Extracting Method of Kansei Design Rules Based on Rough Set Analysis

Tatsuo Nishino and Mitsuo Nagamachi

Hiroshima International University
555-36 Gakuendai, Kurose-cho, Kamo-gun, Hiroshima, Japan
E-mail: t-nishi@he.hirokoku-u.ac.jp

Abstract
Kansei design knowledge acquisition stage is a crucial stage in kansei designing process and kansei engineering (KE) methodology. In kansei engineering methodology, it is essential to extract design knowledge or rules on relationships between customer's kansei and product design elements. We attempt to construct a more powerful method for extracting the design rules from kansei experimental data. We conducted a kansei experiment concerning color kansei evaluation, and analyzed the same data by both conventional quantification theory type I and rough set theory. Finally, we compared the effectiveness of both methods for extracting rules and examined the extensions of rough set theory in kansei engineering.

Keyword: Kansei Engineering, Kansei Rule Discovery, Color Design Rule

1. Introduction

Kansei design knowledge acquisition stage is a crucial stage in kansei designing process and kansei engineering (KE) methodology [3]. In kansei engineering methodology, it is essential to extract design knowledge or rules on relationships between customer's kansei and product design elements. The knowledge or rules acquired by some methodologies can support customers and designer constructing a product that is appropriate to his or her kansei and we can kansei design expert system using these knowledge.

Knowledge acquisition is the most difficult stage in kansei engineering methodology. This process involves extracting the knowledge or rules from a given design domain. Extracting the knowledge directly from design experts is more difficult and time-consuming in kansei engineering in particular. Accordingly, we generally extract the knowledge by statistically analyzing the relationship between kansei evaluation data and design elements from kansei experimental data. Conventionally, we have often used statistical methods such as factor analysis, quantification theory type I. These statistical methods are very powerful to extract the design rules between kansei and product design elements. Realistically, a lot of experiences are, however, needed to extract the knowledge, in particular, the combination knowledge between design elements, from the analysis results [4]. Human kansei that means human feeling or image has essentially vagueness and uncertainty. And moreover, the combination effects among design elements influence kansei. Thus, in order to extracting the more effective design rules from kansei data, a method that can deal with these peculiar kansei properties in knowledge extraction process should be developed. So far, artificial intelligence methods such as neural network, genetic algorithm and so on have been developed. These artificial intelligence methods are also powerful, but these methods have difficulties in inducing relationships in kansei data which have contradictory examples.

We attempt to construct a more powerful method for extracting the design rules from kansei experimental data. Rough set theory, introduced by Pawlak [5], is a new mathematical tool to deal with vagueness and uncertainty. It is concerned with the classificatory analysis of imprecise, uncertain or incomplete information expressed in terms of data acquired from experience. Therefore, we can expect that rough set theory provide a tool for analyzing effectively the kansei data which have substantially vague and nonlinear.

Accordingly, the purpose of this study is to develop a methodology for analyzing and extracting the kansei knowledge or rules which we are able to apply generally in kansei product development processes. We conducted a kansei experiment concerning color kansei evaluation, and analyzed the same data by both conventional quantification theory type I and rough set theory. Finally, we compared the effectiveness of both methods for extracting rules and examined the extensions of rough set theory in kansei engineering.

2. Rough Set Theory

We will describe here the outline of rough set theory. Data for rough set analysis are represented in the form of an attribute-value table. Row of the table represents objects (e.g. a sample product) U. Columns of the table represent attributes (e.g. product design attributes) A characterizing objects. Values of attributes are acquired by measurement or human judgments. Any information system I can be regarded as a pair (U, A). Decision system can be regarded as a triple I_d =(U, A, d) where (U, A) is an information system and d is an extinguished attributes called the decision. In the case of kansei data, d is a human kansei evaluation set to objects with some design elements. Let X be any decision class set. For any attribute set B, we can define the lower and upper approximation of X, denoted $B_*(X)$ and $B^*(X)$, respectively, as follows

$$B_*(X)=\{x\in U : [x]_B\subseteq X\}$$

and

$$B^*(X)=\{x\in : [x]_B\cap X\neq \phi\}.$$

Since kansei-design elements data often include contradictory data, we may be able to approximate kansei rules with lower and upper approximation. We can induce the possible rules from upper approximation of kansei and certain rules from lower approximation by using discernibility function. By using discernibility matrix of Shan and Ziarko[2], we can solve the following reducts R,

$$R=\wedge\{\vee d_{ij} ,d_{ij} \neq\Phi\},$$

where d_{ij} is an element in i row j column.

In this paper, we used the Mori rough set analysis program which can induce the rules using lower approximation.

3. Extraction of Colour Kansei Design Rules

3.1 Kansei Experiment

Figure 1 shows the 3D color space from which we selected the four points along with each axes, and constructed 64 color

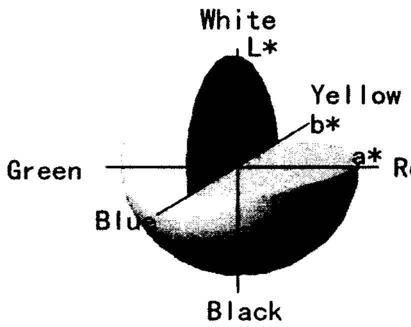

Fig.1 Color sample space

samples. The L*a*b* color presentation system shown in Fig. 1, which has three axes of white- black (L*), green -red (a*), and blue- yellow (b*). They were selected on the basis of each combination of these points on the axes. In this color system, A color is determined by combination L*, a* and b* attribute values. Table 1 shows the item/category table. We used 4items and 14 categories. The alphabetic symbols indicate the condition attribute values, which were used in rough set analysis.

Table 1 Item-category/condition attributes

Design	Category	Symbol
L* value	0	A
	33	B
	66	C
	100	D
a* value	127	E
	42	F
	-43	G
	-128	H
b* value	127	I
	42	J
	-43	K
	-128	L
Gender	Male	M
	Female	W

3.2 Kansei Measurement

Thirty adjective pairs of kansei words were selected on the basis of the most frequently used color words. Each word has a pair of the opposite word. Using 5 points SD-scale of each kansei words, each color sample was evaluated by 40 students (20 male and 20 female, age:19-22).

3.3 Quantification Theory Analysis

Because multiple correlation coefficient in each kansei analysis was higher than 0.70, we can make good regression space in each kansei model. Table 2 showed the category scores in each item. We can induce the color kansei design rules from the category score table. For example, if threshold value of the category score was assumed to be over 0.5, we can induce if-then rule as follows

If kansei is vivid, then L*=100(white) and a*=127(red) and b*= -128(blue)

If kansei is comfortable, then L*=100(white) and b*= -128(blue).

We can induce the rules for other colors by the same way. This method for extracting rules is more useful in many cases. However, It is difficult to deal with the interaction effects between design elements from the results of quantification analysis

3.4 Rough Set Analysis

The condition attributes were L*, a*, b*and gender. Each data was assigned each attribute value to each condition attribute according to their properties. Decision attribute was kansei categories divided into three classes. The average values of 20

Table 2 Results by quantification theory

Kansei words	L*値 0	L*値 33	L*値 66	L*値 100	a*値 -128	a*値 -43	a*値 42	a*値 127	b*値 -128	b*値 -43	b*値 42	b*値 127
Vivid	-1.0766	-0.1037	0.5803	0.6001	-0.1669	-0.1117	-0.3326	0.6112	0.6405	0.0844	-0.5213	-0.2036
Stimulating	-1.0766	-0.1037	0.5803	0.6001	-0.1669	-0.1117	-0.3326	0.6112	0.6405	0.0844	-0.5213	-0.2036
Rich	-0.6284	0.0054	0.3245	0.2985	-0.0520	0.0336	-0.1507	0.1890	0.1102	-0.1058	-0.1340	0.1297
Restful	0.4977	-0.0488	-0.2665	-0.1825	0.3145	0.2454	0.1877	-0.7476	-0.2001	-0.0934	0.2947	-0.0012
Friendly	-0.8239	-0.1079	0.3335	0.5983	0.0629	0.0017	0.0718	-0.1364	0.0839	-0.0501	0.0392	-0.0730
Familiar	-0.2340	-0.1259	0.1038	0.2561	0.2806	0.2349	-0.0065	-0.5090	0.1828	-0.1068	0.0412	-0.0972
Fresh	-0.9374	-0.1438	0.4615	0.6197	0.3466	0.3746	-0.2756	-0.4457	0.6986	0.1024	-0.5343	-0.4668
Young	-1.0242	-0.2076	0.5721	0.6598	0.0645	0.1306	-0.4090	0.2139	0.5225	0.0335	-0.3201	-0.2358
City-like	-0.0772	-0.1673	0.0904	0.1541	-0.1800	-0.0697	-0.2370	0.4867	0.3732	0.1795	-0.3453	-0.2074
Attentive	-0.3966	-0.0217	0.2474	0.1709	-0.1978	-0.1690	-0.4187	0.7854	0.4134	-0.0440	-0.4040	0.0346
Childish	-1.0392	-0.1139	0.4841	0.6689	0.0818	0.1138	-0.3271	0.1315	0.3598	-0.0451	-0.2251	-0.0896
Showy	-0.6262	-0.0649	0.4180	0.2731	-0.4073	-0.2793	-0.3147	1.0014	0.4729	0.1646	-0.4979	-0.1406
Active	-0.7347	0.0145	0.3558	0.3645	-0.1098	-0.0780	-0.3095	0.4973	0.3761	-0.0082	-0.3757	0.0049
Gorgeous	0.0047	-0.0633	0.1179	-0.0593	-0.3720	-0.3028	-0.1139	0.7888	0.1166	0.1137	-0.2249	-0.0057
Calm	-0.3054	-0.0160	0.1304	0.1911	0.1744	0.1769	0.1929	-0.5342	-0.0259	-0.1301	0.1147	0.0413
Cheerful	-0.6029	-0.1243	0.2560	0.4712	0.2464	0.2256	-0.0073	-0.4647	0.2995	-0.0643	-0.0415	-0.1938
Comfortable	-1.0436	-0.2291	0.5555	0.7172	0.2908	0.3691	-0.2003	-0.4585	0.7420	-0.0142	-0.3507	-0.3771
Not tired	0.3292	-0.1491	-0.1535	-0.0266	0.3029	0.2422	0.0301	-0.5752	0.0383	-0.0627	0.0930	-0.0686
Elegant	0.2716	-0.1996	-0.0830	0.0110	-0.0049	-0.0033	0.0775	-0.0693	0.1288	0.0519	-0.0587	-0.1230
Manly	0.5201	0.2360	-0.2275	-0.5286	0.7073	0.6834	-0.1872	-1.2035	0.2882	-0.1928	-0.0721	-0.0243
Warm	0.5207	0.8073	0.7765	0.0485	-0.3408	0.0021	0.1287	0.2100	-0.4347	-0.4217	0.1487	0.7076
Fashionable	-0.1815	-0.2180	0.1889	0.2106	-0.1245	-0.0471	-0.1520	[illegible]	0.2875	0.1468	-0.2012	-0.2031
Delightful	-1.1949	-0.1702	0.6331	0.7320	-0.1829	-0.0308	-0.2009	[illegible]	0.4447	0.0180	-0.3082	-0.1544
Beautiful	-0.4604	-0.1641	0.2594	0.3850	-0.0970	-0.0629	-0.1470	0.2075	0.3647	0.0886	-0.2270	-0.2263
Sanitary	-0.5887	-0.1538	0.3210	0.4715	0.3235	0.2924	-0.2243	-0.3916	[illegible]	-0.0879	-0.1738	-0.2823
Enjoyable	-1.0194	-0.1491	0.5182	0.6104	-0.1433	-0.0023	-0.1880	[illegible]	0.1171	-0.0092	-0.2961	-0.0520
Attractive	-0.0800	-0.1698	0.0890	0.1601	-0.2014	-0.0491	-0.1450	[illegible]	0.4322	0.1240	-0.2078	-0.1485
Happy	-0.8076	-0.0904	0.3799	0.6180	-0.1336	-0.0494	-0.1343	0.5172	0.1175	-0.0901	-0.0453	0.0180
Natural	-0.4705	-0.0824	0.2049	0.3480	0.2743	0.3483	-0.0248	-0.5977	0.2341	-0.1542	0.0215	-0.1014

subjects were used as decision attributes. The number of analyzed data was 124. The purpose of the analysis was to reduce the information table by logical operations, and to solve the minimal reduct of each data for each kansei class. This means that we are able to clear the interaction relationship between kansei and the combination of condition attributes. We constructed the information tables of all the kansei and calculated the minimal reducts of data.

Table 4 shows the results by rough set analysis and also the results of quantification theory of all the kansei words. The results of rough set analysis indicate the rules with higher than CI=0.1. CI means covering index that indicates the ratio of the number of samples that fit to the rule to the number of all the samples belonging in the classified kansei class. The number on the rule in Table4 indicates the CI. The results of quantification theory type I is shown in terms of the combination of the two categories with two higher category score. Only one rule in each kansei word was derived from quantification theory. We can derive other rules, but acquisitions of more complex rules from quantification theory analysis need the domain knowledge and experiences. We can see that the family of sets causing 'fashionable' kansei is EIM, CJM and DHM. This indicates that the combinations of color element EIM, CJM and DHM can contribute to 'fashionable' kansei. Namely, this shows that the combinations of 'blue and green', 'white and red', and 'blue and white' cause the kansei' fashionable'. In similar way, we could be able to extract the family sets of condition attributes causing other kansei.

These sets correspond with our daily experience much better, but it should be noticed that there are the sets t that cannot be got

Table 4 Comparison of quantification analysis and rough set analysis

	Quantification	Rough Set Analysis 1		2		3		4		5	
Showy	H C	B H	0.195	C H	0.195	D H	0.195				
Restful	G D	C F M	0.138								
Stimulating	H I	H I	0.267	B H	0.267	C H	0.267	D H M	0.133		
Yoong	D I	C J	0.133	D H	0.133						
Vivid	D I	E I	0.118	F I	0.118	C J	0.118	D H	0.118	D J	0.118
Comfortable	D E	E IM	0.148	F IM	0.148						
Calm	E A	**									
Gorgeous	H I	**									
Pretty	D I	D H	0.235								
Rich	C I	W C L	0.286	C L G	0.143	D L G	0.143				
Familiar	D M	**									
Friendly	E D	E IM	0.211	F IM	0.211	D K F	0.105	D K G	0.105	E IC	0.105
Natural	F D	F IM	0.129								
Happy	D H	E IM	0.108	W D H	0.108						
Attractve	H W	E IM	0.161	K H M	0.161	D H M	0.161				
Enjoyable	D I	D H	0.167								
Fresh	D I	F I	0.229	E IM	0.114	G IM	0.114				
City-like	IH	B J H	0.1	B K H	0.1	C J H	0.1	C L H	0.1	D H J	0.1
Attentive	M I	D H	0.235								
Childish	D I	D H	0.211	F IM	0.105						
Active	D H	W F I	0.129	W D H	0.129						
Delightful	D I	E I	0.174	F I	0.174	D F	0.174				
Not tired	E A	K E A	0.133	K F A	0.133	L E A	0.133				
Elegant	A M	F IA M	0.2	W J F A	0.2	W K E A	0.2	W K H A	0.2	W L H A	0.2
Manly	G A	E A	0.2	F A M	0.1	W E B	0.1	W B F	0.1		
Warm	H L	D H	0.288	W L H	0.143						
Fashonable	ID	E IM	0.125	C J M	0.125	D H M	0.125				
Cheerful	D I	F I	0.118	C J	0.118	C L	0.118	D F	0.118	D H	0.118
Beautiful	D I	F IM	0.118	K H M	0.118	D IM	0.118	D H M	0.118		
Sanitary	D I	E I	0.222	F I	0.222	W C E	0.111				

by the results of quantification theory type I. For example, BH in showy kansei, EIM in fashionable kansei and LMFA and FAWJ in elegant kansei gave unique solutions. Moreover, we can see that the number of sets in any kansei word shows the wideness of viewpoints in the kansei word. According to Table 4, vivid, friendly, city-like, elegant and cheerful is wider than other kansei words. On the other hand, restful, pretty, natural, enjoyable and attentive presents narrow viewpoints. These results correspond with our daily life clearly.

From the results of quantification theory analysis, many rules on the same kansei cannot be derived with confidence. As shown in Table 4, quantification theory analysis derived the same rule in some kansei words. For example, DI rule appeared in 11 kanei words. This means that quantification theory analysis does not produce a variety of rules compared to rough set analysis. It should be also noticed that the categories with lower category score are included in the sets produced by rough set analysis. For example, twenty-eight female (W) and male (M) categories are included in the sets. These categories were little included in the rules in quantification theory analysis, since items in which these categories belong had lower partial correlations in all the kansei. This means that the sets produced by rough set theory is possible to include the categories with lower category score. Therefore, it is suggested that rough set analysis will be able to produce various and unique sets. In short, quantification theory is appropriate to find out relatively common, simple and exact rules, while rough set analysis is appropriate to find out unique and complex rules.

4. Extension of Rough Set Analysis in Kansei Engineering

We examine to introduce some notions and coefficients of rough set theory into kansei data analysis [1]. In kansei engineering, we need to evaluate the priority between items and categories. Quantification theory is superior to rough set theory in respect with the ability for discriminating the priority between items and between categories. In quantification theory analysis, we can easily determine the priority between items and between categories in terms of partial correlation coefficient and category scores. In rough set analysis, we can estimate the importance of each attribute using the following classification precision coefficient.

$$k=\gamma(C,D)=\Sigma|C_*(X)|/|U|$$

Secondly, Accuracy of approximation of kansei data can be estimate by the following coefficient called roughness.

$$\alpha_B(X) = |B_*(X)| / |B^*(X)|$$

We will propose to introduce the notion of rough membership function defined below to deal with the vagueness of kansei raw data precisely.

$$\mu^B_X(x)=|(X\cap[x]_B)|/|[x]_B|,\ \mu^B_X(x)\in[0,1]$$

Introduction of these notions and coefficients will lead to development of more powerful kansei design extraction method.

Kansei engineering is a practical technology for developing customer-oriented products. In the case that designers have not any kansei rules, quantification theory analysis will be useful. On the other hand, when designers experiences kansei product development and have some kansei knowledge, and must design unique products, rough set analysis will be more useful.

5. Conclusions

We conducted kansei experiment concerning color design on the basis of color attributes L*, a* and b* in order to analyze the relationship between kansei and the color attributes

We applied quantification theory type I and rough set theory into the same data. As a result, Good rules were derived from the results of both analysis methods. It was found that rough set analysis could produce multiple candidates fit to the target kansei. And also, it was suggested that rough set analysis was useful to find unique and variable rules concerning kansei from information table, while quantification theory was useful to find basic rules in kansei data. An application of rough set analysis in kansei engineering will be promised. We have attempted to extend the rough set algorithm appropriate to kansei engineering applications.

References

[1] Ishihara, S., Nishino, T. and Tsuchiya, T.: Introduction to Kansei Engineering (Part 2), Evaluation and Analysis of Kansei Data, *Human Interface*, vol.4 No.1, 2002, 13-24

[2] Mori, N.: Chain Structure of Kansei for Characterizing Kansei Engineering, Kansei Engineering Symposium, 1999,12-17

[3] Nagamachi, M: Kansei Engineering, Japan, Kaibundo Publisher. 1989

[4] Nishino, T., Nagamachi, M., Ishihara, S.: Rough Set Analysis on Kansei Evaluation of Color and Kansei Structure. QMOD, 2001, 543-550

[5] Pawlak, Z., Grzymala-Busse, J., Slowinski, R., and Ziarko, W: Rough Sets, *Communication of the ACM*, November 1995, vol.38, No.11.89-95