A USER EVALUATION SYSTEM USING SENSORS OF SMARTPHONES

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ABSTRACT

Currently, user evaluation systems in online shopping sites and content download sites mainly employ a 5-point evaluation scheme. This scheme was devised to facilitate statistical use by discretizing the continuous quantity of evaluation into 5 points. However, some think that framing the evaluation in terms of only 5 points reduces the dependability of resulting judgments. Therefore, we reasoned that if an evaluation scheme could be designed, which could capture individuals' Kansei evaluation easily and intuitively with continuous quantities, using smartphone sensors, this problem might be partially overcome. The main aim of the present study, then, was to develop a better evaluation system, which reflected the Kansei characteristics of a given user. To this end, we examined the relationship between user evaluation results and the vibration data collected using built-in smartphone sensors, such as accelerometers and gyroscopes, and investigated the error characteristics in the evaluation. In the prototype application we developed, when a user shakes the terminal, the strength of the vibration is measured with the built-in smartphone accelerometer. We conducted an experiment to compare the user evaluation results obtained by our application with those obtained by the conventional 5-point evaluation scheme. The results suggested that the evaluation based on the proposed application was effective because it showed a positive correlation with that based on the 5-point scheme.

Keywords: Kansei evaluation, smartphone, continuous quantity

1. BACKGROUND

Currently, a 5-point scale is the most common scheme used in evaluation systems for online shopping sites and content download sites. A very popular online application is the Google Play application, which is installed on Android devices. As of 2013, Android applications were downloaded more than 50 billion times in total from the Google Play Store, a content marketing site. The Facebook application, one of the applications distributed through Google Play, had been evaluated, on such a 5-point scale, more than 50 million times by December 2016. The 5-point evaluation scheme was developed to discretize evaluation, a continuous quantity by nature, into five points, and thereby make it easier to use the evaluation results for statistics and other purposes. However, some think that evaluations based only on a 5-point scale make it difficult to frame dependable judgments, and are confusing. We reasoned that an evaluation system capable of expressing individual preferences in a simple and intuitive manner, with relatively continuous quantity, could partially solve this problem.

Smartphones are mobile devices equipped with various features. One of these is typically a built-in accelerometer, which can detect subtle movement of the device. Also, gyroscopes and other sensors capable of detecting device movement are often installed in such devices. We hypothesized that if we could develop an evaluation system which measured the intensity of smartphone movement when the device is shaken, we could design a system to express individual preferences in an intuitive manner, with relatively continuous quantity.

The aims of the present study, then, were to determine the relationship between smartphone sensors, such as accelerometers and gyroscopes, and evaluation utilizing such sensors; collect mobile device vibration data to determine error in the evaluation, and analyze the characteristics of Kansei evaluation based on this data; and thereby develop a more sensitive and user-friendly evaluation system.

2. EXPERIMENT TO COLLECT VIBRATION DATA

2.1. Purpose of the Experiment

First, an evaluation based on one piece of data was performed, to determine the general effectiveness of evaluation based on the intensity of vibration. There are two main types of sensors that can detect the movement of a smartphone: an accelerometer and a gyroscope. We conducted the experiment in order to determine whether the maximum value, average value, or frequency value should be used, and how significant the difference was, in terms of the strength with which users shook the smartphone; and obtained device vibration data, using the built-in sensors, to determine:

1. Whether the accelerometer or the gyroscope should be used for such evaluation

2. Whether the maximum value, average value, or frequency value should be used

3. Whether there was a difference in the intensity of vibration among the subjects.

2.2. Measurement Application

To evaluate the intensity of vibration caused by shaking the device, it was necessary to determine the relationship between the intensity of vibration and respective sensor readings. For this purpose, an application was necessary that enabled the output of each sensor to be measured. The experiment aimed to make measurements with only one sensor at a time. Therefore, it was necessary to handle data collected by each sensor separately, for each sensor and for each method of data collection. Also, it was necessary to sort the data by subject, to determine whether there was a difference in the intensity of the vibration between individual subjects, and between male and female subjects. We thus developed an application that enabled the respective output of each sensor to be collected, stored in a database, and viewed.

Three-dimensional data was collected from the accelerometer and gyroscope, and the sensor output was collected roughly 50 times per second.

The average value was obtained by dividing the sum of the absolute values for the period from the start to the end of data collection, by the total number of data collections. To obtain the maximum value, a variable max with an initial value of 0 was created. If the value of max was less than the obtained value, the maximum value was determined by assigning the obtained value to max. The frequency was calculated as follows: if each of the three-dimensional values (x, y, and z) from the accelerometer was opposite in sign to the previously recorded value, 1 was added to the variable count with an initial value of 0. One back-and-forth motion in all directions (x, y, and z) was counted as one oscillation. Then, the frequency was expressed as: count divided by 6.

2.3. Method of the Experiment

The subjects performed the following steps:

1. Shake the device weakly for 5 seconds after a countdown of 3 seconds.

2. Shake the device moderately for 5 seconds after a countdown of 3 seconds.

3. Shake the device strongly for 5 seconds after a countdown of 3 seconds.

The subjects, 20 students in their 20s (14 male, 6 female), repeated steps (1) to (3) 10 times in a seated position. The mobile device used in the experiment was the Xperia Z5.

2.4. Results and Discussion

Five types of data collected with different methods of measurement were divided into three groups: Weak Shaking (-1), Moderate Shaking (0), and Strong Shaking (1), and a correlation analysis was performed. The correlation coefficient was the highest for the intensity of vibration and average acceleration (Table 1).

Table 1: Correlation coefficients: the coefficients in yellow are more than 0.5 (Data Collection Experiment)

Correlation Coefficients					
No.	Maximum Acceleration	Average Acceleration	Maximum Angular Velocity	Average Angular Velocity	Frequency
1	0.830	0.909	0.817	0.869	0.578
2	0.947	0.937	0.917	0.931	0.898
3	0.822	0.964	0.913	0.907	0.898
4	0.735	0.904	0.798	0.881	0.770
5	0.934	0.919	0.901	0.918	0.907
6	0.914	0.923	0.820	0.924	0.887
7	0.902	0.799	0.415	0.604	0.820
8	0.903	0.944	0.897	0.903	-0.084
9	0.970	0.963	0.944	0.953	0.934
10	0.622	0.510	0.580	0.345	0.416
11	0.906	0.891	0.889	0.898	0.768
12	0.910	0.927	0.785	0.816	0.637
13	0.916	0.907	0.913	0.915	0.524
14	0.760	0.890	0.744	0.822	0.307
15	0.890	0.873	0.915	0.909	0.843
16	0.935	0.961	0.916	0.943	0.963
17	0.753	0.839	0.468	0.313	-0.518
18	0.688	0.784	0.637	0.577	0.086
19	0.958	0.946	0.950	0.959	0.880
20	0.671	0.835	0.366	0.258	-0.599
All Subjects	0.848	0.881	0.779	0.782	0.546

Table 1 shows that, generally, there was a high positive correlation, and the average correlation coefficient was the highest for average acceleration. Specifically, the correlation coefficients for maximum acceleration and intensity of vibration, and for average acceleration and intensity of vibration, were more than 0.5 for all subjects, suggesting a strong relationship between the acceleration and intensity of vibration felt by the subjects.

The coefficients for maximum angular velocity, average angular velocity, and frequency were high for most subjects and low for some subjects. There was a negative correlation between intensity of vibration and frequency, probably because, with respect to angular acceleration, some subjects shook the device without twisting the wrist, and with respect to frequency, some subjects shook the device with a large amplitude to generate strong vibrations, causing the frequency to decrease. Given this, we inferred that these measures should be used for measurement with only one sensor, in consideration of the variation among the subjects.

Based on these results, the measure that best represented the intensity of vibration, measured with one sensor, was the average accelerometer value.

Table 2: Standard deviation of the average acceleration for individual subjects. The value in yellow is more than the standard deviation for all subjects

	Standard Deviation Average Acceleration Subject No.			
No.	1	2	3	4
Weak Shaking	1.213	0.424	2.079	2.147
Moderate Shaking	2.077	0.804	2.144	1.977
Strong Shaking	0.977	1.837	0.926	1.264
No.	5	6	7	8
Weak Shaking	0.665	0.757	1.795	1.064
Moderate Shaking	0.919	0.619	2.005	1.009
Strong Shaking	1.326	1.406	2.904	1.348
No.	9	10	11	12
Weak Shaking	0.773	1.042	0.411	1.525
Moderate Shaking	1.999	0.704	1.038	2.443
Strong Shaking	0.980	0.634	1.620	1.913
No.	13	14	15	16
Weak Shaking	0.434	0.575	0.521	0.712
Moderate Shaking	0.764	1.013	0.507	1.563
Strong Shaking	2.099	1.295	3.448	0.955

No.	17	18	19	20
Weak Shaking	1.784	3.235	0.351	1.784
Moderate Shaking	2.965	3.010	0.351	2.877
Strong Shaking	1.647	1.385	1.320	1.405

Table 3: Standard deviation of the average acceleration for all subjects, male subjects, and female subjects

Standard Deviation of Average Acceleration			
	All Subjects	Male Subjects	Female Subjects
Weak Shaking	2.525	2.681	0.940
Moderate Shaking	3.585	3.748	1.948
Strong Shaking	4.972	4.907	4.741

Given the above results, we focused on the average acceleration. Table 2 (male: blue, female: red) shows the standard deviation of the average acceleration for each subject, which was calculated for Weak Shaking, Moderate Shaking, and Strong Shaking, respectively. Table 3 shows the standard deviation of the average acceleration for all subjects, male subjects, and female subjects, also calculated for the three shaking modes.

Table 3 shows that the standard deviation increased for all subjects, male subjects, and female subjects, as the intensity of vibration increased. However, as shown in Table 2, the intensity of vibration that produced the largest standard deviation varied with the subject. The 59/60 standard deviation for individual subjects was less than the value for all subjects. These results indicate that the variation in the average acceleration among the subjects increased as the shaking force increased, regardless of gender.

Given the above, we considered it necessary to provide recognition capability in the application, to accommodate the variation among the subjects, instead of setting separate reference points for all subjects, male subjects, and female subjects.

3. EVALUATION EXPERIMENT USING THE EVALUATION APPLICATION

3.1. Purpose of the Experiment

Based on the results of the experiment in Section 2, we developed an evaluation application capable of recognizing the intensity of shaking by each subject in terms of the average acceleration, and conducted an evaluation experiment to determine whether the evaluation performed by the application corresponded to the Kansei of the subject.

3.2. Evaluation Application

The application was developed using the average acceleration as the index. Each subject performed five sets of three shaking actions (weak shaking, moderate shaking, and strong shaking), and then user registration, so that the application recognized the intensity of shaking by each subject (average acceleration). The first two sets were for practice and not recorded. When the subject tapped the “Start” button on the main screen, the application commenced measurement, collected data on the average acceleration (hereinafter referred to as “the current data”) when the smartphone was shaken, and temporarily recorded the data. The average of the average acceleration for weak shaking and the average acceleration for moderate shaking in the previous data was defined as Reference 1, and the average of the average acceleration for moderate shaking and the average acceleration for strong shaking was defined as Reference 2. The value of the current data was 0 to 25% when it was between 0 and Reference 1, 25 to 75% when between Reference 1 and Reference 2, and 75 to 100% when between Reference 2 and the maximum. The current data was stored in the database as “Weak” when the value was in the blue region, “Moderate” when in the green region, and “Strong” when in the red region. In this way, the application enhanced the recognition process.

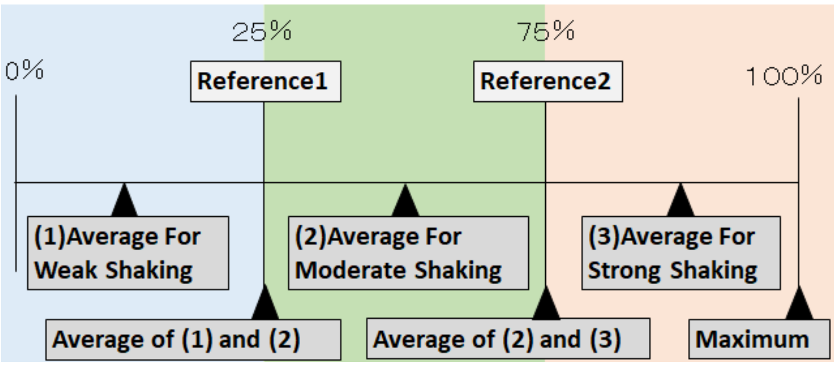

Figure 1: Algorithm for the evaluation application

3.3. Method of the Experiment

The subjects were 15 students in their 20s (10 male, 5 female). The experiment consisted of the following two sessions, in which the subjects used the application.

1. The subjects were asked 15 questions and answered, on paper, using the 5-point evaluation system.

2. The subjects were asked the same 15 questions, and answered using the proposed evaluation application.

If they performed the two evaluations sequentially, the results of the second evaluation may have been affected by the first. Thus, the subjects were each assigned a number, from 1 to 15, in the order in which they underwent the experiment. The odd-numbered subjects performed the 5-point scale evaluation on paper and then the application evaluation, while the even-numbered subjects reversed this order.

The subjects were presented with pictures of a common food and a landscape, and asked how much they liked the food and landscape.

3.4. Results and Discussion

To determine whether there was a correlation between the 5-point evaluation on paper and the application evaluation, correlation analysis was performed on each odd- and even-numbered subject, and all odd- and even-numbered subjects.

Table 4: Correlation coefficients: coefficients in yellow are more than 0.5 (Evaluation Experiment)

Correlation Function								
Odd-numbered	1	3	5	7	9	11	13	15
	0.840	0.940	0.880	0.846	0.232	0.940	0.831	0.875
Even-numbered	2	4	6	8	10	12	14	
	0.959	0.933	0.891	0.912	0.810	0.844	0.815	

Table 5: Correlation coefficients and correlation test results for all subjects, and for the odd- and even-numbered subjects

Correlation Coefficients			Correlation Test Results		
All Subjects	Odd-numbered	Even-numbered	All Subjects	Odd-numbered	Even-numbered
0.829	0.795	0.859	0.000	0.000	0.000
		Maximum		Correlated	Not Correlated

Table 4 shows the respective correlation test results for the 5-point and application evaluations, for each subject; while Table 5 shows the similar results for all subjects and for the odd- and even-numbered subjects. As shown in Table 5, all the values for all subjects indicate a high correlation, and the results for the 5-point evaluation are similar to those for the application evaluation. This indicates that the application algorithm can be applied to Kansei evaluation. The even-numbered subjects, who performed the application evaluation first, show a higher correlation than the odd-numbered subjects, who performed the 5-point evaluation first, suggesting that the application evaluation had a relatively strong effect on the subsequent evaluation, compared to the 5-point evaluation. Table 4 reveals a high correlation in the case of almost all the individual subjects; however, as there was no correlation in the case of one subject, the algorithm must be improved for universal applicability.

Table 6: Average and standard deviation in the application evaluation, with respect to the 5-point evaluation

5-point Evaluation	1	2	3	4	5
Average	15.729	28.062	45.020	69.179	87.990
Standard Deviation	4.513	14.485	20.706	16.190	12.861

Table 6 shows the average and standard deviation in the application evaluation, for all subjects, with respect to the 5-point scale evaluation. As we can see, the average is close to the 5-point score expressed as a percentage (10, 30, 50, 70, and 90), and the standard deviation increases toward a score of 3 in the 5-point evaluation. This indicates that the 5-point evaluation represents the mean value to a lesser extent than the application evaluation.

4. CONCLUSIONS AND ISSUES

The study reveals that the proposed application evaluation using smartphone sensors to measure vibration data can produce results roughly similar to those of an evaluation on a 5-point scale, and at the same time can reveal subtle differences between the two forms of evaluation. We have successfully developed a system that allows for intuitive evaluation. One drawback of the application evaluation, however, is that it takes slightly more time than the 5-point evaluation, with the registration of vibration data by each subject.

Among the issues to be addressed are the development of an algorithm that further reduces the gap between the results of the evaluation application and individual Kansei, and the design of a method that can reduce both the time and the fatigue involved in shaking the smartphone.

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