Proposal of Method to Make Product Design Concepts by Evaluation Structure

Katsuo INOUE*, Mitsuo HIROKAWA**, Kouki ITOH***, Masayuki SAKAI***

** Hiroshima International University, Faculty of Psychological Science, 555-36 Kurose-Gakuendai, Higashi Hiroshima Hiroshima 739-2695 Japan*

*** Tokai University Takanawa Junior College, 2-3-23 Takanawa, Minato-ku, Tokyo, 108-8619, Japan*

**** Takushoku University, 815-1 Tate-machi, Hachiouji-shi, Tokyo, 193-0985, Japan*

*****Sapporo City University, School of Design, 1Geijyutsu-no-mori Minami-ku Sapporo Hokkaido 005-0864 Japan*

Abstract: Recently the necessity of making a product design concept is increasing as the methodology of a product design so that the design process becomes transparent. However, from result of our reference research in both scientific fields and company design fields, we found that there were few studies about the method to make the product design concept. Therefore, we proposed a method to make a new concept by transforming user's cognitive evaluation structure which was constructed from the result of the fact finding about products in the market by quantitative analysis. Concretely, after we extracted user's attitudes such as cool or interior matching and impressions of those products by Evaluation grid method, we obtained the cognitive evaluation structure consisted of attitudes in higher rank, impressions in the middle rank and recognition parts in the low rank by multiple regression analysis and Rough set theory. Thus we could make a new design concept by rearranging these impressions contributed to a specific attitude mentioned above. This method has the advantage that a new design concept can be made from various view points. We considered the availability of the method by the case study of a light instrument design on the latter half of the research. Specifically, after we assumed a new design concept made by some impressions extracted from light instrument samples now in use, we asked a designer to draw sketches based on the new design concept. We confirmed the validity of it by comparing impressions of light instrument samples with those of sketches by user evaluation.

***Key words*:** *Product design, Design concept, Rough sets*

1. Introduction

We propose a method with concrete procedures for making design concepts by reconstructing human cognitive evaluation structure for a product in design development. We have verified and discussed the above method using lighting fixtures, which are being produced in a wide variety but in a limited quantity, as a case study.

2. Analytical Methods

We have employed an analytical method with a human evaluation structure based on Personal Construct Theory [1], a base theory of cognitive psychology, where “attitudes,” upper most abstract notions which vary greatly by individual, were hierarchically resolved, via “impressions” in the middle layer, into the lowermost “(cognitive) geometrical elements” (physical quantity), in the reverse direction to that of behaviors. To be specific, evaluation terms such as attitudes and impressions were experimentally extracted by the Laddering method used in the Evaluation Grid Method [2], and were used in a survey experiment. The relationships between attitude and impressions were analyzed with the data from the survey by multiple regression analysis, and then the relationships between impressions and “recognition parts” were determined using Rough Sets [3] and a decision rule analysis [4].

3. Extraction of Evaluation Terms and Recognition Parts

An interview survey experiment was conducted with 10 university students as subjects using photographs of 45 different interior lighting fixtures (Oct. 2005). We extracted evaluation terms in the experiment, and then classified them into three attitudes and 12 impressions. Table 3 shows the results. We also determined three

major divisions and 19 items and 58 categories in Fig.2 based on recognition parts extracted in the survey experiment. We determined three attitudes because it would be natural for consumers to reach a purchase decision based on not only purchase desire attitude but also other attitudes comprehensively.

4. Relationship Analysis between Attitudes and Impressions

A questionnaire survey was conducted with 30 university students as subjects using the above photographs of the 45 lighting fixtures with a five-grade evaluation by the SD method (Oct. 2005). The evaluation terms used for attitude and impressions were the 15 terms extracted in the previous experiment. Using the surveyed data, we analyzed the relationships between attitudes and impressions with multiple regression analysis (Table 1). The partial regression coefficients for the three attitudes in Table 1 indicate that the attitudes are strongly influenced by the following five impressions: “interest retaining,” “mature” “playful” “posh” and “useful.”

Table 1 Relationship Analysis Results between Attitudes and Impressions

(attitude)	**Want-to-buy**	**Cool**	**Interior matching**
Multi-correl. coeff.	0.878	0.893	0.849
1. Posh	-0.15	-0.05	**0.19**
2. Cute	0.13	0.01	**0.17**
3. Mature	**0.40**	**0.43**	**0.27**
4. Simple	0.01	-0.08	-0.06
5. Presence	0.16	0.13	-0.20
6. Interest retaining	**0.56**	**0.53**	0.15
7. Japanese	0.06	-0.01	0.03
8. Playful	**0.23**	**0.30**	**0.48**
9. Warm feeling	0.01	-0.11	0.05
10. Unique	**-0.14**	-0.09	**-0.20**
11. Stately	-0.10	-0.12	-0.05
12. Useful	**0.21**	0.08	**0.18**

5. Relationship Analysis between Impressions and Recognition Parts

In relationship analysis between impressions and recognition parts, quantification theories have been used with the categorical data of recognition parts. This, however, involves problems of *multicollinearity*. To avoid the problems, we used a method using Rough Sets, for which application studies have started recently, to analyze the relationships between impressions and recognition parts.

5.1 Determination of Decision Classes

To analyze the relationships between impressions, which have strong influences on the three attitudes, and recognition parts, the decision classes of Rough Sets have to be determined. Conventionally, decision classes have been determined by simple methods such as equal divisions of two or three using averaged values. These, however, brought cases where clear characteristics could not be obtained. We, therefore, employed a method to divide data into three decision classes using the frequency distributions for a five-grade evaluation to reflect the data contents. For example, to decide a class of Y=3 (unique), Y=2 (neutral) or Y=1 (not unique), seven different frequency patterns had been prepared in advance and correlated with the data to classify the data by the correlation coefficients.

Seven frequency patterns, as in Fig.1, comprise five typical patterns (pattern 1 to 5), a pattern having two peaks (double peaks) and a pattern having a flat plateau (no peak), totaling seven. When the correlation coefficient with pattern 1 or 2 gives the maximum value, then the decision is Y=1, when the coefficient with pattern 3 or the pattern with double peaks or no peaks gives the maximum, Y=2, and when the coefficient with the pattern 4 or 5 gives the maximum, Y=3. If a human decision was required, an analyzer gave the decision.

Since many decision rules obtained for Rough Sets brought difficulties in examining results, we applied a decision rule analysis method proposed by us to calculate data for easy examination. Table 2 shows the results.

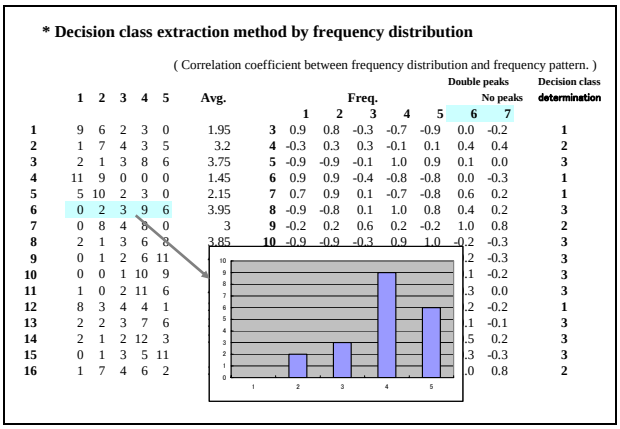

Fig.1 Determination of Decision Classes (a part of outcomes)

5.2 Examination of Analysis Results

We made Rough Sets with five impressions obtained through the examination of the results from multiple regression analysis in the previous section. To be specific,

we calculated the decision rules (low approximation) of Rough Sets by creating decision tables with the recognition parts as conditional attributes and the impressions as decision attributes, which we obtained in Section 3. Then, we obtained standardized column scores (Table 2) with the above-mentioned decision rule analysis method. The table contains only standardized column scores more than or equal to 0.5 for ease of reading.

Table 2 Analysis Results of Rough Sets

				Interest retaining	Mature	Playful	Posh	Useful
Shade	Size	Large	A1	**1.13**				
		Standard	A2			**2.04**	**1.54**	**2.22**
		Small	A3		**4.27**			
	Length	High	B1	0.68				
		Standard	B2					**2.50**
		Short	B3		**0.90**	**0.94**		
	Shape	Cylindrical	C1	**2.94**				
		Cone	C2					**1.53**
		Square prism	C3				**0.74**	
		Others	C4					
	Material	Plastic	D1	**0.79**	0.77	**1.10**	**1.92**	**5.94**
		Japanese paper	D2					
		Special (bamboo etc)	D3			**0.94**		
	Style	Linear	E1	**2.94**	**1.62**		**2.95**	
		Curved	E2			**0.78**		**1.63**
Light	Number of lights	One	F1		**3.97**			
		Multiple	F2			**1.41**	0.58	
	Position	High (top open)	G1					
		High (bottom open)	G2					**2.99**
		High (same for high & low /special)	G3				**0.76**	
		High to middle	G4			**1.88**		
		Top to bottom entirely	G5	**1.35**				
	Mounting	Hanging	H1					
		Fixed to post	H2		**2.09**			**0.97**
		Fixed to base	H3	**1.13**				
		To branches etc.	H4			**0.94**		
	Mobility	Yes	I1					
		No	I2	**1.02**	**1.79**		**0.83**	
Post	Length	Long	J1		0.55			**2.02**
		Standard	J2				**2.34**	
		Short	J3					
		None	J4					
	Thickness	Standard	K1	**1.58**		**0.94**	**1.43**	**1.39**
		Thin	K2				**1.34**	
		None	K3					
	Shape	Cylindrical	L1					**1.18**
		Square prism	L2			**1.41**		
		None	L3					
	Material	Metal	M1		**0.77**	**1.88**	0.54	**1.47**
		Wood	M2					
		Metal + Wood	M3					
		None	M4					
	Number	One	N1				0.54	
		Multiple	N2	**2.37**		**0.78**	**1.83**	
		None	N3					
	Presence of feet	No	O1					
		Yes	O2		**1.15**		**0.98**	0.52
	Style	Linear	P1	**1.35**	**2.69**			
		Curved	P2					
Base	Size	Standard	Q1		**1.84**			**0.72**
		Large/Small	Q2	**4.74**		**1.10**		
		None	Q3			**0.94**	0.58	
	Shape	Round	R1	**2.94**	**0.77**			**0.79**
		Rectangular	R2					
		None	R3			**0.94**	0.58	
	Material	Metal	S1		**0.77**		0.51	
		Wood	S2					0.69
		None	S3			**0.94**	0.58	
(Attitude)		Want-to-buy		0.56	0.34	0.23		0.21
		Cool		0.53	0.43	0.3		
		Interior matching			0.27	0.48	0.19	

Focusing on high scores in the standardized column of "interest retaining," for example, we find that the "interest retaining" impression can be expressed by the following necessary conditions: a cylindrical and linear shade, multiple posts, and a large or small round base (Fig.2). Similarly, other impressions can be examined.

The impressions having strong influence on the attitude "cool" are "interest retaining," "mature" and "playful," according to the analysis results in Section 4. Thus examination of the attitude on Table 2 with the three impressions will help us determine the present recognition parts that express the attitude "cool." Similarly, recognition parts for the other attitudes can also be determined respectively. As indicated above, Table 2 represents the cognitive evaluation structure of the designs of present lighting fixtures.

We determined the combination patterns for five individual impressions relating to the three attitudes, and a part of them is shown in Table 3. For example, the first combination pattern from the left in the column of the impression "playful" indicates only one attribute (characteristic), i.e., "the number of lights is one (F1)," by the filled circle. The next pattern to the right indicates a combination of the two attributes, i.e., "the material of the shade is special (D3)" and "the style of the shade is curved (E2)." The eighth pattern including open circles indicates the three combinations: the one represented by the filled circles, i.e., "the size of the shade is standard (A2)" and "the material of the post is a metal (M1)," followed by each one of the open circles, which are "A2 M1 Q3," "A2 M1 R3" and "A2 M1 S3."

6. Method for Making Design Concept

The analysis results in the previous section do not provide creativity themselves. Thus new design concepts have to be made based on the analysis results. One of the ways to do this is to reconstruct the evaluation structure by, for example, changing the order of the importance of the impressions in the middle layer, emphasizing some impressions, or introducing new impressions from outside. We call this "reconstruction of the evaluation structure." For example, there may be a concept emphasizing "playful," which is placed at a low order in the attitude "cool," or a concept adding the impression "useful" for the attitude "want-to-buy" to "cool." The modification of the evaluation structure is up to the creativity of designers and planners.

One of the procedures for making design concepts is to use the combination patterns in Table 3. For example, the characteristic impressions for "want-to-buy" and

"interior matching" are "interest retaining" and "playful," respectively (Table 2, bottom row). These two impressions are greatly different each other, but we determined that the trial design concept was "a lighting fixture having 'playful' and 'interest retaining' impressions" to emphasize the present results of the analysis. To make a design to express the design concept as a trial, we selected, for example, three combinations from the impression "interest retaining," which is to be emphasized most, and one from "playful," which is the next to be emphasized, as represented by the rectangular frames in Table 3.

Table 3 Combination Patterns Indicating Characteristics of Individual Impressions

			Interest retaining	Playful
Shade	Size	A1	●	
		A2		● ○
		A3		
	Length	B1		
		B2		
		B3		●
	Shape	C1		
		C2		●
		C3		
		C4		
	Material	D1		●
		D2		
		D3		●
	Style	E1	●	
		E2		●
Light	Number of lights	F1		●
		F2		
	Position	G1		
		G2		
		G3		
		G4		● ● ○
		G5	●	
	Mounting	H1		●
		H2		
		H3	●	
		H4		●
	Mobility	I1		
		I2		
Post	Length	J1		
		J2		●
		J3		
		J4		
	Thickness	K1		
		K2		
		K3		●
	Shape	L1		
		L2		● ●
		L3		
	Material	M1		● ○
		M2		
		M3		
		M4		
	Number	N1		
		N2	●	●
		N3		
	Presence of feet	O1		
		O2		
	Style	P1		
		P2		
Base	Size	Q1		
		Q2	● ● ●	●
		Q3		○ ●
	Shape	R1	●	●
		R2		
		R3		○ ●
	Material	S1		
		S2		
		S3		○ ●

To be specific, it represents "a lighting fixture consisting of a shade made of a special material with a curved shape, lights distributed from the top to bottom entirely, and a round base (large or small) to which the lights are fixed." In the process, we need to select the combination patterns in Table 3 where individual attributes do not conflict with one another.

This idea is an expanded version of "merger" proposed by Mori [5]. The idea of Mori only refers to elements within any of the impressions in Table 3. This can be applicable between impressions provided no above conflicts occur. We call it "expanded merger." Mori mentioned that merger was a way to create an idea, and this matches the creativity of the design concept.

7. Experimental Confirmation of Design Concept

To confirm the effectiveness of the trial design concept, we used an active designer to make a design proposal as an experiment. The concrete processes were as follows: The designer was presented with the sample photographs of lighting fixtures used in the analysis followed by explanation of the design concept determined in the previous section. The designer was then instructed to draw idea sketches based on the explanation. The designer drew several designs and then selected himself/herself the one that expressed the design concept the most accurately as the finished proposal (Fig.2, left).The experiment was conducted in January 2007.

Welch official approval

Interest retaining :

$t(39.01)=3.5$、$p < 0.005$

Playful :

$t(33.29)=3.6$、$p < 0.005$

Fig.2 Sketch of the Experimental Confirmation and Significance Test Results

To confirm how much the two impressions adopted in the sketch, i.e., "interest retaining" and "playful," were realized, we conducted a questionnaire survey (Feb. 2007) with a five-grade evaluation by the SD method with 30 university students as subjects using the proposed sketch as well as the same photographs of 45

lighting fixtures used in the previous survey for multiple regression analysis. The results were analyzed using the notion of Welch official approval (Fig.2, right).

The values of the “Significant probability (*p*)” are smaller than those of the “Significance test (0.005)” for both the impressions “interest retaining” and “playful.” Thus the sketch is considered to be emphasizing the impressions analyzed.

8. Conclusions

We have quantitatively obtained a cognitive evaluation structure of consumers for lighting fixture design using multiple regression analysis and Rough Sets. We proposed a method for making design concepts by reconstructing the resulting evaluation structure. We demonstrated the effectiveness of the proposal through experimental confirmation in which we made a design sketch based on the method.

Acknowledgments

We wish to express our thanks to students of Kansei Design Department at Hiroshima International University for their cooperation. We are grateful to Professor Hirokawa of Tokai University for giving us valuable advice.

References

1. Architectural Institute of Japan: Introduction to Environmental Physiology Survey Methods. Gihodo Shuppan Co., Japan, pp 13 (2000).
2. “*ibid*” Evaluation Grid Method. Section 3-2-1, pp 57-64.
3. Mori N, Tanaka H, Inoue K: Rough Sets and *Kansei*. Kaibunndo, (2004).
4. Inoue K, Hirokawa M: Proposal of Rough Sets Method for Analyzing Relationship between Recognitive Parts and Evaluation Words. Journal of Japan Society of *Kansei* Engineering, vol. 5/No.1, pp 43-52 (2004).
5. Mori N, Tanaka H, Inoue K. Rough Sets and *Kansei*. Kaibunndo, pp 43-50 (2004).