task experiments.

2 FUZZY MEASURE AND CHOQUET INTEGRAL

Definition 2.1. Consider a set of n information elements $K = \{s_1, s_2, \ldots, s_n\}$. If a set function $g : 2^k \rightarrow [0,1]$ has the following properties, g is called a fuzzy measure.

$$g(0) = 0 \text{ and } g(K) = 1 \tag{1}$$

$$A \subset B \subset K \rightarrow g(A) \leq g(B) \tag{2}$$

Definition 2.2. Consider a fuzzy measure space $(K, 2^k, g)$. The Choquet integral of a function $f : K \rightarrow [0,1]$ with respect to g is defined as follows.

$$(C)\int f(k)dg \equiv \int_0^\infty g(\{k \mid f(k) > h\})dh \tag{3}$$

3 SELECTION OF ELEMENTS

Suppose that an object is evaluated by n elements, $X = \{x_1, x_2, \cdots, x_n\}$. Fix a combined element $A_i \, (i = 1,2,\cdots,2^n - 2)$ where A_i is neither an empty set ϕ nor a universal set X. Let other combined elements be $B_m \in P(X)$ which is composed of m elements $\{x_1^i, x_2^i, \cdots, x_m^i\}$ and $A_i \subset B_m$. In this case, a combined element A_i is a composed element of B_m in the sense of $A_i \subset B_m$. The combination of m elements is $2^m - 1$ without an empty set. Let $A_{1(m)_i}, A_{2(m)_i} \cdots$ and $A_{j(m)_i}$ be disjoint sets which divide the difference set $B_m - A_i$.

The maximum value (MAXV) and the minimum value (MINV) about $A_i \subset B_m$ are defined as follows.

$$MAXV(A_i, A_{k_i} \subset B_m - A_i) = g(A_i) + g(A_{1(m)_i}) + g(A_{2(m)_i}) + \cdots + g(A_{j(m)_i}) - \min\{g(A_i), g(A_{1(m)_i}), g(A_{2(m)_i}), \cdots, g(A_{j(m)_i})\}$$

$$MINV(A_i, A_{k_i} \subset B_m - A_i) = g(A_i) + g(A_{1(m)_i}) + g(A_{2(m)_i}) + \cdots + g(A_{j(m)_i}) - \max\{g(A_i), g(A_{1(m)_i}), g(A_{2(m)_i}), \cdots, g(A_{j(m)_i})\}$$

where $A_{k_i} \in \{A_{1(m)_i}, A_{2(m)_i}, \cdots, A_{j(m)_i}\}$.

LR (Low Rate) - the increment from the MAXV to $g(B_m)$, HR (High Rate) - the increment from the MINV to $g(B_m)$ and Increment Degree (ID) - the sum of the increment from the MAXV to $g(B_m)$ and the increment from the MINV to $g(B_m)$ about $A_i \subset B_m$ are defined by

$$LR(A_i, A_{k_i} \subset B_m - A_i) = \frac{g(B_m) - MAXV(A_i, A_{k_i} \subset B_m - A_i)}{MAXV(A_i, A_{k_i} \subset B_m - A_i)}, \quad (4)$$

$$HR(A_i, A_{k_i} \subset B_m - A_i) = \frac{g(B_m) - MINV(A_i, A_{k_i} \subset B_m - A_i)}{MINV(A_i, A_{k_i} \subset B_m - A_i)}, \quad (5)$$

and

$$ID(A_i, A_{k_i} \subset B_m - A_i) = LR(A_i, A_{k_i} \subset B_m - A_i) + HR(A_i, A_{k_i} \subset B_m - A_i), \quad (6)$$

respectively. The ID implies the possibility of supperadditivity of $g(B_m)$ from fuzzy measures of composed elements. The larger the ID, the larger the possibility of supperadditivity of $g(B_m)$. $ID(A_i, A_{k_i} \subset B_m - A_i)$'s are obtained depending on the selection of $A_{k_i} \subset B_m - A_i$. The number of ID's is equal to the number of selected A_{k_i}'s.

Normalized Increment Degree (NID) is defined by

$$NID(A_i, A_{k_i} \subset B_m - A_i) = \begin{cases} 1 - \dfrac{1}{1 + ID(A_i, A_{k_i} \subset B_m - A_i)} & \text{for } ID(A_i, A_{k_i} \subset B_m - A_i) \ge 0. \\ ID(A_i, A_{k_i} \subset B_m - A_i)/2 & \text{for } ID(A_i, A_{k_i} \subset B_m - A_i) < 0. \end{cases} \quad (7)$$

That is, $ID(A_i, A_{k_i} \subset B_m - A_i) \in (-2, \infty) \rightarrow NID(A_i, A_{k_i} \subset B_m - A_i) \in (-1, 1)$.

An *Average of Normalized Increment Degree* (ANID) of a combined element $A_i \, (i = 1,2,\cdots,2^n - 2)$ is defined by

$$ANID(A_i) = \frac{\sum_{A_i \subset B_m \subset X} \sum_{A_{k_i}} \{NID(A_i, A_{k_i} \subset B_m - A_i)\}^3}{l}, \quad (8)$$

where l is the sum of the number of sets of disjoint sets which divide the different set $B_m - A_i$. The ANID represents the average increment and the relative possibility of superadditivity. That is, the larger the ANID of a composed element, the larger the relative possibility of superadditivity of a combined element including the composed element. If the ANID of a composed element is large, the composed element should be selected in the evaluation. However, g(.) must be also taken into consideration, because g(.) represents the importance degree of the element in the evaluation.

The *Necessity Degree* (ND) of an element $A_i \, (i = 1,2,\cdots,2^n - 2)$ is defined by

$$ND(A_i) = g(A_i) \times ANID(A_i). \quad (9)$$

Relative Necessity Degree (RND) is defined by equation (10), which represents the relative value of the ND on condition that the number of composed elements of A_i is the same. Necessity of an element is investigated by this value.

$$RND(A_i) = \frac{ND(A_i)}{ND(avr)}, \tag{10}$$

where $ND(avr)$ is the average value of the ND on condition that the number of the composed elements is the same with that of A_i, defined by

$$ND(avr) = \frac{\sum_{i=1}^{r} ND(A_i)}{r}, \tag{11}$$

where r is the total number of A_i on condition that the number of composed elements is the same with that of A_i.

4 TASK EXPERIMENT

4.1 Contents of experiment

Let us consider the situation that a human operator works several tasks simultaneously on the monitor screen which is shown in Fig. 1. The operator must finish two kinds of tasks as fast as possible under the given condition. The first kind of the task is a copy task. The operator duplicates 25colors(12 kinds of colors) shown in the part (1) to the part (2) identically. Colors are selected from the palette (3). The second kind of the task is an operating task. The operators must keep hands of dials out of red (R) zones by operating levers (8) and (9). Dials are divided into 4 zones. The green (G) zone is located in the upper center of the dial and the hand of the dial moves right or left randomly in this zone. If the hand of dial enters into yellow (Y) zones, it moves to only one direction randomly. That is, if the hand of the dial enters into the left-hand yellow zone, it moves to only left-hand direction randomly. In the pink (P) zone, the movement of the hand is the same with that in the yellow zone. If the hand of the dial enters into the red zone, then the task is ended.

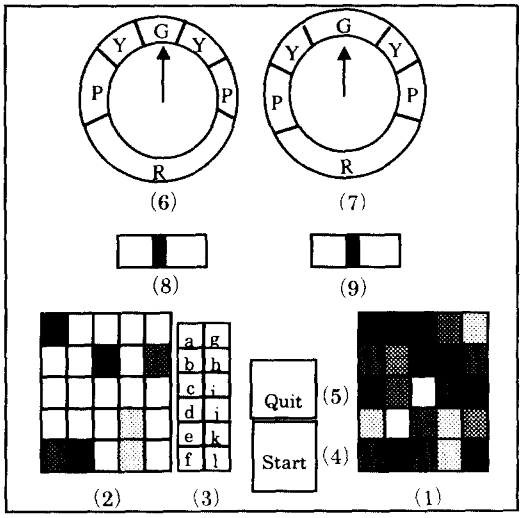

Figure1 A screen of task interface

4.2 Subjects' experiment

The following elements are considered as interface elements in this experiment.

- Warning sound (sound)
  When the hand of the dial enters into the pink zone, the interface sounds the alarm as the warning sound.
- Classification of color (color)
  Colors in through 'a' to 'f' of the palette (3) are distinguishable easily. And colors in through 'g' to 'l' of the palette (3) are distinguishable easily or less distinguishable.
- Size (A/R)
  A remember part (1) and an answer part (2) are given in a large size or a small size.
- Confirmation of accuracy (× mark)
  When the same color of the part (1) is finished being copied to the part (2), the × mark appears in this color part of the palette (3). The × mark means that the color needs not being selected any more.

When the start button (4) in Fig. 1 is pushed, the hands of dials (6) and (7) begin to swing randomly and colors are displayed randomly on the part (1). At the same time, the start button changes to a display button. If the start button is pushed, then the part (1) is shown just 10 seconds. And if the display button is pushed during the experiment, then the part (1) is also shown just 10 seconds. An operator pushes the start button at the beginning of the experiment and the display button only two times during the experiment. Then the total display time of part (1) is 30 seconds. If the copying task is finished and the 'quit button' is pushed, then the task experiment is ended. Six kinds of interfaces, which are composed of 2 kinds of elements, are trained to understand the interface before the experiment. A subject practices 16 kinds of interfaces randomly. After each experiment, subjects answer questionnaire about the interface elements. After all experiments, subjects answer the questionnaire about the importance degree of each interface element.

Subjects are 6 males and 3 females. Subjects take 39.9 seconds in average time and the average completeness is 90.8 percent. Evaluation values of each element and each interface are normalized into [0,1] as follows.

$$+7 \to 1, +6 \to \frac{5}{6}, +5 \to \frac{2}{3}, +4 \to \frac{1}{2}, +3 \to \frac{1}{3}, +2 \to \frac{1}{6} \text{ and } +1 \to 0$$

Fuzzy measures are identified using data collected by questionnaires and the fuzzy measures are applied to the proposed model. Table 1 shows the analysis results. Numbers 1,2,3 and 4 in Table 1 correspond to interface elements, sound, color, size of A/R and × mark, respectively.

From Table 1, it is found that

(1) The (sound) or the (× mark) is necessary to subjects, when the interface is evaluated by only one interface element.

(2) Subjects attach great importance to the pair of (sound, × mark) or (color, × mark), when the interface is evaluated by two interface elements.

(3) The triplet of (sound, size of A/R, × mark) or (sound, color, × mark) is chosen as a necessary element, when the interface is evaluated by three elements.

Table 1 Analysis results about interface evaluation

IFN	CBE	g(.)	ANID	RND	ORD
0	0	0.0			
8	1	0.2484	0.3275	1.1826	2nd
4	2	0.0495	0.5973	0.4299	4th
2	3	0.2024	0.3124	0.9192	3rd
1	4	0.2238	0.4513	1.4684	1st
12	12	0.5898	0.3297	0.9666	3rd
10	13	0.2564	0.5714	0.7283	5th
9	14	0.6415	0.5178	1.6511	1st
6	23	0.2690	0.4176	0.5583	6th
5	24	0.7020	0.3338	1.1649	2nd
3	34	0.4933	0.3797	0.9309	4th
14	123	0.6136	0.5194	0.7368	4th
13	124	0.9998	0.5074	1.1728	2nd
11	134	0.6423	0.8623	1.2803	1st
7	234	0.7719	0.4540	0.8101	3rd
15	1234	1.0000			

IFN: Interface Number, CBE: Combined Element, ORD: Order

Table 2 shows the results of questionnaires about the importance degree of element. Comparing Table 1 and Table 2, it is found that human interface elements in higher rank in Table 1 are consistent with those in Table2. The proposed method measures favorite interface elements of user's.

Table 2 Results of Questionnaires

1 element		2 elements		3 elements	
element	person	elements	person	elements	person
Sound(S)	3	S, C	1	S, C, A/R	0
Color(C)	2	S, A/R	0	S, C, X	7
A/R	0	S, X	4	S, A/R, X	2
X	4	C, A/R	0	C, A/R, X	0
		C, X	4		
		A/R, X	0		

5 CONCLUSIONS

It is important to select necessary element in a human evaluation model. This paper proposes the method that evaluates necessary interface elements considering the relation among more than two elements. In this method, three concepts are introduced; *Increment Degree*, *Average of Increment Degree* and *Necessity Degree*. These concepts are applied to the evaluation of the human interface that is used in task experiments. As a result, it is found that the proposed method estimates operators' favorite interface elements well. In a future the proposed method will be applied to a design of a human interface.

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