Usability Evaluation Method Employing Elements of “Thinking” and “Seeking”

Nobuyuki Nishiuchi¹, Takehiro Ando¹, and Mi Kyong Park²

¹ Department of Management Systems Engineering, Tokyo Metropolitan University

² Division of Management Systems Engineering, Tokyo Metropolitan University,
6-6 Asahigaoka, Hino, Tokyo, 191-0065, Japan

nnishiuc@sd.tmu.ac.jp, takehiro.ando@gmail.com,

mkpark@sd.tmu.ac.jp

Abstract. Current usability evaluation approaches are costly, time-consuming and suffer from evaluation subjectivity, and in addition, it is often difficult to acquire the operation logs of existing electrical products. To overcome these limitations, we developed a new method for usability evaluation. During the operation of either an actual product or a reproduced interface on a touch screen, the hand movements of users were recorded with a video camera. Before evaluation of the target interface, the users operated three basic interfaces, classified as “Standard”, “Thinking”, and “Seeking”, and the users’ unique elements related to hand movements, which were based on the distribution of stationary time, during operation of the “Thinking” and “Seeking” interfaces were extracted. Finally, usability was evaluated based on the amount of each element (“Thinking” and “Seeking”) that was included in the target interface.

Keywords: Usability, interface, evaluation method, image processing.

1 Introduction

Current techniques for usability evaluation encompass several approaches [1]-[3], such as video capture and eye-tracking during user operation, conducting interviews, administering questionnaires, and recording user operation logs, among others. However, these evaluation approaches are costly, time-consuming, suffer from evaluation subjectivity, and are often not feasible, as it is difficult to acquire the operation logs of many existing electrical products.

To overcome these limitations, we developed a new method for usability evaluation, which involves video recording a user’s operation, extracting the movements of the user’s fingertip by image processing, and then evaluating usability by analyzing the distribution of stationary time of the user’s fingertip movements based on the elements of “Thinking” and “Seeking” [4].

This study is organized as follows. In section 2, the detailed methodology of the usability evaluation is described. In section 3, the results of an evaluative experiment are present. Finally, in section 4, conclusions are discussed.

2 Methodology of Usability Evaluation

The proposed usability evaluation method is divided into three parts: (1) Extraction of usability elements, (2) Analysis of a target interface, (3) Usability evaluation. The details of each part are described in the following sections.

2.1 Extraction of Usability Elements

Prior to evaluation of the target interface, the user operated three basic interfaces, classified as “Standard”, “Thinking”, and “Seeking” interfaces, on a touch screen (Figure 1 and Table 1).

In the “Standard” interface, a random number from 1 to 50 was displayed in the task indication area, and buttons corresponding to numbers from 1 to 50 were displayed below in increasing order, in the button display area. The task required of the user in the “Standard” interface was to push the button of the number indicated in the task indication area.

In the “Thinking” interface, an addition task involving 5 numbers was displayed in the task indication area, and buttons corresponding to numbers from 1 to 50 were displayed below in increasing order in the button display area. The task required of the user in the “Thinking” interface was to push the button that corresponded to the correct number of the solved addition task.

In the “Seeking” interface, a random number from 1 to 50 was displayed in the task indication area, and buttons corresponding to numbers from 1 to 50 were randomly displayed in the button display area whenever a button was pushed. The task required of the user in the “Seeking” interface was to push the button of the number indicated in the task indication area.

For all interfaces, when the user pushed a button, the task indication area was updated, and the task was repeated 50 times. During the operation of the three interfaces on a touch screen, users’ hand movements were recorded with a video camera. The movements of the user’s index fingertip were then extracted by image processing.

Fig. 1. Basic “Thinking” interface displayed on a touch screen. The task indication and button display areas are indicated.

Fig. 2. Image processing for extracting hand movement (yellow lines) and stationary time (circle size)

Table 1. Characteristics of the three basic interfaces

Interface	Task indication area	Button display area
Standard	Random number	Sequence
Thinking	Addition task	Sequence
Seeking	Random number	Random

It was judged from the movements of the fingertip whether the hand was stationary or not. If the following equation (1) was fulfilled, the user’s hand was judged to be in a stationary state.

$$\sum_{i=1}^T D_i \leq D \times T \tag{1}$$

where D_i represents the distance between the positions of the finger in the current and preceding (i) video frame, and T indicates the number of previous frames in which the user’s hand is considered to be in a stationary state for at least $T \times (1/30)$ seconds. D represents the average distance that a subject’s finger moves between each frame for $T \times (1/30)$ seconds. T and D were determined by a preliminary experiment. Figure 2 shows the image of the locus of finger movement (yellow line) and circles, which are in a proportional size to the stationary time, during operation of the “Thinking” interface.

From the distributions obtained during operation of the “Standard,” “Thinking,” and “Seeking” interfaces, histograms for each subject were plotted with stationary time and frequency on the x- and y-axes, respectively (Figure 3).

Fig. 3. Histograms of stationary time for the three interfaces

To extract the unique elements of the “Thinking” and “Seeking” tasks, the histogram obtained from the “Standard” interface operation was subtracted from each histogram. In addition, because the operation time differed between the “Thinking” and “Seeking” interfaces, the histograms were normalized.

In this evaluation approach, data for two or more users’ operations are needed. Notably, however, there is a possibility that the elements of “Thinking” and “Seeking” could be similar, and a user having two similar elements is unsuitable for this proposed evaluation approach. To determine whether a user is suitable for evaluation, it is necessary to examine the degree of similarity (ϵ) in the elements of “Thinking” and “Seeking”, which can be accomplished using the cross-correlation coefficient shown in equation (2).

$$\varepsilon = \sum_{i=1}^{i_{\max}} \sqrt{H_a(i) \times H_b(i)} \quad (2)$$

where $H_a(i)$ and $H_b(i)$ represent the values at the class of i^{th} in each histogram to be compared, and ε is a value from 0 to 1. We consider that a user is appropriate for the proposed evaluation approach when ε is close to 0 (both elements are not similar).

2.2 Analysis of a Target Interface

During the user operation of the target interface, the movement of the fingertip is captured, and the histogram of the target interface is plotted based on the stationary time of the finger movement determined through the image processing. Using the histogram of target interface and the “Thinking” and “Seeking” histograms, the elements of “Thinking” and “Seeking” included in the target interface was analyzed by equation (3).

$$\sum_{i=1}^{i_{\max}} (H_c(i) - \alpha H_a(i) - \beta H_b(i)) \rightarrow \min. \quad (3)$$

where $H_a(i)$, $H_b(i)$, and $H_c(i)$ represent the values at the class of i^{th} in the “Thinking”, “Seeking”, and target interface histograms, respectively, and α and β obtained from expression (3) indicate the amount of “Thinking” and “Seeking” elements, respectively, when the target interface was operated. By the best-subset selection procedure for α and β , the combination of α and β at which equation (3) is minimized is obtained.

2.3 Usability Evaluation

The usability of the target interface was evaluated by plotting the circles obtained for α and β in a graph (Figure 5). Circle size depends on the degree of similarity ε in equation (2), with a larger circle being more suitable for the proposed evaluation. If the plotted circles are close to the point of origin, the usability is high. However, when numerous elements of “Thinking” are included in the target interface, the plotted circles will be close to α axis (the element of “Thinking”). It is thought that the plotted circles in the graph move in the direction of the point of origin on improvement of the element of “Thinking” in the target interface.

3 Evaluative Experiment

We conducted an evaluative experiment involving 10 users operating the test interface, which included both “Thinking” and “Seeking” elements (Figure 4). Based on our analysis, we confirmed that the unique elements of “Thinking” and “Seeking” could be extracted from the test interface for each of the 10 users (Figure 5). Several of the plotted circles were close to the line of $\beta=\alpha$, indicating that both “Thinking” and “Seeking” elements were extracted successfully from the test interface. However, a few plotted circles were located closer to the β axis (the element of “Seeking”) in

the graph shown in Figure 5. Although the location of the circles was dependent on the user, the elements of “Seeking” in test interface were clearly identified. In other words, an improvement of usability on the element of “Seeking” in the test interface was indicated.

3 + 5 + 9 + 5 + 2 =									
44	49	41	20	23	40	6	5	33	1
50	10	35	15	26	29	7	17	34	4
28	36	24	19	27	3	47	42	31	46
8	25	39	30	14	38	48	12	16	45
37	2	32	9	18	43	11	21	13	22

Fig. 4. Test interface including both “Thinking” and “Seeking” elements **Fig. 5.** Results of evaluation for the test interface

4 Conclusions

We have proposed a new method for usability evaluation, which involves taking a video recording of the user’s operation, extracting the movements of the user’s fingertip by image processing, and then evaluating usability based on the elements of “Thinking” and “Seeking”. From the results of an evaluative experiment, our proposed method of usability evaluation appears potentially suited for quantitative analysis, and has applicability that is comparable to classical methods.

References

1. Bojko, A.: Using Eye Tracking to Compare Web Page Design: A Case Study. *Journal of Usability Studies* 1(3), 112–120 (2006)

2. Siegenthaler, E., Wurtz, P., Groner, R.: Improving the Usability of E-Book Readers. *Journal of Usability Studies* 6(1), 25–38 (2010)

3. Ryu, Y.S., Smith-Jackson, T.L.: Reliability and Validity of the Mobile Phone Usability Questionnaire (MPUQ). *Journal of Usability Studies* 2(1), 39–53 (2006)

4. Yoshimoto, K., Onari, H., Watanabe, K.: *Methods Engineering*. Asakura Publishing Co., Ltd., Japan (2001)