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STUDY ON DIGITAL STYLE DESIGN - ROBUST DESIGN SYSTEM FOR KANSEI USING MULTIVARIATE ANALYSIS AND TAGUCHI METHOD

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ABSTRACT

In recent years, aesthetic design is becoming increasingly important in industrial product development due to the growing maturity of product functions. The designer is required to reflect consumer needs in the aesthetic design while giving consideration to the applications and functions of the product. For this reason, effective techniques enabling design creation based on consumer preference and needs are indispensable. The Taguchi Method has been effectively used for the robust design of product functions. In this study, a design support method applying the Taguchi Method to robust aesthetic design in respect to the inconsistencies of human Kansei (sensitivity, emotion) is proposed. As an example using the method, it is applied for quantitatively analyzing the robustness of design solutions created in accordance with the design concept of a digital camera.

KEYWORDS

Taguchi Method, KANSEI, Robust design, Aesthetic design, Emotional design

1. INTRODUCTION

Through advances in manufacturing technology, it is becoming more difficult to differentiate products by their quality, and the relative contribution that the design of the appearance makes to the appeal of products is getting bigger. Appearance design largely depends on the Kansei (sensitivity, emotion) of the designer, and it is thought that creating designs based on scientific theory would be difficult [Hsin-Hsi Lai], [Sang W. Hong]. Nevertheless, to design products that will be well received by many consumers, what is needed is the analysis of the kinds of designs that are sought by consumers, and the development of methods that make it possible to create robust designs for the different Kansei of each consumer.

There have been many studies that aimed to analyze the relationship between form and Kansei, and to generate designs that correspond with designers' intended impressions [Chun-Chih Che], [Ezgi Aktar Demirtas], [Shana Smith], [Andreas K. NORDGREN], [Anitawati M. Lokman], [Fu Guo], [Hsin-Hsi Lai], [Mitsuo Nagamachi], [Pierre Lévy]. These studies are valid for analyzing the relationship between form and Kansei, but their analyses use averages of Kansei data, and do not take into account the differences in the Kansei of each person.

This study considers the differences in Kansei, and conducts an analysis of the relationship between form and Kansei. Based on survey information, the study analyzes users' Kansei of a target product with Hayashi's Quantification Method I and the Taguchi Method, and proposes methods for deducing designs that allow more people to experience the concept of the product along with quantitatively understanding customer preferences and needs. Furthermore, the study formulates a design support system based on the proposal methods. This system applies to the design of digital cameras that are coming under serious consideration for its designability.

In this paper, the words of "Kansei" and "Kansei-words" are used in various explanations. Here, "Kansei" is taken to mean "the impression obtained visually when viewing the target object," and "Kansei-words" is taken to mean "natural language expressing an impression."

2. ANALYZING KANSEI FOR SHAPE FACTORS

To aim for design optimization, it is essential to vary the design criteria and evaluate the relationship between those criteria and their output. This study analyzes the relationship between design parameters and Kansei assessment values in using digital camera shape design parameters for design criteria and output for Kansei assessment values.

2.1 Design Parameters

For design parameters, we used six exemplary parameters which have effects on Kansei: lens radius, corner radius, aspect ratio, hue, saturation, and brightness of the camera unit as shown in Figure 1.

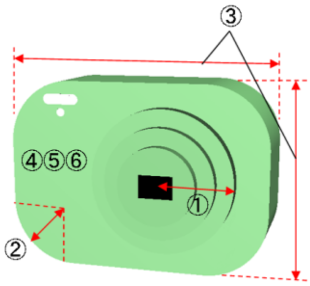

Figure 1. Design Parameters

The above six design parameters were each given six variations labeled Levels 1 through 6 as shown in Table 1. We then made samples shown in Figure 2 by using combinations of the different levels of each variable. The method for combining the levels referred to an orthogonal table which is a planning table for conducting experiments with relatively low frequency of evaluations concerning a large number of factors. We took a survey of impression assessments based on the samples shown in Figure 1, and collected Kansei data.

Table 1. Levels of Design Parameters

Parameter \ Level	1	2	3	4	5	6
Lens radius	3.0	2.7	2.4	2.1	1.8	1.5
Corner radius	0	0.48	0.96	1.44	1.92	2.40
Aspect ratio	1.0:1.0	1.0:1.2	1.0:1.4	1.0:1.6	1.0:1.8	1.0:2.0
Hue	0°	60°	120°	180°	240°	300°
Saturation	0%	20%	40%	60%	80%	100%
Brightness	0%	20%	40%	60%	80%	100%

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Figure 2. Examples of Digital Camera Design

2.2 Selecting Kansei-words for Expressing Impressions and Images of Product

Kansei data was collected through a survey. In the survey, several antonym-pairs of Kansei-words were shown to test subjects to evaluate the scale of impressions of each digital camera design shown in Figure 2. We selected several relevant antonym-pairs of Kansei-words to use on the survey from among a great number of Kansei-words to reduce the burden on the test subjects.

First, we chose 20 antonym-pairs of Kansei-words that can be used to express impressions of digital camera design from dictionaries and other sources. That is, we decided to describe impressions of digital camera appearances using 20 antonym-pairs of Kansei-words. In this instance, we excluded Kansei-words antonym-pairs describing the product quality: like "Good-Bad" and "Beautiful-Ugly," because they do not fit the intended goal of this system.

Next, we presented the digital camera shapes shown in Figure 2 to the subjects, and asked them about the impression of each camera shape to complete a survey of an 11-step scale on each of the 20 antonym-pairs of Kansei-words. The test subjects were 11 university students.

We conducted a cluster analysis of the survey result data, and classified four clusters that had close evaluation trends. Then we selected one antonym-pair of Kansei-words representing each cluster. As the result, the following antonym-pairs of Kansei-words: Unique-Orthodox, Cool-Cute, Formal-Casual, and New-Old were used for representing the impressions of digital cameras. The impression and image of digital camera shape is expressed according to these four Kansei-words antonym-pairs.

2.3 Collecting Kansei Data

We conducted an SD survey that had test subjects to evaluate the 36 samples shown in Figure 2 using an 11-step scale of the four selected antonym-pairs of Kansei-words as shown in Figure 3. The test subjects were 43 university students. We then conducted an analysis using the survey results as Kansei data.

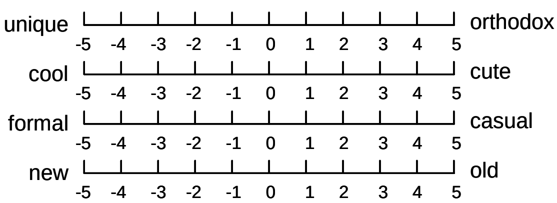

Figure 3. SD Scale of Evaluation

2.4 Analytical Methods

This study's analyses were conducted using Quantification Theory I (Hayashi's Quantification Method I) and the Taguchi Method. Each method is described below.

2.4.1 Quantification Theory I (Hayashi's Quantification Method I)

Hayashi's Quantification Method I is an analysis method in which the target variables are quantitative and the explanatory variables are qualitative, and is one method for analyzing by quantifying qualitative variables. Equation (1) expresses this with y for the target variable, x_i for the explanatory variable, and b_i for the coefficient. This study applies Hayashi's Quantification Method I using the Kansei assessment values for the target variables and the design parameters for the explanatory variables to quantify the effects that the design parameters have on Kansei assessment values.

$$y = b_o + b_1 x_1 + b_2 x_2 + \cdots + b_i x_i \tag{1}$$

2.4.2 Taguchi Method

The Taguchi Method is a technique for efficiently deducing robust design, and is used mainly in the design of functional products. This study creates robust designs for the dispersion of individual Kansei by applying the Taguchi Method to Kansei analysis. Equation (2) generally shows the output fluctuation (dispersion) S, the output average β, and the output standard deviation σ of the Taguchi Method.

$$S = \frac{\sigma}{\beta} \tag{2}$$

Generally, the output expands in the positive range as shown in the left part of Figure 4, and the output average β and output standard deviation σ are thought to be roughly proportional. Thus, normalizing the output standard deviation using the output average as in Equation (2) operates to avoid having a reduction of the output fluctuation (dispersion) merely reduce the output. Thus, the inverse of the output fluctuation is calculated with Equation (3). The η is called the SN ratio.

$$\eta = 10 \log \left(\frac{\beta}{\sigma} \right)^2 \tag{3}$$

By increasing the SN ratio to get the inverse of the output fluctuation, the output dispersion decreases. In the Taguchi Method, optimal design solutions are found by setting standards that allow the SN ratio to increase.

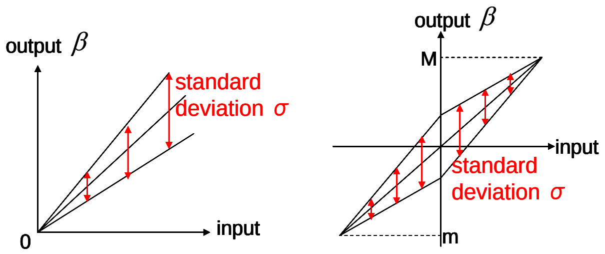

Figure 4. Relationship between the output and the standard deviation of the Taguchi method

In our method, the range of Kansei assessment values (outputs) is set from -5 to +5. In this way, when there are upper and lower limits to the output range, the relationship between output average β and output standard deviation σ is such that the upper and lower limit values of the output range, output average differences (expressed below as ℓ to simplify explanation), and output standard deviation σ are thought to have a proportional relationship as shown in the right side of Figure 4. This trend can be confirmed by the correlation between ℓ and σ shown in Figure 5. Because the relationship between the output average and output standard deviation differs from what was mentioned above, the SN ratio from Equation (3) cannot be used.

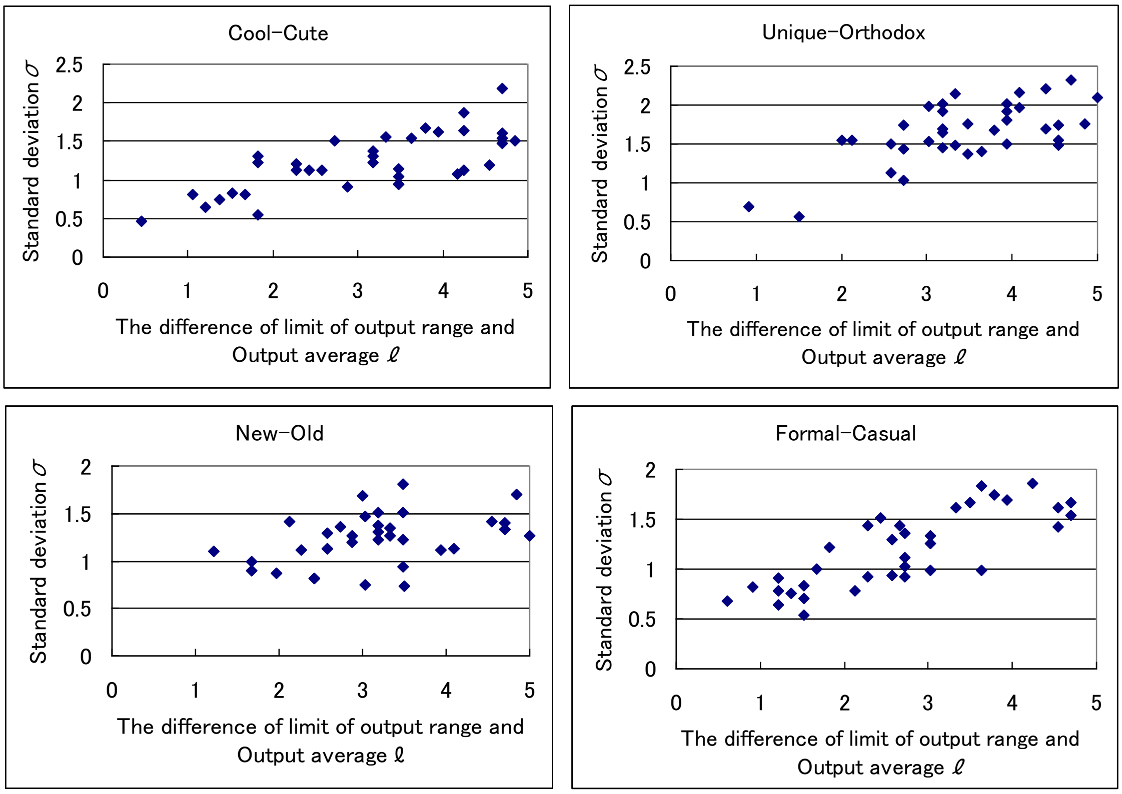

Figure 5. Relationship between σ and ℓ

Thus, this study defines output fluctuation S as in Equation (4). Reduction of the output fluctuation (dispersion) is kept from merely reducing the output by normalizing the output standard deviation σ with the denominator ℓ in Equation (4).

$$S = \frac{\sigma}{\frac{M-m}{2} - \left|\beta - \frac{M+m}{2}\right|} \tag{4}$$

Then, the output fluctuation inverse η that was obtained is used as the SN ratio in this method, as in Equation (5).

$$\eta = 10\log\left(\frac{\frac{M-m}{2} - \left|\beta - \frac{M+m}{2}\right|}{\sigma}\right)^2 \tag{5}$$

As with the conventional SN ratio in the Taguchi Method of Equation (3), as the SN ratio derived in our method increases the output dispersion decreases because the output fluctuation inverse has been taken. This study deduces the optimal design solution by setting standards that increase the SN ratio of Equation (5).

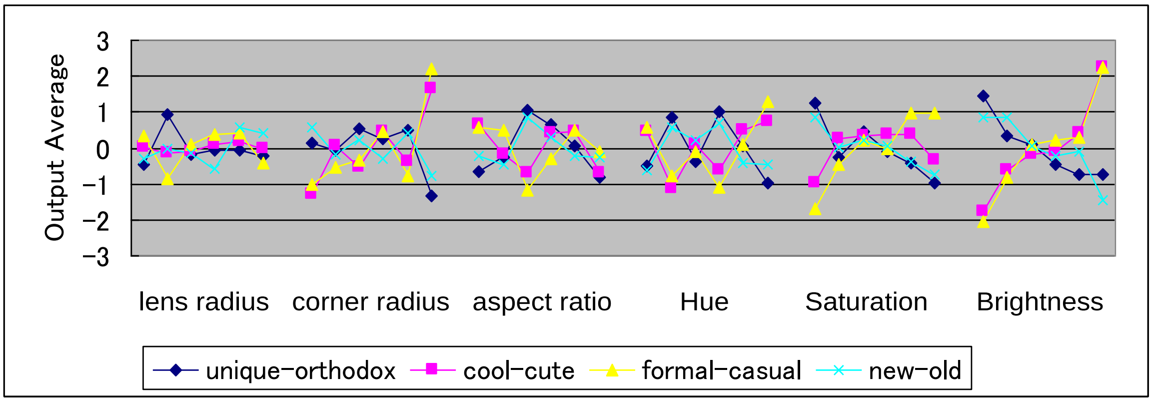

Figure 6. Output Average

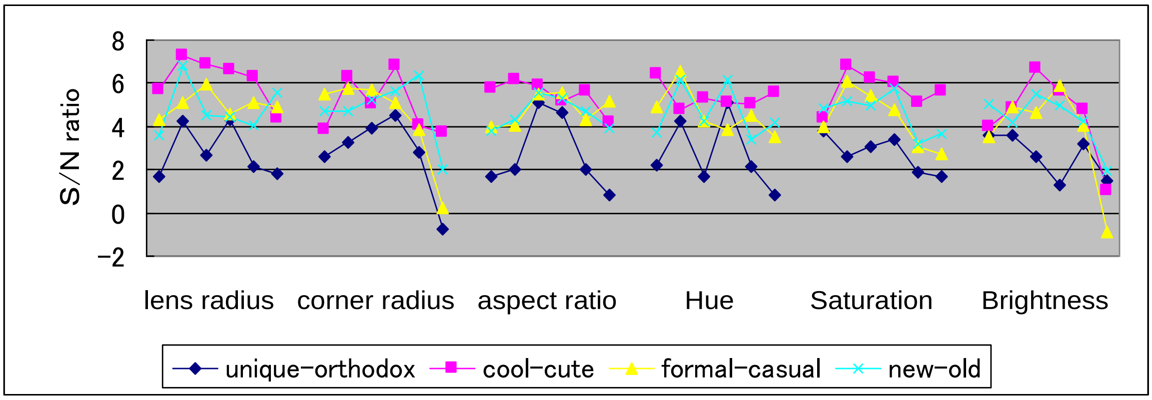

Figure 7. S/N ratio

2.5 Analysis Results

The output averages and the SN ratio accompanying changes of each parameter are shown in Figures 6 and 7, respectively. Based on these two sets of results, we deduce the robust design parameter values that fulfill the desired output values as well as have high SN ratios.

3. SYSTEM DEVELOPMENT AND PROPOSED METHOD ASSESSMENT

3.1 Developed System

Based on the above analysis methods and results, we developed a system for creating robust designs that suit the desired impression for customer Kansei. A system user (designer) first selects the impressions that he/she wishes to adjust from among the four antonym-pairs of Kansei-words. He/she then sets the target value for the impression assessment of the selected antonym-pairs of Kansei-words. Target values are set on the same -5 to +5 scale as the Kansei data collection survey.

Furthermore, to reflect a plans/idea of a system user in the design solution, the initial settings (design values) are entered. Entering initial settings is done by setting the initial levels as the levels that are closest to the design plan/idea for each parameter. Next, the user sets the maximum number of level modifications for the initial settings. This determines the number of level changes that will be permitted from the combination of levels chosen in the initial settings. Accordingly, the maximum number will be set low to give respect the initial design, and set high to prioritize enhancing robustness. The design solution is derived with the range of the number of level modifications. Furthermore, when the user has strong preferences about certain parts of the design, he/she can set those design parameters as fixed conditions in the initial level settings.

When the above settings are entered, the system selects all designs (level combinations) that comply with the input conditions (output fulfills the target values; modified number is within the maximum for the initial design; parameters set as fixed conditions are the same level as in the initial design) from among the enormous quantity of level combinations. The SN ratio is calculated for the selected design solutions, and the system puts forth those solutions with high SN ratios as the optimal solutions.

To summarize, the outline of this system is as follows:

1. Select Kansei-words pairs
2. Set target output values
3. Enter initial design settings (optional)
4. Enter fixed conditions (optional)
5. Extraction of design solutions that satisfy the conditions
6. Calculation of SN ratio
7. Output of optimal solution

3.2 Assessment of the Proposed Method

We reviewed the usefulness of this system by comparing the analytical results of the optimal solution extracted by the proposed system with other solutions. As an example, we will compare the analytical results when the selected conditions were a range of target output values from the scale 2.5-3.5 on the “Unique-Orthodox” antonym-pairs of Kansei-words. In the following explanation, Solution A is the optimal solution from the proposal system, and Solution B is the other solution. For Solution B, we used a solution that fit the target output values but had a somewhat low SN ratio. The degree of influence that Solutions A and B had on the SN ratio of each parameter’s level for the design parameters is shown in Figure 8. In Figure 8, The red triangles are Solution A’s levels and the blue triangles are Solution B’s levels. Each parameter shown in Figure 8 shows the levels 1 through 6 from left to right. The actual form of Solutions A and B are shown in Figure 9.

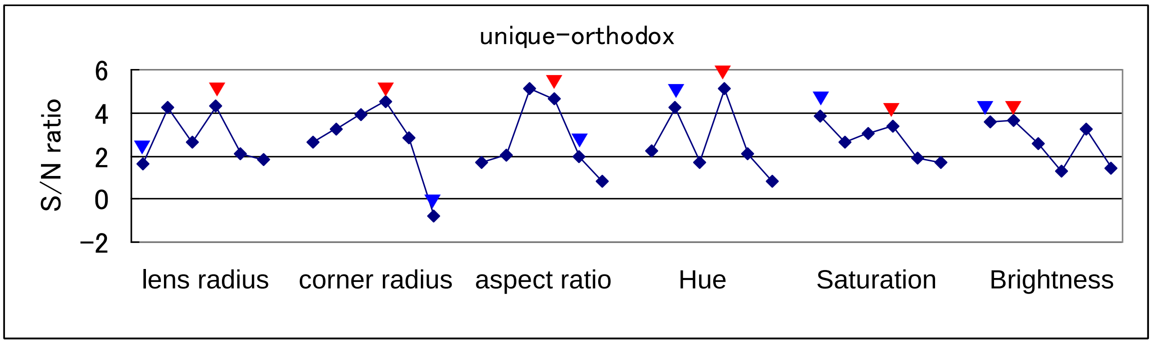

Figure 8. S/N ratio and levels of solution A and B

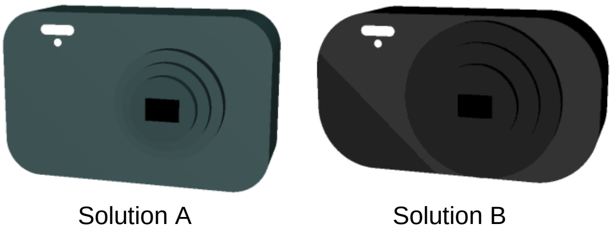

Figure 9. Shape of Solution A and B

As shown in Figure 8, when the SN ratios of the levels set for Solutions A and B are compared, Solution A has higher levels for most of the parameters, and a comprehensive assessment shows that Solution A selects for levels with higher SN ratios. This is because Solution A was deduced using the Taguchi Method. Furthermore, for Solution A as the optimal solution, not all parameter levels are set as the level with the highest SN ratio because the system operates to adjust within the target values for output average in parts in which the SN ratio fluctuation is small.

Figure 10 shows the analytical results of Solutions A and B. The vertical axis is the output, and it takes the standard deviation with the output average at center. The set target value range of 2.5-3.5 is shown in red.

The output average of Solution A is 3.25, and its output standard deviation is 2.88. On the other hand, the output average of Solution B is 2.83, and its output standard deviation is 6.78. As can be seen in Figure 10, the output average values for both Solutions A and B are within the range of target values, but the range of the output standard deviation is smaller for Solution A which was the optimal solution obtained by the developed system.

As we have shown above, it was confirmed that the proposal system was able to create robust design solutions for the variations in Kansei.

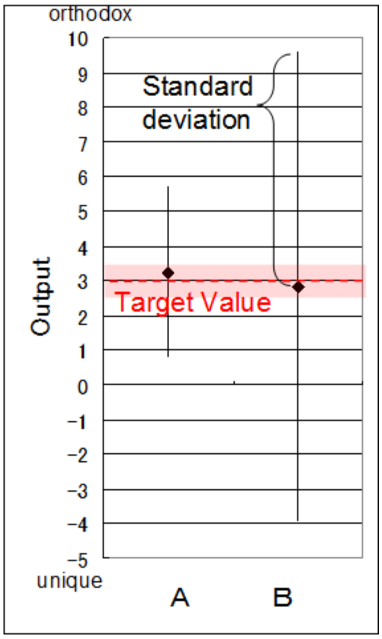

Figure 10. Analysis Results of Solutions A and B

4. CONCLUSION

This study conducted a proposal for a design support system aiming to create forms that meet a greater number of consumers' Kansei tendencies while also fitting the image that the designer intends. We analyzed the relationship between form and Kansei with consideration for the variability of Kansei, through multivariate analysis and the Taguchi Method. We formulated a system for creating robust designs for the variability of Kansei. We confirmed that through the proposal system, forms can be deduced that give the impression that the designer intends to a greater number of consumers. Furthermore, the following can be mentioned as topics for further study. The test subjects for both the Kansei-words selection survey and the Kansei data collection survey were university students. However, the Kansei of professional designers may differ from that of students. Therefore, it will be necessary to take the opinions of professional designers into account.

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