INVESTIGATION OF PLEASANTNESS IN THE MANIPULATION OF DEFORMABLE INTERFACES FOR MUSICAL EXPRESSION

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ABSTRACT

Currently, deformable user interfaces are a popular topic in the Human Computer Interaction (HCI) community. These interfaces enable intuitive manipulation for users. Deformable interfaces are also reported in the field of musical expression, such as sound controllers. However, the user experience of the manipulation of these interfaces is not well studied so far. This paper therefore focuses on the clarification of *pleasantness* in the manipulation of deformable interfaces for musical expression. First, evaluation experiments were conducted to investigate the pleasantness and user impressions of deformable interface manipulation using 36 dissimilar interface mockups. The evaluation results explained that the impressions related to the activity factor particularly correlate with pleasantness. Also, Hayashi's quantification theory type I revealed the relationship between the physical features of the interfaces and pleasantness. Based on the findings, the ideal deformable interface design for pleasant musical expression was finally proposed. The design was with medium deformation and squashing manipulation.

Keywords: deformable interface, user experience, interface for musical expression, pleasantness, impression

1. INTRODUCTION

Deformable user interfaces currently are popular topic in the HCI (Human-Computer interaction) community. Key applications of deformable interfaces include a flexible handheld display that allows deformation-based interactions (Steimle et al., 2013). These interfaces enable

intuitive manipulation for users. Applications of deformable interfaces are also reported in the field of musical expression, such as a sound controller in which sounds are controlled by bending or stretching deformation of the interface (Chang & Ishii, 2007). Therefore, by means of mapping the deformation to sound change, these controllers enable intuitive control of sounds not only discretely but also continuously. However, the user experience and *pleasantness* in the manipulation of these controllers is basically designed for taking pleasure in the expression of sounds, are not well studied so far.

This study therefore focuses on *pleasantness* in the manipulation of deformable interfaces for musical expression and investigates how the physical features of the interfaces affect *pleasantness* based on the Kansei engineering approach (Nagamachi, 1995). The study also investigates user impressions of deformable interface manipulation and discuss the relationship between the impressions and *pleasantness*. Based on the findings, this study finally proposes a prototype of the ideal deformable interface design that provide more pleasant user experience.

2. EVALUATION OF PLEASANTNESS AND IMPRESSIONS

2.1. Deformable Interfaces

Evaluation experiments that employ deformable interface mock-ups were conducted to quantify user impressions and *pleasantness* in the manipulation of deformable interfaces for musical expression. For preparing mock-ups, various types of deformable interfaces were collected from previous studies (Kinoshita et al., 2014; Dezfouli & van der Heide, 2013; Singer, 2003; Chang & Ishii, 2007; Kiefer, 2010; Jensenius & Voldsund, 2012; Grierson & Kiefer, 2013; Wikström et al., 2013; Alberto, 2014; Milczynski et al., 2006; Watanabe et al., 2007; Henriques, 2012; Bisig & Schiesser, 2013; Marier, 2014; Kildal et al., 2012; Raphael & Patrick, 2011; Vanderloock et al., 2013; Herkenrath, 2008; Troiano et al., 2014; Bacim et al., 2012; Sugiura et al., 2012; Burstyn et al., 2013; Lahey et al., 2012). Based on the collected interfaces, 36 dissimilar interfaces were selected and their mock-ups are shown in Figure 1 were finally prepared for the target of the evaluation experiments. The materials of the mock-ups include paper, wood, rubber tube, elastic cloth, sponge, cotton wool, silicone rubber, latex, metal spring, metal wire, clay, plastic sheet and a rubber ball. Although some of the mock-ups allow two or more types of deformation, this study only focuses one representing deformation for each mock-up since user impressions and *pleasantness* in the interface manipulation may depend on deformation types. The representing deformation for the mock-up Nos. 1, 2, 5, 6, 14, 18, 19, 26, 29 and 31 are *stretching*; Nos. 3, 11, 13 and 21 employ *twisting* manipulation; Nos. 4, 10, 15–17, 23–25, 32, 33 and 36 employ *bending*; Nos. 7–9, 20, 22 and 34 employ *squashing* while Nos. 12, 27, 28, 30 and 35 employ *pushing*.

Figure 1: Mockups of deformable interfaces for musical expression

2.2. Adjective Words

This study employed adjective words in pairs to express user impressions in the manipulation of deformable interfaces. First, 271 adjectives related to interface manipulation were collected from dictionaries and previous studies. Therefore, it is by combining similar adjectives and pairing them with those having opposite meanings, a total of 19 adjective pairs are refined and shown in Table 1.

Table 1: Adjective pairs for the evaluation of user impressions

No.	Adjective Pairs
1	cold - warm
2	poor - rich
3	rough- delicate
4	cramped- spacious
5	styleless - stylish
6	heavy – light
7	uncomfortable - comfortable
8	unfavourable - favourable
9	fuzzy – clear
10	chancy – secure

No.	Adjective Pairs
11	biological - mechanical
12	difficult-to-understand - easy-to-understand
13	unapproachable - approachable
14	ordinary - unique
15	dark - bright
16	undependable - dependable
17	quiet - lively
18	conservative - flashy
19	conventional - unconventional

2.3. Methods

A total of 12 university students that comprised of nine males and three females aged 21–27 years with a mean age of 22.58 (standard deviation = 1.44) years took part in the experiment. Six of them had one or more years of experience of playing musical instruments. The participants received one of the 36 mock-ups and its instruction as a video clip. The video clip lasts approximately 20 minutes and shows the way of manipulating modulation, pitch and volume of sounds by the representing deformation of the mock-up. After watching the video, the participants used the mock-up as if they were actually manipulating sounds and checked the sense of the manipulation. The participants were then asked to evaluate the impressions of the

manipulation using the 19 adjective pairs with five-point Semantic Differential (SD) scale. They also evaluated *pleasantness* of the manipulation using the statement 'I felt pleasant with the mock-up manipulation and a five-point Likert scale where '1' and '5' represents disagree and agree, respectively. The set of evaluations was followed by an interview in which the participants responded to the question 'What kinds of features were pleasant/unpleasant in manipulating the mock-up?' Each participant executed the aforementioned evaluation procedure for all the 36 mock-ups. The order of mock-up presentation was balanced between participants.

2.4. Results and Remarks

Figure 2 shows the evaluation results of *pleasantness* in the manipulation of each deformable interface mock-up. The best-rated mock-ups were Nos. 6, 2 and 1, and their average scores were 4.50, 4.08 and 4.00, respectively. All these mock-ups were with manipulation resistance, manipulated by stretching deformation and recovered to their original form by themselves after the deformation. Their deformation scale was neither too small nor too large. Meanwhile, the mock-ups Nos. 19, 31 and 34 were worst rated with the average score of 1.50, 1.75, 1.83, respectively. The deformation scale of these mock-ups was commonly small.

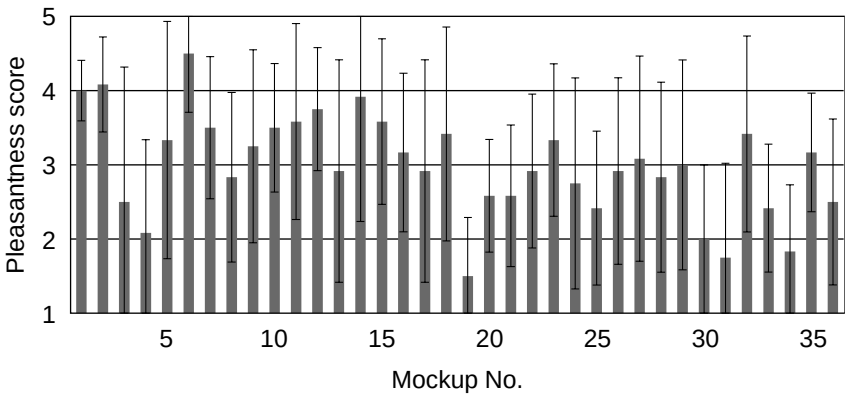

Figure 2: Evaluation results of pleasantness in the manipulation of each mock-up

The evaluation scores of the six participants with the experience of playing musical instruments are compared with those of the remaining six participants without the experience. The results of the *t*-test explained that no significant difference exists between the two groups in relation to all the mock-ups except mock-up No. 3. The average pleasantness scores for the mock-up No. 3 were 1.33 and 3.67 because the participants involved are a mixture of between experienced and inexperienced, respectively. An inexperienced participant commented that 'The unexpected movement was fun.' in the interview. However, a participant with musical experience commented 'Adjusting the sound was difficult due to the unexpected movement.' These results suggested that the unexpected movement was one of the contributing factors that decrease pleasantness for users with musical experience. The difference of the evaluation scores between the participants with and without the musical experience was not significant except for the one mock-up, the effect of the musical experience was not considered in the after-mentioned analyses.

3. INVESTIGATION OF PLEASANT MANIPULATION

3.1. Relationship between Impressions and Pleasantness

In order to analyse the relationship between user impressions and *pleasantness* in the manipulation of deformable interfaces for musical expression, the semantic space of the impressions was simplified. A Factor Analysis with the principal factor method was performed using the average impression evaluation scores for all participants. Four factors were extracted where the eigenvalue was over 1.0. Table 2 shows the result of factor matrices rotated by the Varimax method. Note that the result is sorted in descending order of the absolute value of factor loadings with respect to each factor. The factor loadings in the table indicate that Factors 1, 2, 3 and 4 are considered as the factors of activity, amenity, stability and clarity, respectively. The accumulated contribution ratio was 73.7%. This value indicates that most characteristics of user impressions for the manipulation can be expressed by these four factors.

Based on the extracted four factors, the relationship between user impressions and pleasantness was analysed. Figure 3 illustrates the relationship between the factor scores and the average pleasantness scores. A statistically significant correlation was observed between Factor 1 (activity) and *pleasantness* (two-sided test: $t(34) = 5.26$, $p < 0.01$) with the correlation coefficient of $r = 0.67$. The pleasantness scores also correlated with the scores of Factor 2 (two-sided test: $t(34) = 3.27$, $p < 0.01$) and Factor 4 (two-sided test: $t(34) = 2.70$, $p < 0.05$) with the correlation coefficients of $r = 0.49$ and $r = 0.42$, respectively. Meanwhile, no correlation was observed for Factor 3 (two-sided test: $t(34) = 0.45$, $p = 0.65$).

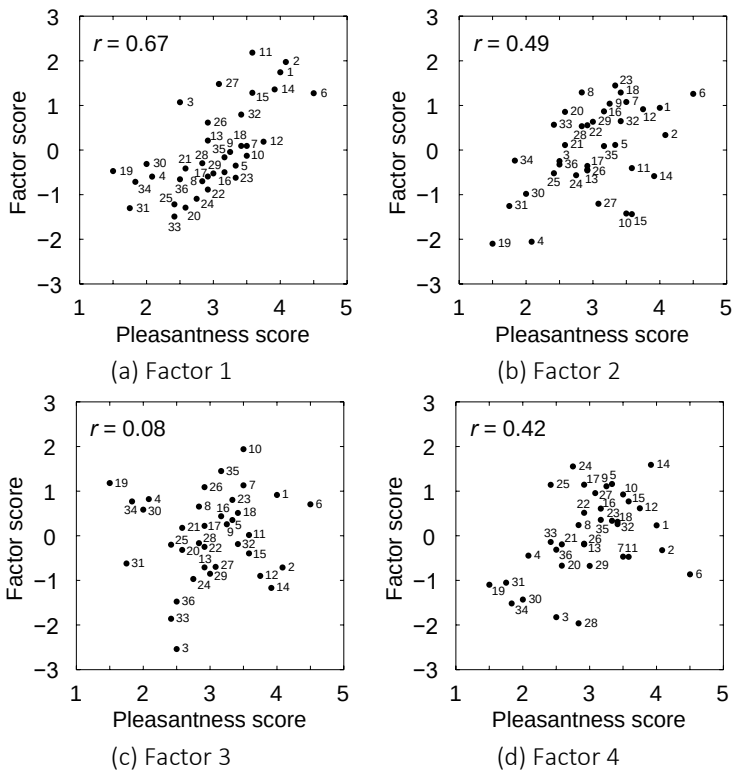

Figure 3: Relationship between factor scores and the evaluation scores of pleasantness

Table 2: Result of factor analysis

Adjective Pairs	Factor 1	Factor 2	Factor 3	Factor 4
conservative – flashy	0.916	−0.161	−0.162	0.056
poor – rich	0.862	0.078	−0.028	0.301
styleless - stylish	0.859	0.171	−0.014	0.038
quiet – lively	0.814	−0.159	−0.192	0.122
rough- delicate	0.783	0.135	0.066	−0.011
dark – bright	0.715	0.350	0.044	0.216
ordinary – unique	0.667	−0.127	0.294	−0.413
conventional – unconventional	0.654	−0.139	0.295	−0.517
cramped- spacious	0.625	0.488	0.021	0.405
heavy – light	−0.088	0.873	−0.348	0.078
uncomfortable – comfortable	0.273	0.741	0.140	0.286
cold – warm	−0.083	0.677	0.360	0.013
unapproachable – approachable	−0.004	0.626	0.358	0.514
unfavourable – favourable	0.520	0.582	0.183	0.408
chancy – secure	−0.343	0.269	0.844	0.034
undependable – dependable	0.103	−0.145	0.773	0.191
biological – mechanical	0.201	−0.136	0.544	−0.157
difficult-to-understand - easy-to-understand	0.093	0.291	0.292	0.794
fuzzy – clear	0.446	0.118	0.046	0.583
Contribution Ratio (%)	32.1	16.9	12.5	12.2

3.2. Relationship between Physical Features of Interfaces and Pleasantness

In order to clarify the relationship between the physical features of deformable interfaces for musical expression and *pleasantness* of their manipulation, an analysis based on quantification theory type I (Hayashi, 1952) was conducted using the average pleasantness evaluation score for all participants. The analysis used the seven items with up to five categories shown in Table 3 to express the physical features.

Table 4 shows partial correlation coefficients between *pleasantness* and each item. The first and second highest coefficients explained that the items of deformation scale and deformation type strongly affected pleasantness. Meanwhile the items of shape recovery and manipulation resistance were explained that they were hardly related to pleasantness. Figure 4 shows the category scores regarding to pleasantness. The scores represent how the physical features of the interfaces affect pleasantness in the manipulation. The scores represented that medium deformation increased pleasantness in the manipulation though too large deformation scale resulted in decreasing pleasantness. Some of the participants commented, 'Because the limit of deformation was unclear, I felt afraid of how far I can operate.' and 'I will get tired because of the

large deformation amount.' in the interview. These comments accorded with the results. The scores also indicated that pleasantness increased by using the squashing manipulation while it decreased by using the twisting manipulation. Several participants commented, 'It is easy to understand that the more I squash this, the more the sound changes.' and 'I cannot imagine the twisting manipulation to control the sound.' The comments also corresponded with the results.

Table 3: Items and their categories for the analysis of quantification theory type I

Item	Categories				
deformation type	pushing	squashing	stretching	bending	Twisting
deformation scale	large	medium	small		
manipulation resistance	large	medium	small		
shape recovery after manipulation	yes	no			
held in hand when manipulated	yes	no			
hand region used for manipulation	fingertip	palm	palm+arm		
number of hands used for manipulation	one-handed	two-handed			

Table 4: Partial correlation coefficient for each item

Item	PCC
deformation type	0.508
deformation scale	0.757
manipulation resistance	0.126
shape recovery after manipulation	0.010
held in hand when manipulated	0.298
hand region used for manipulation	0.342
number of hands used for manipulation	0.331

4. PROTOTYPE OF DEFORMABLE INTERFACES FOR MUSICAL EXPRESSION WITH PLEASANT MANIPULATION

Based on the findings throughout this study, a prototype design of the ideal deformable interface for pleasant musical expression is finally presented. In order to realise pleasant musical manipulation, the interface needs manipulation resistance and to be recovered to its original form after the manipulation as mentioned in Section 2.4. It is also important to adopt a medium deformation scale and squashing manipulation as described in Section 4.2. A prototype of deformable interface that satisfies these attributes was implemented as shown in Figure 5. This prototype is made out of a sponge cuboid covered with elastic cloth with a width of 10 cm, a depth of 10 cm and a height of 20 cm. Sound attributes like modulation and pitch can be controlled by using a single-hand squashing of the prototype. A 12 cm bending sensor is connected to a microcontroller (Arduino Uno) that is installed alongside the sponge cuboid so that the amount of squashing can be detected. The sensor value is transmitted to a PC through

the microcontroller and converted into MIDI data using PC software running on the Pure Data programming environment. The MIDI data is finally sent to a synthesiser.

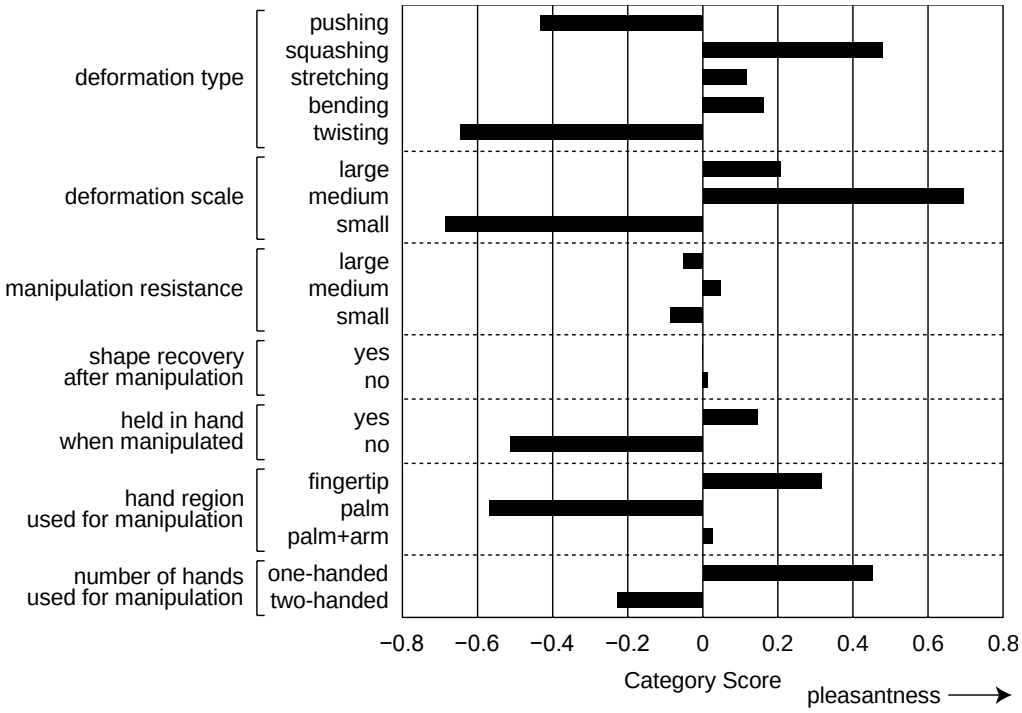

Figure 4: Category scores regarding to pleasantness in the manipulation

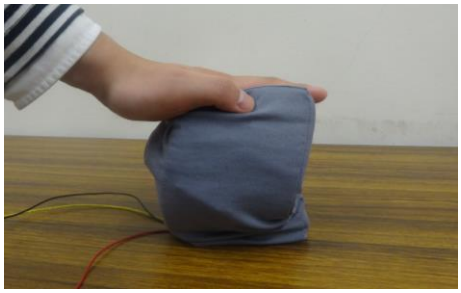

Figure 5: Prototype of the proposed deformable interface for musical expression

5. CONCLUSION

This paper focused on *pleasantness* in the manipulation of deformable interfaces for musical expression and investigated the ideal deformable interface design for pleasant musical expression. In the investigation process, a set of evaluation experiments was conducted to quantify user impressions and *pleasantness* in the manipulation. The results clarified the relationship between the impressions and pleasantness as well as the relationship between the physical features of the interfaces and pleasantness. This study provided the following findings regarding to *pleasantness* in the manipulation of deformable interfaces for musical expression.

1. User impressions in the manipulation of deformable interfaces are expressed by mainly four factors which are activity, amenity, stability and clarity.

2. The factor most related to *pleasantness* in the manipulation is the activity factor.

3. The physical features of the interface are strongly related to *pleasantness* in the manipulation are the scale and the type of deformation. The attributes of medium deformation scale and squashing manipulation respectively contribute to increase *pleasantness.*

These findings can be used as a guideline to create future deformable musical interfaces that provides a heightened pleasantness user experience. This study is focused on *pleasantness* with respect to the manipulation. Further investigations upon the effects of the physical appearance of deformation from the approach of user experience should be expedited.

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