Kansei Engineering International Vol.8 No.2 pp.147-152 (2009)

ORIGINAL ARTICLES
SPECIAL ISSUE

TACTILE SENSATION AS EMOTION ELICITOR

Hyeon-Jeong Suk*, Sang-Hoon Jeong**, Tae-Heun Yang*** and Dong-Soo Kwon***

** Department of Industrial Design, KAIST, Daejeon 305-701, Republic of Korea, h.j.suk@kaist.ac.kr*
*** Department of Industrial Design, Mokwon University, Daejeon 302-729, Republic of Korea, diasoul@mokwon.ac.kr*
**** HRI Research Center, KAIST, Daejeon 305-701, Republic of Korea, yangth@robot.kaist.ac.kr*

Abstract: Recent empirical studies have categorized tactile qualities in terms of being rugged, prickly, smooth, tender, etc. The studies manipulated the frequency and amplitude of stimuli and revealed that tactile sensation changed. In this study, the emotional responses to 12 tactile sensations were examined with regard to the manipulation of frequency (4 levels) and amplitude (3 levels) in the pin-array tactile display. The emotional response to tactile sensation was assessed by pleasure and arousal dimension of emotion, and by 6 bipolar scales—6 pairs of texture related adjectives. Based on the empirical results, we described the emotional profile of tactile sensation. Particularly, we adopted Russell's Circumplex Model in order to define certain areas in emotion space discretely. The emotional responses to 12 tactile sensations appeared to be within a diagonal in emotion space, and the implication thereof is discussed.
Keywords: *Tactile sensation, Emotion, Pleasure, Arousal*

1. INTRODUCTION

Since the time ubiquitous computing environments started to be developed, researchers have examined how the five human senses receive information and are stimulated to produce a more immersive, interactive, and natural feeling. Visual and auditory channels are more often focused as the major sensory channels to convey information to users when using electronic devices. The sense of touch can be added to the auditory and visual senses to enhance multimodal feelings.

Our research interest is in mechanical tactile feedback that can improve usability and performance of users through intense perception. In previous studies on tactile feedback, there have been two kinds of remarkable streams. The first regards how to design a tactile display. In order to display detailed textures and small-scale shapes, there have been various attempts to develop a pin-array tactile display that can locally stimulate a human finger's mechanoreceptors with an independently-actuating, delicate array of pins. Kim and his colleagues [1] developed a compact pin-array type tactile display unit and attached it to a PHANTOM TM haptic device. Some researchers have used piezoelectric bimorphs as the skin contactor [2] or an ultrasonic linear motor to construct a new miniature tactile module [3].

The second stream of research regards how to enable subjects to feel the tactile sensation. Some previous studies have dealt with sensation-to-tactile stimuli with a developed tactile display. The essential parameter in tactile sensation is the pins' frequency and amplitude. The response to artificial tactile stimuli created by a tactile device was quantitatively evaluated [3]. Some have tried to view the responses as an aspect of emotion. In Sohn and Yi's study [4], text-tactile sensibility was estimated to determine which emotional states were aroused. Ten sensation and 8 emotional adjectives were extracted to describe text-tactile stimuli. The study concluded that as the tactile stimuli are presented, perceptual and emotional responses are simultaneously elicited. Nevertheless, there has been no systemized way to define the relationship between the emotional response and tactile sensation yet. In this study, we aimed at investigating the emotional profile of tactile sensation generated by varying frequency and amplitude.

2. PERCEIVING TACTILE STIMULI

This study extends a previous experiment of Kim and his colleagues [5], focusing on the emotional response to tactile sensation. In this study, a pin-array tactile display was devised in order to examine how differently the subjects perceive tactile stimulation. Before the empirical study, the authors collected tactile related adjectives asking the subjects to touch various sandpapers. Ten adjectives were collected to represent tactile sensations: "bumpy", "rugged", "prickly", "lumpy", "rough", "smooth", "acute", "tender", "sparse", and "dense". The tactile adjectives were used for subjects to describe tactile sensation generated by the pin-array tactile display.

2.1 Tactile module

The tactile module consisted of thirty piezoelectric bimorphs with pins for normal vibrotactile stimulation, as

Received 2009.xx.xx
Accepted 2009.xx.xx

shown in Figure 1, and the tactile modules were embedded into a mouse as shown in Figure 2. The piezoelectric bimorphs were stacked to a holder to minimize pin gap to 1.8 mm spacing, and the pins were attached to the end of each bimorph. The maximum deflection was over 700μm, and the blocking force was 0.06 N. The range of working frequency was from 0 to 250Hz. We used discrete levels of amplitude as well as frequency: 3 levels of amplitude (20μm, 50μm, 200μm) and 4 levels of frequency (2Hz, 5Hz, 25Hz, 100Hz) for12 tactile stimuli in total.

The 12 tactile sensations were applied, and the subjects responded using the 10 adjectives. A 7-Point Likert Scale, ranging from 1 (not at all) to 7 (absolutely), was used to evaluate the quality of the tactile sensation provided by the tactile display that generated stimuli while varying the log-scaled frequency and amplitude.

2.2 Tactile sensation manipulated by frequency and amplitude

Based on the ratings from the 7-point scale, the tactile adjectives were allocated to the corresponding tactile stimuli, as shown in Figure 3. The figure shows that as the frequency and amplitude increase, sensations such as "prickly", "rough", "acute", "lumpy", "dense", and "uneven" were intensified proportionally. As the frequency and amplitude decrease, other sensations, such as "smooth" and "tender" were intensified. As the frequency increases and the amplitude decreases, the sparse and bumpy sensations were amplified.

The study explains how to generate different tactile sensations through the manipulation of amplitude and frequency of a pin-array display. Extending this empirical study, we intended to identify the emotional response to the tactile sensation.

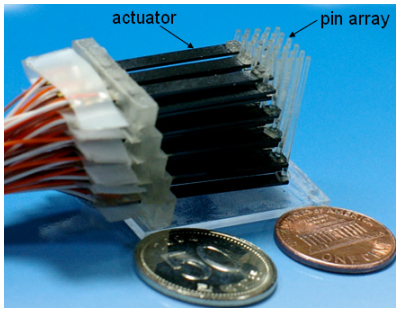

Figure 1: Planar Piezo-actuating unit.

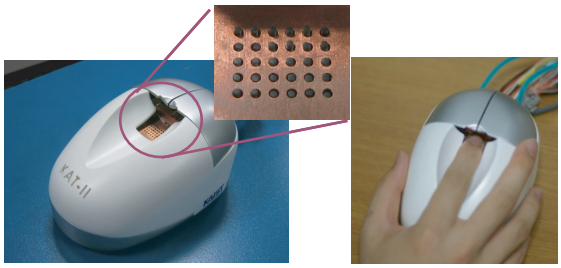

Figure 2: Planar distributed pin-array tactile display and Piezo-actuating unit.

3. GOALS

The purpose of this study is to investigate the emotional responses to the tactile sensation. The 12 tactile stimuli were used, and a set of bipolar scales was prepared to measure emotional response.

4. EXPERIMENT

A preliminary test and a main experiment were conducted. In the preliminary test, the adjectives were collected that were related to tactile sensation. In the main experiment, the emotional response to the tactile sensation was assessed in terms of pleasure and arousal as well as in terms of the collected emotional adjectives.

4.1 Preliminary Test

In this test, emotional adjectives were collected while subjects were experiencing different types of material surface. This test was divided into two steps. First, the emotional adjectives were collected that matched the most frequently mentioned verbal response to ten kinds of material surface. Second, the collected adjectives were compared with the adjectives from an existing study [4].

1) Results

Nine people, 8 males and 1 female, participated in the preliminary test. (Mean of age = 27, ranging between 24 and 32 years). All participants reported no known coetaneous or kinesthetic problems. All of them participated in the main experiment later.

The subjects were asked to touch the material samples

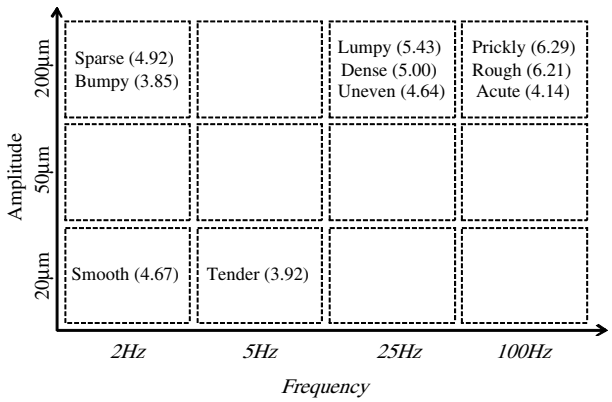

Figure 3: Tactile adjectives matched to corresponding tactile stimuli. In parentheses is the averaged rating of each adjective.

and to describe their emotional response with adjectives (in the Korean language). The most mentioned six adjectives were “comfort”, “unique”, “nice”, “cool”, “new”, and “interesting”. Previously, Sohn and Yi conveyed an experiment to assess the emotional responses to various cloths. In their study, emotional adjectives were collected: “comfort”, “unique”, “new”, “cool”, “luxury”, “clean”, and “old” [4]. So, four of the adjectives were already in common. In addition, we added two sets of adjectives that illustrate two dimensions of emotion: “pleasant” and “arousal”. Therefore, 8 adjectives including five adjectives and two sets of adjectives were collected in order to assess the emotional response to tactile sensations in the main experiment.

4.2 Main Experiment

In the main experiment, our goal was to investigate the emotional responses to tactile sensations that were in the pin-array tactile display.

1) Subjects

The 9 subjects from the preliminary test participated.

2) Stimuli

Frequency and amplitude were modulated to generate 12 types of tactile stimuli, as described in section 2.1. In order to assess the emotional response, the 8 adjectives were utilized to provide the subjects with 8 bipolar scales (see Table 1).

3) Procedure

The subjects placed their index finger over the pin-array of the tactile display and experienced one of the the 12 tactile stimuli in random order. They were asked to gently press their finger over the tactile display and then to assess the emotional responses to each stimulus using the 8 bipolar scales. The subjects were permitted to explore the actuating pin-array while filling out the questionnaire for each stimulus. Each scale was divided into 7 points, and the subjects rated stimuli between a pair of the adjectives presented in Table 1. The ratings were encoded as between -3 and +3.

Figure 4: Material samples for tactile experience preliminary test. In the upper row from left: silver foil, polymer, sandpaper (very fine), sandpaper (very rough), and sandpaper. In the lower row from left: felt, hemp cloth, cotton fabrics, sponge, and cotton.

4) Results

On pleasure and arousal

Table 2 presents the mean ratings of the 12 tactile stimuli on the pleasure and arousal. In Figure 5, the plots of 12 stimuli are depicted in emotion space as defined by pleasure (horizontal axis) and arousal (vertical axis). The rating range is between “-3” and “+3”, and the distance from the center is also calculated. For example, the subjects rated “S12” (100Hz, 200μm) to be unpleasant (-1.44) and highly arousing (2.67), and thus the distance from the center is 3.03. The emotion space illustrated in Figure 5 provides not only the internal relationship between the stimuli in aspects of pleasure and arousal, but also relates every 22.5 degrees to a corresponding

Table 1: Emotional adjectives

	(–)	(+)
The selected tactile emotion adjectives	불편한 (Discomfort)	편안한 (Comfort)
	평범함 (Plain)	독특한 (Unique)
	불쾌한 (Bad)	상쾌한 (Nice)
	답답한 (Stuffy)	시원한 (Cool)
	식상한 (Boring)	신선한 (New)
	재미없는 (Not Interesting)	재미있는 (Interesting)
Emotional dimension	<Unpleasant> *불만족한 (Unsatisfied)* *불행한 (Unhappy)* *불안한 (Nervous)* *절망적인 (Desperate)* *우울한 (Melancholy)*	<Pleasant> *만족한 (Satisfied)* *행복한 (Happy)* *좋아하는 (Pleased)* *희망적인 (Hopeful)* *안정된 (Balanced)*
	<calm> *둔한 (Slow)* *차분한 (Calm)* *졸리는 (Sleepy)* *평온한 (Quiet)* *느긋한 (Relaxed)*	<aroused> *성급한 (Rushing)* *흥분한 (Excited)* *깨어있는 (Awake)* *흥분한 (Aroused)* *자극된 (Stimulated)*

Table 2: Results in Terms of Pleasure and Arousal

Frequency	Amplitude (Stimulus Nr.)	Pleasure	Arousal	Distant from the Center
2Hz	20μm (S1)	-0.44	-0.56	0.71
	50μm (S2)	-0.11	-0.44	0.45
	200μm (S3)	1.00	-0.78	1.27
5Hz	20μm (S4)	0.33	-0.22	0.40
	50μm (S5)	0.22	-0.44	0.49
	200μm (S6)	0.67	-0.33	0.75
25Hz	20μm (S7)	-0.56	0.22	0.60
	50μm (S8)	-0.33	1.22	1.26
	200μm (S9)	-0.56	2.00	2.08
100Hz	20μm (S10)	-0.88	0.25	0.91
	50μm (S11)	-0.89	1.33	1.60
	200μm (S12)	-1.44	2.67	3.03

emotional quality proposed by Russell [6]. Therefore, Figure 5 shows how to understand the quality of the emotional response to the 12 tactile stimuli. The emotional response to "S12" (100Hz, 200μm) elicited a very "nervous" feeling, whereas that to "S11" (100Hz, 50μm) elicited a "nervous" feeling. Hence, the farther the distance from the center is, the more intense was the affectivity.

Figure 6 associates each stimulus with a corresponding emotional quality and presents the distance from the center in parentheses: the longer the distance from the center, the more intense the emotional response. Comparing the results presented in Figure 3 suggests combinations between tactile sensations and emotional quality: "Smooth" elicits a lethargic feeling, whereas "Prickly" elicits a nervous feeling. Moreover, the results present a tendency where an increase of frequency and amplitude is positively correlated with the intensity of the emotional response.

The emotional quality of each tactile stimulus shown in Figure 6 is, however, not yet focused on tactile emotion. It's based on Russell's framework, which outlines human beings' emotional responses in general. Therefore, the following analysis of responses with tactile emotion adjectives provides deeper insights into the different emotional responses to the 12 tactile stimuli.

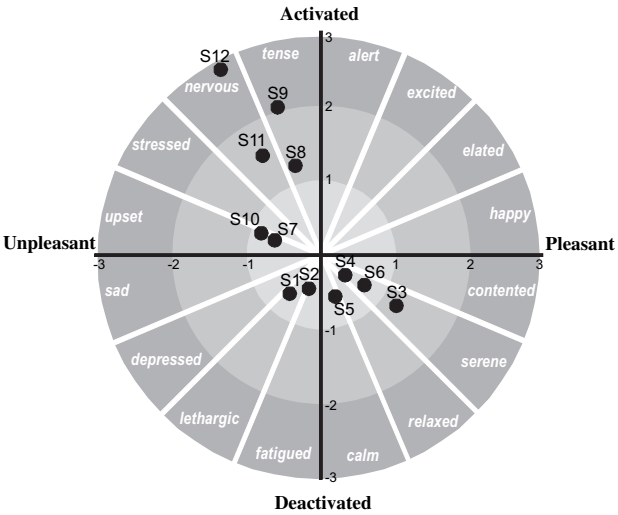

Figure 5: The Averaged Values of 12 Tactile Stimuli Depicted in Russell's Circumplex Model.

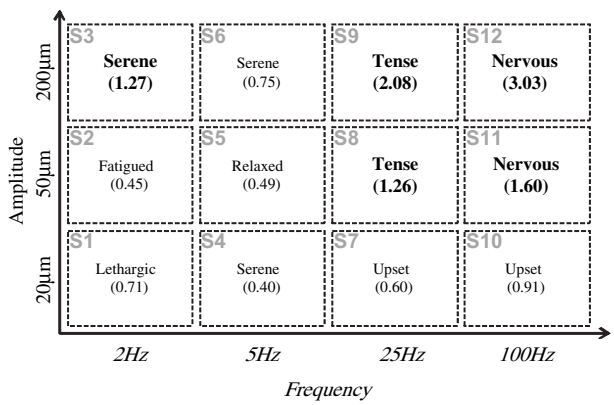

Figure 6: Matching the 12 Tactile Stimuli with Russell's Emotion Terms, with Distance from the Center in Parenthesis.

Responses with tactile emotion adjectives

Table 3 presents the averaged ratings of 6 bipolar scales for 9 subjects. The mean values whose absolute values are more than 1 were taken into account and are underlined in Table 3. In terms of tactile emotion adjectives, "S12" (100Hz, 200μm) elicits "very discomforting", "very unique", "quite bad", "quite new", and "quite interesting" feelings.

Accordingly, Figure 7 illustrates the tactile emotional responses to the 12 stimuli and the likelihood of each adjective is presented, ranging from 0 to 3. In addition, some tendencies are indicated, as follows.

Table 3: Responses with Tactile Emotion Words.

D↔C: Discomfort↔Comfort, P↔U: Plain↔Unique
B↔N: Bad↔Nice, S↔CL: Stuffy↔Cool
BR↔NW: Boring↔New, N.I↔I: Not Interesting↔Interesting

Stimulus properties		Tactile emotion adjectives					
		D ↔ C	P ↔ U	B ↔ N	S ↔ CL	BR ↔ NW	N.I ↔ I
2Hz	20μm (S1)	-0.11	-0.67	-0.33	-0.67	**-1.00**	**-1.33**
	50μm (S2)	0.67	**-1.00**	0.00	-0.56	-0.89	**-1.22**
	200μm (S3)	0.78	0.22	-0.11	-0.56	0.00	0.11
5Hz	20μm (S4)	0.22	-0.67	-0.11	0.00	0.44	0.00
	50μm (S5)	0.33	-0.56	-0.33	0.33	-0.33	-0.56
	200μm (S6)	**1.11**	0.33	-0.22	0.56	0.89	**1.00**
25Hz	20μm (S7)	0.00	-0.78	-0.67	-0.11	-0.33	-0.44
	50μm (S8)	-0.44	0.67	-0.22	0.00	0.33	0.22
	200μm (S9)	**-1.78**	**1.78**	-0.33	0.67	**1.22**	**1.56**
100Hz	20μm (S10)	**-1.00**	-0.25	-0.38	-0.13	-0.75	**-1.13**
	50μm (S11)	**-1.11**	0.89	-0.22	-0.11	0.44	0.22
	200μm (S12)	**-2.11**	**2.11**	**-1.78**	0.67	**1.67**	**1.00**

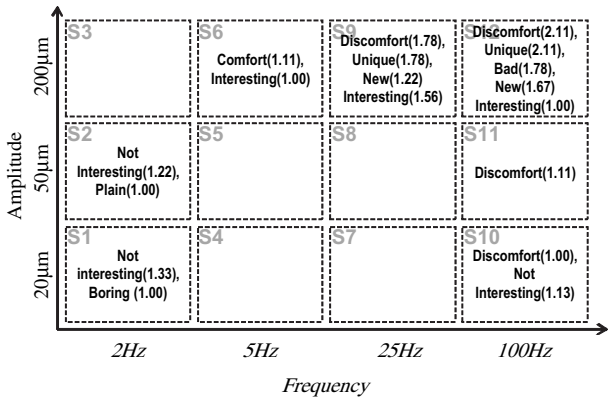

Figure 7: Tactile Emotional Responses to the 12 Stimuli.

- As the level of frequency and amplitude is increased, the emotional responses appear to be clearer.
- As the level of frequency and amplitude is increased, the emotional adjectives related to curiosity were elicited: unique, new, and interesting. On the other hand, negative emotional adjectives were elicited as well: discomforting and unpleasant.

The emotional quality of each tactile stimulus shown in Figure 6 is, however, not yet focused on tactile emotion. It's based on Russell's framework, which outlines human beings' emotional responses in general. Therefore, the following analysis of responses with tactile emotion adjectives provides deeper insights into the different emotional responses to the 12 tactile stimuli.

5) Discussion

This study investigated the characteristics of emotional responses to tactile sensation. Twelve tactile stimuli were generated, varying in frequency and amplitude using a pin-array display implemented in a mouse. Since only 9 subjects participated in the empirical study, the small number of ratings is insufficient to generalize the results. Nevertheless, the study explored the emotional profile of tactile sensation and a research methodology was developed and applied, which could be employed in a further experiment. Based on the emotional responses in terms of pleasure and arousal, we would like to address the uniqueness of tactile affectivity. As presented in Figure 5, the emotional responses to the 12 tactile stimuli are plotted in the emotion space defined by pleasure and arousal and appear to be shaped as a diagonal shape crossing over the 2nd quadrant and the 4th quadrant.

This observation indicates that tactile stimuli used in this study elicit emotional responses more easily in the 2nd and the 4th quadrants than in the 1st and the 3rd quadrants. Some recent studies discussed this uneven distribution of emotional responses in the emotion space. Bradley and her colleagues indicated a "boomerang-shaped" concentration. They presented the subjects with more than 950 color pictures and revealed that the emotional responses were placed either in the 1st quadrant or the 3rd quadrant in the emotion space [7]. The emotion space was defined by pleasure and arousal, which is identical to the emotion space in this study. In another study on the emotional response to color, the mean values of pleasure and arousal were plotted either in the 1st or in the 3rd quadrants [8]. Therefore, emotional responses to the different types of the stimuli modality may provide different emotional profiles in the emotion space. Since the emotional impact of multi-sensorial stimuli is receiving increasing attention, more research is clearly needed.

5. SUMMARY AND CONCLUSION

In this study, a pin-array display was used to investigate the emotional responses to tactile sensation, which were varied with by level of frequency (4 levels) and amplitude (3 levels). In the preliminary test, 6 emotion words (adjectives) related to tactile sensation were collected and employed in the main experiment. Besides the 6 adjectives, two dimensions of emotion, "pleasure" and "arousal," were taken into account. Sets of adjectives describing "pleasure" or "arousal" were prepared and, in total, 8 bipolar scales were provided. The subjects were asked to assess their emotional responses to the 12 tactile sensations using the 8 bipolar scales, and the mean values were presented in an emotion space defined by pleasure and arousal (see Figure 5) as well as in coordinates defined by frequency and amplitude (see Figure 7). Therefore, we showed the quality of emotion elicited by the tactile stimuli not only in terms of general emotion terms but also in terms of tactile specific adjectives.

Although no statistical evidence is yet provided, the results illustrate the emotional profile of the 12 tactile stimuli. For instance, as the level of frequency and amplitude increases, the emotional responses are intensified. Based on the empirical results provided in this study, the methodology can be applied in a future study with a larger number of subjects in order to provide more robust results. In addition, as shown in Figure 5, the mean values of 12 tactile stimuli are plotted in emotion space, appearing to be in a shape of ellipse. The responses are concentrated either in the 2nd or in the 4th quadrants of the emotion space. It remains an open question, whether it is, in fact, more difficult to elicit emotional responses in the 1st or in the 3rd quadrants using tactile stimuli. Further study is thus needed. The empirical results provided in this study could be applied to a tactile interface in order to enhance the emotional quality of the usability.

REFERENCES

1. S.C.Kim, K.U.Kyung, J.H.Sohn; An Evaluation of human sensibility on perceived texture under variation of vibrotactile stimuli using a tactile display system. In the Proceeding of 14th Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems; pp.429-436 (2006).
2. I.R.Summers, C.M.Chanter; A broadband tactile array on the fingertip. The Journal of Acoustic Society of America;112(5), pp.2118-2126 (2002).

3. K.U.Kyung, J.S.Park; Ubi-Pen: development of a compact tactile display module and its application to a haptic stylus. broadband tactile array on the fingertip. In the Proceeding of Second Joint EuroHaptics Conference and Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems; pp.109-114 (2007).
4. J.H.Sohn, I.G.Yi; Psychophysiological Approach for the Study of Texture-tactile Sensibility. Fiber Technology and Industry; 2(4), pp.439-450 (1998).
5. S.Y.Kim, K.U.Kyung, J.S.Park D.S.Kwon; Real time area-based haptic rendering and the augmented tactile display device for a palpation simulator. In Proceedings of Advanced Robotics; pp.961-981 (2007).
6. J.A.Russell; A Circumplex model of affect. Journal of Personality and Social Psychology; 39, pp.1161-1178 (1980).
7. M.M.Bradely, P.J.Lang; The International Affective Picture System (IAPS) in the Study of Emotion and Attention. In; J.A.Coan, J.J.Allen (Ed.) Handbook of Emotion Elicitation and Assessment, pp.29-46 (2007).
8. H.J.Suk, H.Irtel; Emotional Response to Simple Color Stimuli. *Kansei* Engineering International; 7(2), pp.181-188 (2008).

Suk, Hyeon-Jeong

Hyeon-Jeong Suk has obtained her Ph.D. in psychology from the University of Mannheim in Germany and is an assistant professor at department of Industrial Design in KAIST. Her research area includes color education, color psychology, and emotional design, and she tries to bridge the two disciplines-industrial design and psychology- to apply scientific background for design practice. She is a member of the Korea Society of Emotion and Sensibility, Korea Society of Design Science, Korea Society of Color Studies, Korea Society of Fashion Business, and Japanese Society of *Kansei* Engineering. Professionally, she worked as a designer for LG Internet Inc. in Seoul and Steinbeis GmbH in Cologne, and currently conducts design projects for industry.

JEONG, Sang-Hoon

Sang-Hoon JEONG is a professor at the department of industrial design in MOKWON University, Korea. His research interests include user-interface design, emotional design, and product design. He teaches interaction design, emotional design, design methodology, product design, presentation skill, and so on in MOKWON University. He is also a regular member of Korean Society of Design Science (KSDS), Korean Society for Emotion & Sensibility (KSES), Japan Society of *KANSEI* Engineering (JSKE), and Asia Digital Art and Design Association (ADADA). He has published about 18 papers in international and domestic journals by this time. He has worked for the major companies in Korea like Samsung Electronics and Samsung Heavy Industries for several years and established the design consulting firm, Design Dream Co., Ltd. in 1998. He had consultations with many companies on product design and user-interface design.

Yang, Tae-Heon

Tae-Heon Yang is a Ph.D Student at the department of mechanical engineering in KAIST, Korea. His research interest includes haptics, specially developing new miniature tactile actuators & modules. He has published about 9 papers in international & domestic conference and about 40 international & domestic patents by this time.

Kwon, Dong-Soo

Dong-soo Kwon is a professor at the department of mechanical engineering in KAIST, Korea. His research interests include haptics, human-robot interaction and medical robot. He teaches human-robot interaction, haptics, optimal control and so on in KAIST. He is also a President of Korea Haptics Community, vice president of Korea Robotics Society (KRS), board of directors of Bio-Engineering Division in the Korean Society of Mechanical Engineers (KSME), advisory committee of Agency for Defense Development, and board of directors, Federation of International Robot-Soccer Association (FIRA). He has published about 69 papers in international & domestic journals and about 120 international & domestic patents by this time. He has worked for the telerobotics section, robotics & process systems division in the Oak Ridge National Laboratory, USA. He is currently a director of Human-Robot Interaction Research Center, KAIST and a director of Center for Future Medical Robotics