Title:
Method for grouping of customers and aesthetic design based on rough set theory

Authors:
Masakazu Kobayashi, kobayashi@toyota-ti.ac.jp, Toyota Technological Institute
Kouki Niwa, sd12067@toyota-ti.ac.jp, Toyota Technological Institute

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Introduction:
Due to maturation of science and technology, it becomes increasingly difficult to differentiate products in terms of performance, functional feature or price. Therefore, companies are required to differentiate their products in terms of subjective and abstract qualities such as aesthetic and comfort that are evaluated by customer's feeling, which is called "Kansei" in Japanese. The quality evaluated by customer kansei is called "Kansei quality".
In the field of emotional engineering or kansei engineering, the methods for measuring customer kansei or the impression of products have been developed and applied to many case studies [8], [16]. In these methods, semantic differential method (SD method) is widely used. In addition, various methods for supporting aesthetic design by utilizing measured customer kansei have also been developed [2-5],[10],[13],[15]. These methods generate a new aesthetic design which a customer prefers best by analyzing the relationships between the results of customer's kansei evaluation of existing products and their aesthetic elements. Most of industrial products are geared toward many customers, not a single customer, and it is quite difficult to design a product that satisfy all customers due to the diversity of their kansei. To overcome such problem, robust design methods using Taguchi method [7],[12] and grouping methods [6],[14] were proposed.

In this research, we also focus on such diversity and propose a method for grouping of customers and aesthetic design based on rough set theory [11]. In the proposed method, customers evaluate existing products using SD method. By using rough set theory, rules that describe the relationships between customers' impressions taken from existing products and their aesthetic features are extracted from their evaluation results. Customers are then classified into several groups based on the similarities of their extracted rules and new aesthetic designs are synthesized by combining extracted rules for each group. The feature of the proposed method is to utilize the rules extracted by rough set theory to both grouping of customers and aesthetic design. Grouping based on the rules extracted by rough set theory increases the similarity of rules of customers belonging to the same group and enables synthesizing product aesthetics preferable to all customers of the same group.

Proposed method:
The proposed method consists of the following 4 steps. The rest of this section explains their details.

Step1: Questionnaire investigation
Step2: Rule extraction
Step3: Grouping
Step4: Aesthetic design

Preparation of the proposed method
A designer makes a questionnaire sheet by selecting existing products and pairs of kansei words suited for the design target. The pair of the word that describes the degree of customer's preference should

be selected as one of pairs of kansei words. A designer also selects aesthetic elements and measures parameters of aesthetic elements of existing products.

Step1: Questionnaire investigation

Using questionnaire sheets, customers carry out questionnaire investigation. They score their preferences and impressions of existing products by using the selected pairs of kansei words and their evaluation scales.

Step2: Rule extraction

Based on the questionnaire results, rules that describe the relationships between customers' preferences & impressions taken from existing products and parameters of their aesthetic elements are extracted and their covering index (CI) are calculated by using rough set theory. Specifically, score of kansei words and parameters of aesthetic elements are handled as decision and condition attributes respectively. In case n kansei words are evaluated on a m-point scale, rules for nm decision attributes are extracted.

Step3: Grouping

Similarity of the extracted rules among customers are calculated. Similarity of customer i and j's rules $Score_{ij}$ is defined by the below equation.

$$Score_{ij} = \sum_{l=1}^{L}\sum_{k=1}^{K}\left\{\left(\frac{N_{ij}^{kl}}{N_{i}^{kl}} \times CI_{i}^{kl}\right) + \left(\frac{N_{ij}^{kl}}{N_{j}^{kl}} \times CI_{j}^{kl}\right)\right\}$$

Where, N^{kl}_{i} is the number of customer i's rules whose decision attribute is kansei word l with score k. N^{kl}_{ij} is the number of common rules between customers i and j's rules whose decision attribute is kansei word l with score k. CI^{kl}_{i} is the covering index of customer i's rules whose decision attribute is kansei word l with score k. K and L is the number of point scale and kansei words. After calculating similarities among all customers, they are classified into several groups based on the calculated similarities by using hierarchical clustering analysis and ward method.

Step4: Aesthetic design

Aesthetic design is performed for each group based on the Mori's method [9]. In this step, only rules concerning the kansei word that describes the degree of customer's preference are used. The rule having high score of the kansei word that describes the degree of customer's preference is named "preference rule" while the rule having low score is named "non-preference rule"

First of all, n preference rules are selected in a descending order of CI for each customer. New rules are then generated by selecting one preference rule from each customer and combining them. Condition attributes of the new rule is a combination of the condition attributes of the selected rules. New rules are generated from all combinations of all customers' preference rules. Condition attributes of the generated rules are then checked and the rules containing condition attributes that cannot coexist or is equivalent to ones of non-preference rules are eliminated. CI of the generated rules are then calculated by adding together CI of the original rules. Finally, the rule having highest CI is adopted to a new aesthetic design. The rule is named "Design rule" Fig.1 illustrates the flow of this step. In many cases, the rule having highest CI may not contain several aesthetic elements. Therefore, until options of all aesthetic elements are decided by rules, rules that don't compete with the highest and higher rules are selected in descending order of CI and added to the design rule.

Case study:

To show the flow of the proposed method, it was applied to a car exterior design.

Details of the case study

8 male undergraduate and graduate students were participated as subjects. 9 aesthetic elements (a: Shape of a front light, b: Shape of a front grill, c: Type of a front grill, d: Size of a front grill, e: Size of a bonnet, f: Global body shape, g: Body type, h: Gap between spokes, i: Orientation of a side mirror) were configured and each aesthetic element had 2 to 5 options. 20 automobiles were selected for existing products and options of their aesthetic elements were identified. Since color was not configured as an aesthetic element, Color of all cars was unified into white. "Attractive-Not attractive" was selected as the pair of kansei words that describes the degree of customer's preference and 9 pairs of kansei words (Heavy-Light, Flat-Lumpy, Rugged-Smooth, Straight-Rounded, Swift-Slow, Simple-Complicated,

Calm-Dynamic, Unique-Popular, Masculine-Feminine, Intellectual-Wild, Childish-Adult, Revolutionary-Retro, Warm-Cool, Plain–Rich) were additionally selected. “Attractive–Not attractive” was evaluated on a scale of 1 to 3 while others were evaluated on a scale of 1 to 5.

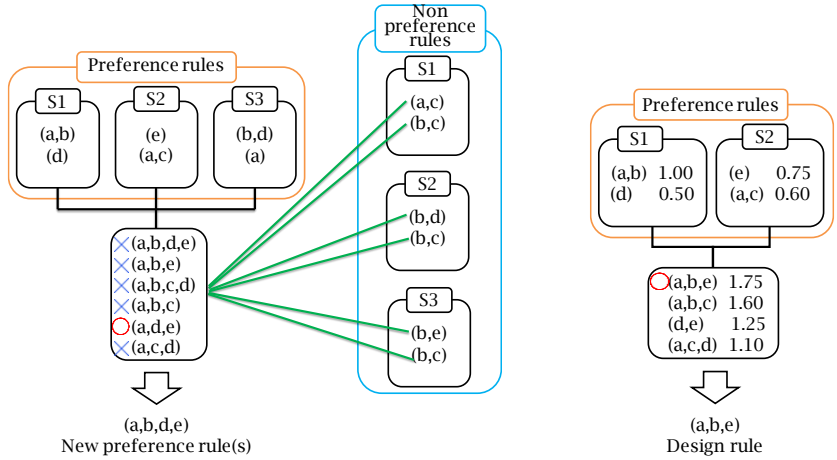

Fig. 1: (a) Generation of new preference rules, (b) Evaluation and selection of rules.

Results

8 subjects were classified into 3 groups. Tab. 1 shows the group members, the rule having highest *CI*, its value and the design rule for each group. Fig. 2 shows car exterior generated by the design rules. These pictures were generated by 3D tuning [1].

	Group1	Group2	Group3
Member	S1,S4	S2,S3,S5,S8	S6,S7
Selected rule	a1,c1,d1,g1,h2	a1,b1,d1,e2,f1,i3	a3,c1,e2,f1
CI (Total)	1.6	2.96	1.07
CI (Per person)	0.8	0.74	0.54
Design Rule	a1,b1,c1,d1,e1,f1,g1,h2,i2	a1,b1c3,d1,e1,f1,g1,h2,i3	a3,b3,c1,d1,e2,f1,g2,h2,i3

Tab. 1: Result of aesthetic design.

Fig. 2: Car exterior generated by the design rules.

For comparison, subjects were classified into groups by using traditional grouping method and aesthetic design was performed by using the proposed method for each group. In the traditional method, grouping was based on the similarity of evaluation scores of SD method. 8 subjects were classified into 2 groups. Tab. 2 shows the group members, the rule having highest *CI*, its value and the design rule for each group. Fig. 3 shows car exterior generated by the design rules.

	Group1	Group2
Member	S1,S2,S4,S6,S7	S3,S5,S8
Selected rule	a1,b1,c1,d1,e2,f1,g1,h2,i3	a1,d1,f1,h2,i3
CI (Total)	3.53	1.96
CI (Per person)	0.71	0.65
Design Rule	a1,b1,c1,d1,e2,f1,g1,h2,i3	a1,b1,c3,d1,e1,f1,g1,g2,i3

Tab .2: Result of aesthetic design

Fig. 3: Car exterior generated by the design rules.

At the end of experiments, subjects evaluated the cars designed by two methods on a scale of 1 to 5. Fig. 4 shows the evaluation results. The results show that most subjects were satisfied with the cars designed by the proposed method. The results also show that most subjects preferred the cars designed by the proposed method rather than the cars designed by the traditional method. Since subjects 3, 5 and 8 belonged to the same group in both cases and design rules generated in 2 cases were identical, their score was same.

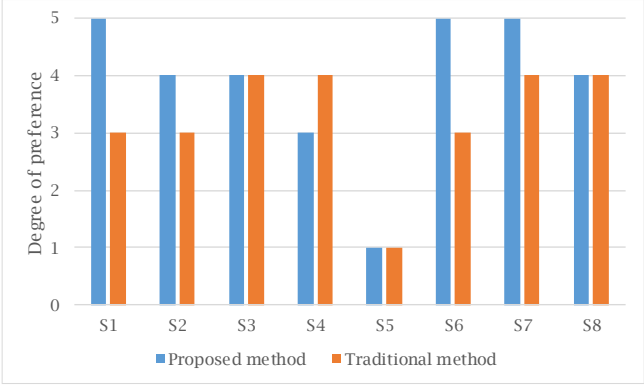

Fig. 4: Evaluation results.

Conclusion:

To maximize satisfaction of customers with diverse kansei, we propose a new method for grouping customers and designing product aesthetics based on rough set theory. In the proposed method, customers evaluate existing products using SD method. Based on the results, rules that describe the relationships between customers' impressions and aesthetic elements are extracted. Customers are then classified into several groups based on the similarity of their extracted rules and new aesthetic designs are synthesized by combining extracted rules for each group. To show the flow of the proposed method and its effectiveness, the proposed method and the traditional method were applied to car exterior design. The results show that most subjects preferred the cars designed by the proposed method rather than the cars designed by the traditional method.

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