The predictive model on the user reaction time using the information similarity

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1. Introduction

Human performance is frequently degraded because people forget. Memory is one of brain processes that are important when trying to understand how people process information. Although a large number of studies have been made on the human performance, little is known about the similarity effect in human performance. The purpose of this paper is to propose and validate the quantitative and predictive model on the human response time in the user interface with the concept of similarity. However, it is not easy to explain the human performance with only similarity or information amount. We are confronted by two difficulties: making the quantitative model on the human response time with the similarity and validating the proposed model by experimental work. We made the quantitative model based on the Hick's law and the law of practice. In addition, we validated the model with various experimental conditions by measuring participants' response time in the environment of computer-based display. Experimental results reveal that the human performance is improved by the user interface's similarity. We think that the proposed model is useful for the user interface design and evaluation phases.

2. Models and methods

2.1 The importance of similarity

When we are going to the nearest vending machine, the reason how we can easily go there is the result of our memory operatoin. The similarity can reduce the time of human information processing to do some actions. The effect of similarity is emphasized by other researchers. However, they mention about that in the qualitative way. Therefore, our paper proposed a quantitative model to predict a choice reaction time based on the information amount and similarity.

2.2 The information amount

Hick's law, which is expressed as Equation (1), explains that the choice reaction time in visual search task become longer as the information amount increases.

$$T = A + BH \quad (1)$$

where H is the information or alternatives amount of an interface, A and B are regression coefficients. Originally, the information amount is calculated by the concept of entropy. But in this study, it is calculated simply by the number of alternatives.

2.3 The information similarity

In this paper, Tversky's featural model was used to calculate the similarity (Tversky, 1977). The matching function in this study is the following Eqation (2).

$$S(A,B) = \frac{f(A \cap B)}{f(A \cap B) + \alpha f(A-B) + \beta f(B-A)} \qquad (\alpha, \beta \geq 0) \quad (2)$$

The set A means the current state. Therefore, the similarity matching function can be changed as following Equation (3).

$$S(A,B) = \frac{f(A \cap B)}{f(A \cap B) + \alpha f(A-B)} \qquad (\alpha \geq 0) \quad (3)$$

Let us assume the denominator as the set A, which means $\alpha = 1$.

$$S(A,B) = \frac{f(A \cap B)}{f(A)} \quad (4)$$

Above equation means how much information are same as the previous states. We can express the Equation (4) as the notation of information amount.

$$S(A,B) = \frac{H_S}{H} \quad (5)$$

The law of practice concerns the relationship between expected response time and amount of practice in skill acquisition paradigms with the sameness, which means the degree of similarity is full. For most of the previous 20 years, researchers have believed that the law of practice was well described by a power function, due mainly to evidence collected by Newell and Rosenbloom (1981). Therefore, our study chose the Equation (6) for applying the law of practice.

$$T = A_E + B_E e^{-\alpha N} \quad (6)$$

2.4 The development of our prediction model

Let us think about simple case in general as shown as Figure 2. The part of (b) is the same as the part of (a). Therefore, there is a similarity between (b) and (a). We can apply the law of practice for the same part. The expected response time of part (b) may be decreased along path (1), (2), (3) or other shpaes as the similarity increases (Figure 3). We cannot know the correct shape of similarity curve but know only its trend.

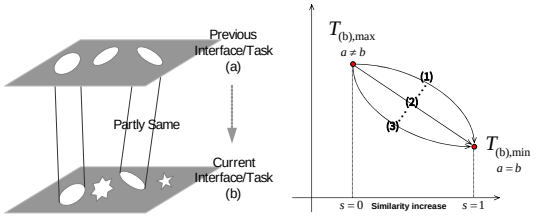

Figure 2. Simple general case of two serial interfaces. (left)
Figure 3. Similarity curve on the expected response time. (right)

As summarized above things, we can make the following equations.

$$T_{(b),\min} \le T_{(b)}(S(b,a),H) \le T_{(b),\max} \quad (7)$$

$$T_{(b)}(1,H) \le T_{(b)}(S(b,a),H) \le T_{(b)}(0,H) \quad (8)$$

$$T_{(b)}(S(b,a),H) = pS(b,a)+q \quad (9)$$

Equation (9) represents the path (2) of Figure 6. We can calculate the boundary values by Equation (1) and (6). Therefore, we find a relation between the expected response time and information similarity.

$$T_{(b)}(S(b,a),H) = B_E\left(\frac{1}{e^{2\alpha}}-\frac{1}{e^{\alpha}}\right)S(b,a)+(A+BH) \quad (10)$$

We can expand the Equation (10) to the most general case that we usually confront to complete a task as shown as Figure 4.

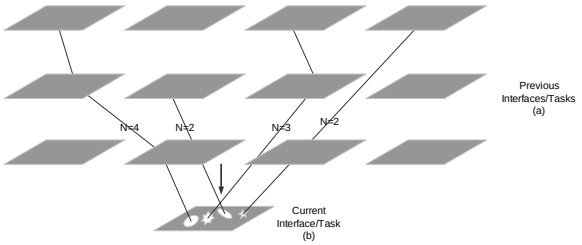

Figure 4. Conceptual example of various past memories to current work.

When the current interface has several same parts, each part may have the different practice level. Each same part has its own practice level and same information amount.

$$\vec{S} = \left(S(b,a)_1 \quad \cdots \quad S(b,a)_m\right)$$

$$\vec{B}_S = \left(B_E\cdot\left(\frac{1}{e^{\alpha N_1}}-\frac{1}{e^{\alpha}}\right) \quad \cdots \quad B_E\cdot\left(\frac{1}{e^{\alpha N_m}}-\frac{1}{e^{\alpha}}\right)\right) \quad (11)$$

$$T_{(b)}(\vec{S},\vec{B}_S,H) = \vec{B}_S\cdot\vec{S}^T+(A+BH)$$

This model can cover the range from Hick's Law to the Law of Practice.

3. Experimental works

We made simply window-based GUI for visual search tasks, which is consists of center text box and circular text boxes and considers the letter-position effection in the navigation of the user. The experiment factors are the information amount and the degree of similarity. We performed the experiments with 20 participants.

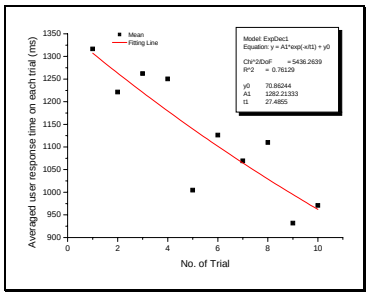

Figure 5. Experiment of law of practice.

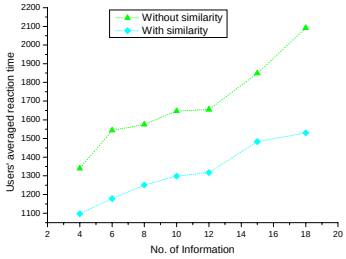

Figure 6. Experiment of similarity effect.

4. Conclusions

Proposed model has been developed for the quantitative and mathematical prediction method on the expected response time in sequential operations. This model also represents the unified equation of both Hick's law and the law of practice using the information similarity. As designers or evaluators in HCI field use this proposed model, they may make efficient and effective interfaces or easily find out the defects of developed interfaces. We think that the similarity curve that is proposed in this study indicates the nature of human. However, this study should refine the basic logics and the approach methods by revewing with many researchers.

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