Intuitive Color Design Support System Using Onomatopoeia

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Abstract: With the widespread use of computers in recent years, opportunities to design presentation materials such as posters have been increasing. This study proposes a method which recommends colors appropriate for user's intuitive, sensitive, and ambiguous design image. We focus on onomatopoeia (i.e., imitative or mimetic words such as "kira-kira" expressing a sparkling image) by which Japanese frequently express their intuitive or ambiguous image unable to be expressed by the general vocabulary. We propose a method for quantifying images expressed by onomatopoeia and estimating colors fit for the images. Our method enables users to select colors appropriate for onomatopoeia automatically. In addition, since our study focuses on phonemes composing onomatopoeia, it enables users to deal with novel expressions created by users and large variety of onomatopoeia. Referring to phoneme image data and color image data in database, our system estimates onomatopoeia images. Our system subsequently selects colors, which represent images similar to onomatopoeia images in the color selection module. When users input some graphic design materials and onomatopoeic words associated with users' image, the system recommends new graphic design candidates with colors appropriate for users' image. Our system is expected to contribute to creative activity as an intuitive design support system.

Key words: design support system, onomatopoeia, colors, sound symbolism

1. Introduction

With the widespread use of computers in recent years, the opportunities to design presentation materials such as posters and slides have been increasing. Many systems which propose a graphic design based on user's image have been developed (Obata and Hagiwara [10], Terashima and Komatsu [14]). The most of previous studies (ex. Obata and Hagiwara [10]) use adjectives to recommend design of graphics. Terashima and Komatsu [14] propose a system which gives image effect to layers of drawings by onomatopoeia. However, it has a limitation in the variation of onomatopoeia and users cannot input original onomatopoeic words.

This study proposes a method which recommends colors appropriate for user's intuitive, sensitive, and ambiguous design image. Although the choice of color is an important factor in considering design, it is difficult to choose colors appropriate for our intuitive and sensitive feelings and express our intentions or feelings literally. In this study, we focus on onomatopoeia (i.e., imitative or mimetic words) by which Japanese frequently express their intuitive or ambiguous image, which is hard to be expressed by the general vocabulary (Komatsu and Akiyama [8]). For example, we would say "we want a design with "kira-kira" image" to express a sparkling image.

The goal of our study is to develop a system which recommends appropriate colors based on onomatopoeia inputted by users and contribute to creative activity as an intuitive design support system.

In order to express user's feelings intuitively, this study focuses on onomatopoeia. The existence of synesthetic associations between sounds and sensory experiences (sound symbolism) has been demonstrated over the decades (e.g., Köhler [9], Sapir [12]). It is also known that the sensory-sound correspondence can be found not only in words referring to visual shapes, which were demonstrated in the landmark studies (e.g., mal/mil and bouba/kiki for round and sharp shapes in Sapir [12] and Ramachandran & Hubbard [11], respectively), but also in those referring to tactile, smell, and taste sensations. Watanabe et al. [15], [16] are investigating the sound symbolic associations between the phonemes of Japanese sound symbolic words (onomatopoeia) for expressing tactile sensations and subjective evaluations of comfort/discomfort for touched objects. For example, onomatopoeic words expressing a sense of smoothness often use the consonant /s/ in the first syllable as in "sara-sara", while those expressing roughness often use /z/ in the first syllable as in "zara-zara". However, little attention has been given to the sound symbolic association between phonemes and colors.

Fujisawa et al. [1] quantified the relationship between phonemes and sound images and they pointed out that images evoked by onomatopoeia could be predicted by linear sum of images associated with each phoneme of onomatopoeia. Based on the model proposed by Fujisawa et al. [1], Shimizu and Sakamoto [13] have developed a system which estimates images of onomatopoeia inputted by users as shown in Figure 1.

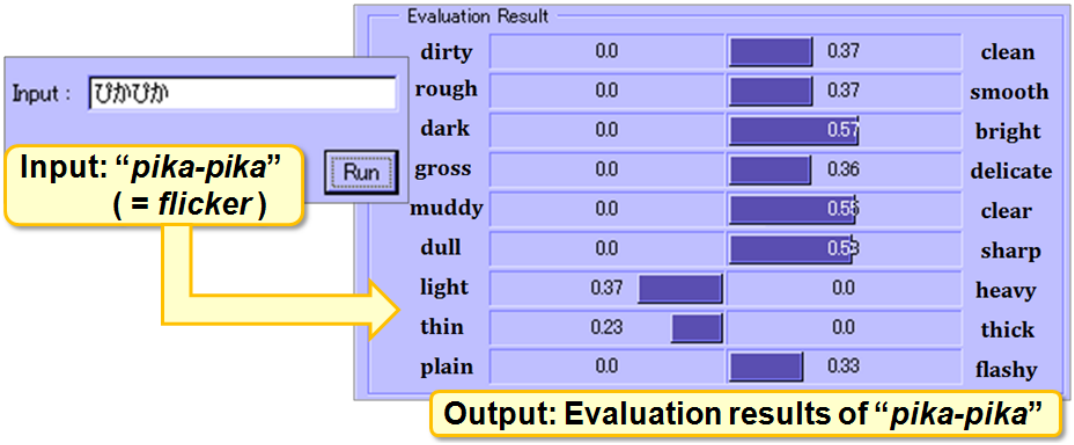


Figure.1 A system which evaluates images of onomatopoeia [13]

By improving the system of Shimizu and Sakamoto [13], Iiba et al. [3], [4] developed a system which proposes color associated with onomatopoeia based on sound symbolism (Figure 2-a, 2-b). This system quantifies images of inputted onomatopoeia using 43 adjective scales related to colors as shown in Table 1, and recommends colors fit for impressions associated with onomatopoeia.

By applying the system of Iiba et al. [3], [4], we develop a system which recommends design candidates using colors appropriate for users' image expressed intuitively by onomatopoeia.

Table 1. SD scales used for our study

Scales (no.1 – no.43)	
bright / dark	simple / complex
warm / cool	like / dislike
thick / thin	slippery / sticky
easy / uneasy	sharp / dull
good / bad	static / dynamic
impressive / unimpressive	fashionable / unfashionable
happy / sad	pleasant / unpleasant
stable / unstable	masculine / feminine
comfortable / uncomfortable	elastic / non-elastic
hard / soft	glossy / non-glossy
regular / irregular	strong / weak
clean / dirty	bumpy / flat
modern / old-fashioned	smooth / rough
individual / typical	stretch / non-stretch
cheerful / gloomy	intense / calm
natural / artificial	loud / plain
friendly / unfriendly	positive / negative
wet / dry	Western-style / Japanese-style
sharp / mild	young / old
heavy / light	luxury / cheap
elegant / vulgar	repulsive / non-repulsive
firm / fragile	

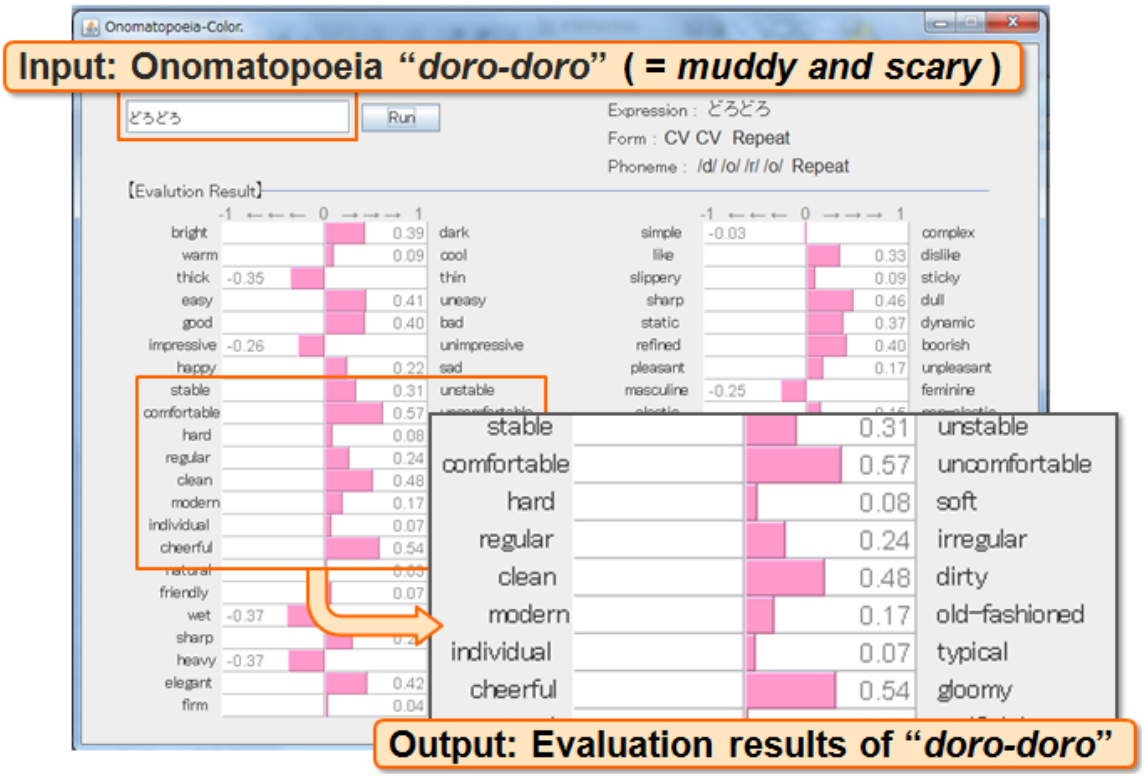


Figure.2-a A system which proposes colors associated with onomatopoeia [3], [4]

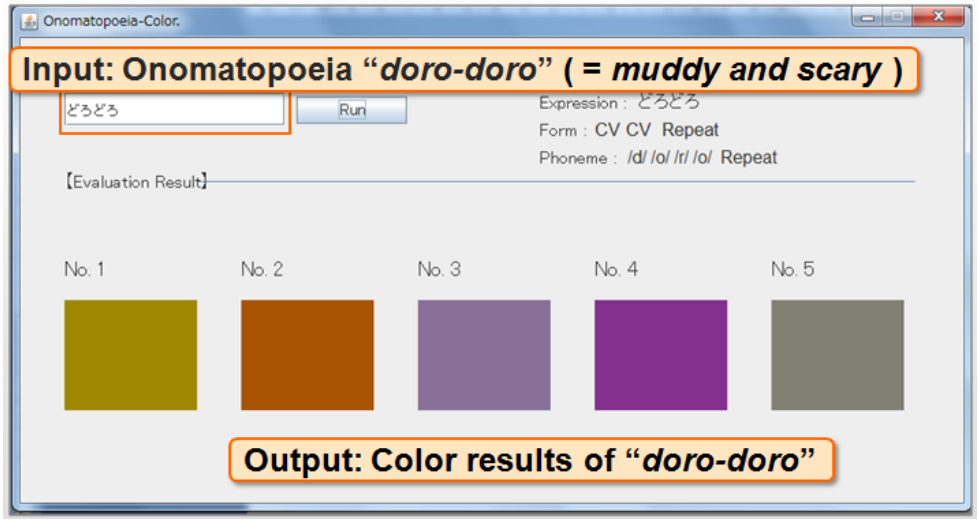


Figure.2-b A system which proposes colors associated with onomatopoeia [3], [4]

2. Procedure of the System Construction

In our study, we constructed a system which recommends design candidates using colors appropriate for users' image expressed intuitively by onomatopoeia.

To develop our system, we made two types of database: "color image data" and "phoneme image data". The color image data indicate the quantitative values of color impressions evaluated by semantic differential (SD) scales, and the phoneme image data mean the quantitative values of phoneme impressions evaluated by the SD scales. We conducted two psychological experiments to collect those two data. We employed 45 color samples as shown in Figure 4. The color samples are those that 5 participants selected as the representative colors of each hue and tone among 130 colors in Kobayashi [7].

Our method hypothesizes that the impression created by an onomatopoeic expression could be predicted by the phonological characteristics of its constituent phonemes. Because of this, the experimental stimuli are required to include all kinds of phonemes; basic sounds (consonant /C/ and vowel /V/), special sounds (syllabic nasal /N/, choked sound /Q/, long vowel /R/ and adverb ending in "li" /Li/) [6].

Fast of all, we combined all sounds in Japanese syllabary from the first sound /a/ to the last sound /n/, and created two-morae expressions (/aa/, /ai/, …, /wan/, /nn/). We obtained 11,075 words as those made by repeating two-morae onomatopoeic expressions (e.g., /aa-aa/, /ai-ai/). Moeover we added 3,509 words with all types of special sounds such as /huwaLi/ and /peQtaLi/. Second, among those 14,584 expressions we selected 312 words, which were judged by 3 participants as tactile onomatopoeic expressions. We confirmed that the selected 312 words covered all kinds of phonological characteristics and decided to use the words as experimental stimuli. Table 2 shows examples of the stimuli.

To collect color image data, we conducted a psychological experiment. 20 participants (10 males and 10 females) were asked to evaluate the impression of respective 45 colors against 43 pairs of adjectives in seven-points SD scales. As a result, the data of evaluated values (i.e., 45 colors × 43 scales × 20 participants) were obtained. By calculating the average evaluated values among the participants, we collected the color image data (45 colors × 43 scales) used in our system.

To make phoneme image data, we conducted a psychological experiment. 78 participants (51 males and 27 females in 6 groups of 13 people) were asked to evaluate the impressions of respective 312 onomatopoeic

expressions (in 6 groups of 52 words) against 43 pairs of adjectives in seven-points SD scales. Onomatopoeic stimuli were displayed on the computer screen in random order for each participant. As a result, the data of evaluated values (312 words × 43 scales × 13 participants) were obtained. We calculated the standard deviations of each evaluated value, and removed 275 values with the standard deviation of 2.0 or over (i.e., 2% of the total obtained data). By calculating the average evaluated values among the participants, we collected the onomatopoeic image data (312 words × 43 scales).

Our method evaluates color images and tactile sensations associated with onomatopoeic expressions based on phonological characteristics. We designed "onomatopoeia image estimation model"; which quantifies images of onomatopoeic expressions by calculating a linear sum of phonological image values by the following equation (1).

$$\hat{Y} = \frac{X_1 + X_2 + \cdots + X_{12} + X_{13}}{n} \times 2 \quad (1)$$

Here, $\hat{Y}$ represents an estimation value of onomatopoeia's image for a certain scale. X1-X13 show image values of respective phonological characteristics (the detailed correspondences between variables and phonemes are shown in Table 3), and n indicates the number of morae composing onomatopoeic expressions. When users input expressions with two or more morae, our model corrects the weight of values to be equal to two-morae expressions.

We applied the onomatopoeic image data obtained in the above experiment to our model, and calculated the impression values of each phoneme by making use of a mathematical quantification theory class I. Table 4 shows examples of relationship between phonemes and impression values. For example, an expression "zagu-zagu" as those made by repeating /zagu/ is composed of the first mora /za/ (/s/ + voiced sound + /a/) and the second mora /gu/ (/k/ + voiced sound + /u/). Therefore, the impression value of "smooth / rough" scale is estimated by the following equation. Since impression values set in seven-points scales, the estimated value 6.12 suggests that "zagu-zagu" is strongly associated with rough impressions.

$\hat{Y}$ = /z/ + /a/ + /g/ + /u/ + repeat
= /s/ (X1) + voiced sound (X2) + /a/ (X4)
+ /k/ (X7) + voiced sound (X8) + /u/ (X10) + repeat (X13)
= -2.26 + 1.06 + 3.32 + 1.16 + 0.63 + 2.19 + 0.02
= 6.12

To evaluate the accuracy of our model, we compared the impression values estimated by our model with real values for 312 onomatopoeic stimuli obtained from the participants through experiment 2 (hereafter, we call the former as "estimated values" and the latter as "real values"). We calculated values multiple correlation coefficients between the estimated values and the real values for respective 43 scales. As a result, as for 33 scales, the values of multiple correlation coefficients were in the range of 0.8 to 0.9, and as for the other 10 scales they were 0.9 or more. Therefore, we considered our model is good enough for estimating onomatopoeia images to be evaluated by humans. In our system, we utilized the onomatopoeia image estimation model and the impression values of phonemes obtained by the process above.

Figure 3 shows the overview of our system. The user interface takes an onomatopoeia created by users, and the word analysis module analyzes the phonological characteristics composing the input onomatopoeia. Referring to the phoneme image data and the color image data in database, our system estimates the images of onomatopoeia. Our system subsequently selects colors which have the images similar to onomatopoeia images in the color

estimation module. We use a cosine similarity to measure similarities between onomatopoeia images and 45 color images as shown in Figure 4. Our system calculates the cosine similarity between onomatopoeia image vectors and color image vectors. Those vectors consist of 43 elements because the images of onomatopoeia and color were evaluated against 43 scales. The cosine similarity is in the range of -1 to 1. The colors with higher values of cosine are regarded as the colors strongly associated with the onomatopoeia.

Table 2. Examples of onomatopoeic stimuli in our study

unyo-unyo	jyori-jyori	nucha-nucha	kusyaA
gasa-gasa	sube-sube	necha-necha	zazaQ
gito-gito	tiku-tiku	huka-huka	zaraA
gutyo-gutyo	chapu-chapu	bunyu-bunyu	subeQ
keba-keba	tiri-tiri	punyu-punyu	doroOri
gotu-gotu	tubu-tubu	huwa-huwa	pahuQ
koro-koro	turu-turu	becho-becho	huUwari
gowa-gowa	teka-teka	beto-beto	moQsa
zazazaza	toro-toro	mosha-mosha	boko-boko
zasyu-zasyu	doro-doro	yore-yore	howa-howa
sara-sara	nayo-nayo	washa-washa	muni-muni
zara-zara	nyupu-nyupu	uNnyuri	wasyaLi

Table 3. Correspondences between variables and phonemes

First mora	Second mora	Phonological characteristics	Phonemes
X_1	X_7	consonants	/k/, /s/, /t/, /n/, /h/, /m/, /y/, /r/, /w/ or absence
X_2	X_8	voiced sounds / p-sounds	presence or absence
X_3	X_9	contracted sounds	presence or absence
X_4	X_{10}	vowels	/a/, /i/, /u/, /e/, /o/
X_5	X_{11}	semi-vowels	/a/, /i/, /u/, /e/, /o/ or absence
X_6	X_{12}	special sounds	/N/, /Q/, /R/, /Li/ or absence
X_{13}		repetition	presence or absence

Table 4. Examples of phoneme values in our system

Scales	First mora				
	Consonants			Sounds	
	/k/	/s/	/h/	voiced sounds	p-sounds
bright / dark	-2.11	-2.05	-2.36	1.09	-0.34
hard / soft	-1.16	-0.67	-0.06	-2.47	0.11
heavy / light	-0.83	-0.48	-0.72	-1.40	-0.12
bumpy / flat	-0.32	0.30	-0.14	-1.04	-0.58
positive / negative	-2.05	-2.06	-2.18	0.86	-0.54
young / old	-1.54	-1.79	-1.72	0.59	-0.56

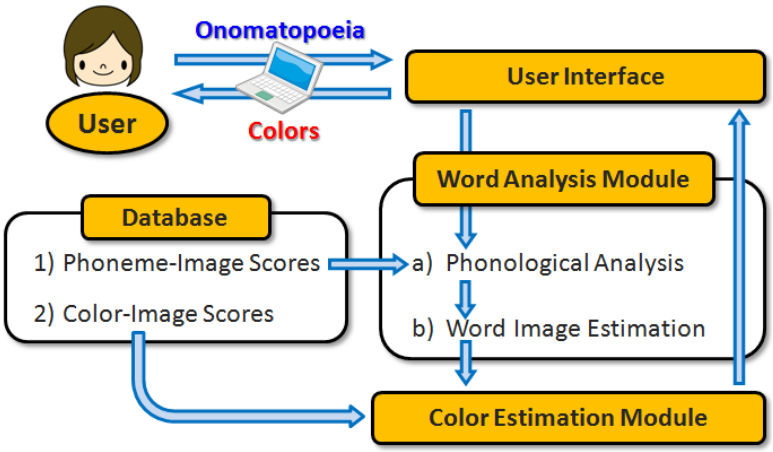


Figure.3 outline of our system

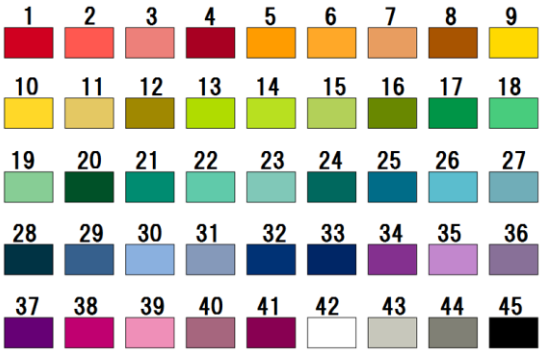


Figure.4 Color samples used for our system

Our system is implemented as a Java program. Graphical user interface is constructed by using a Swing library (GUI component). We show an example of the interface of our system in Figure 5.

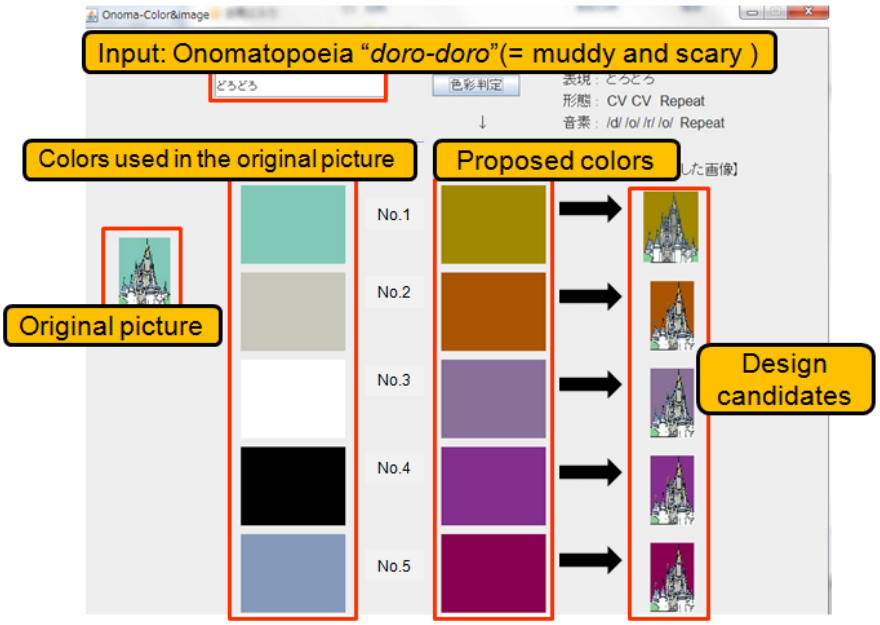


Figure.5 User interface of our system

Users input the original picture into the system as well as onomatopoeia representing their design request. Then, our system extracts the color information for each pixel on the original picture, and displays representative colors used in the original picture. Referring to the color estimation module, colors appropriate for inputted onomatopoeia and design candidates using the colors are proposed in the interface. Referring to the recommendation of the system, users can change colors of the original picture by using a graphic editing software. We give another example of how this system be applied in designing picture. Figure 6 shows the practice use of the system in a graphic design. In Figure 6, picture 1 is the original design (free picture, http://www.studio-robin.com/), and picture 2-4 are pictures using colors respectively based on onomatopoeia such as “hunn-waka” (= soft and comfortable) / “doro-doro” (=muddy and scary) / “pika-pika” (= flicker).

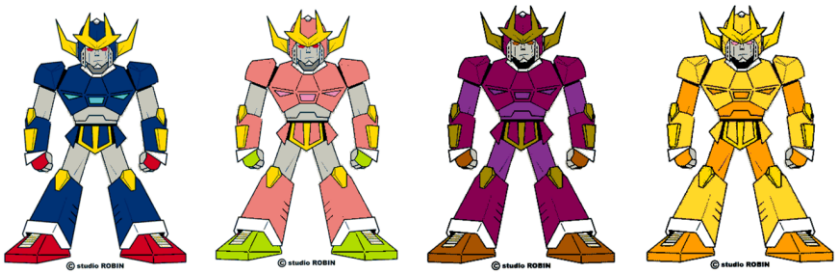


Figure.6 Practice use of the system in a graphic design

3. System Evaluation

To evaluate the accuracy of our system, we conducted a psychological experiment. 5 Japanese undergraduates aged 21 to 24 (3 males and 2 females) participated in the experiment. Participants were asked to evaluate the impressions of 6 pictures against 43 pairs of adjectives in seven-points SD scales. The pictures were displayed on the computer screen in random order for each participant (Figure 7 is an example of the stimuli).

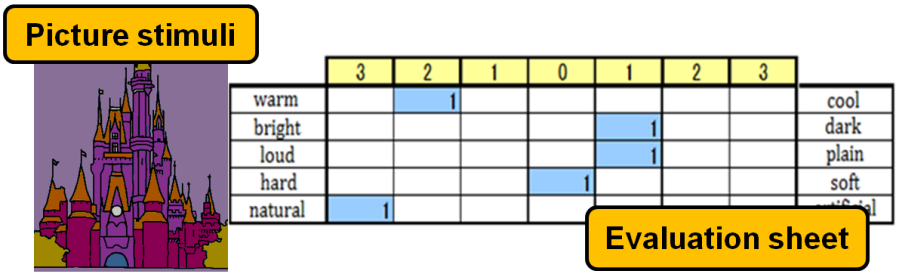
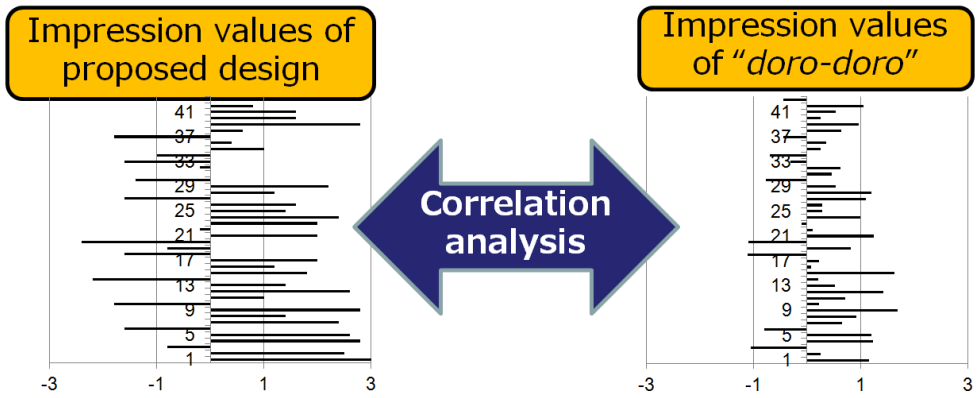


Figure.7 An example of picture stimuli and evaluation sheet

We chose 2 pictures among free pictures used in the Internet as stimuli and calculated the amount of colors used in the picture referring to 45 color samples as shown in Figure 4. Onomatopoeia used to change the original picture were “hunn-waka” (= soft and comfortable) / “pika-pika” (= flicker) / “sara-sara” (=smooth and dry) / “doro-doro” (=muddy and scary).

We calculated the correlation coefficient between impression values of onomatopoeia’s and those of original pictures. In the same way, we calculated the correlation coefficient between impression values of onomatopoeia’s and those of recommended designs by our system. Figure 8 shows an example of the correlation analysis in case

of onomatopoeic word “doro-doro”. As a result, the correlation coefficients of original pictures in each onomatopoeia were from -0.530 to 0.420. On the other hand, those of recommended designs by our system were from 0.519 to 0.683 as shown in Table 5. This result shows that impressions of designs recommended by our system got much closer to those of onomatopoeia than those of original pictures. Therefore, we considered that our system is good enough for proposing designs appropriate for user’s impression expressed by onomatopoeia.



Vertical axis: scale numbers, Horizontal axis: impression values

Figure.8 Correlation analysis between the impression values of recommended designs and those of an onomatopoeic word “doro-doro” in 43 scales

Table 5. Correlation coefficients between impression values of onomatopoeia and those of original pictures or design recommended by our system

	“*doro-doro*”	“*pika-pika*”	“*hunn-waka*”	“*sara-sara*”
Original pictures	-0.530**	0.022	0.019	0.420**
Designs recommended by our system	0.683**	0.519**	0.621**	0.675**

** : $p < 0.01$, * : $p < 0.05$

4. Conclusion and future work

This study proposed a method which recommends colors appropriate for user’s intuitive, sensitive, and ambiguous design image. Using onomatopoeia by which Japanese frequently express their intuitive or ambiguous image unable to be expressed by the general vocabulary, we proposed a method for quantifying images expressed by onomatopoeia and estimating colors fit for the images. Our system is expected to contribute to creative activity as an intuitive design support system. As a limitation of the proposed method, our method does not consider the influence of the meaning of the image. For example, regardless of colors, flowers may evoke warm and bright impression. Our future work, therefore, needs to consider the impression of designs that have a specific image such as a flower. As our future work, we also plan to combine our system with the font proposing system (Ishibashi and Miyata [5], Iiba et al. [2]) and propose a comprehensive design support system.

5. Acknowledgement

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6. Citations

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