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

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**ABSTRACT**
Due to maturation of science and technology, companies are required to differentiate their products in terms of subjective qualities such as aesthetics and ergonomics whose evaluation depends on customer feeling i.e. kansei. To consider customer kansei in product developments, various design methods have been developed, but diversity of customers' kansei is becoming a big issue. More specifically, most of industrial products are designed for many customers, not a single customer, and it is quite difficult to design products that satisfy all customers due to the diversity of their kansei. To overcome this problem, we propose a new method for grouping of customers and aesthetic design based on rough set theory. In the proposed method, customers make kansei evaluation of existing products using SD method. By using rough set theory, rules that describe the relationships between customers' preference and impressions taken from existing products and aesthetic features of existing priducts are extracted from their evaluation results. Customers are then grouped based on the similarities of their extracted rules. New aesthetic designs are finally synthesized by combining extracted rules for each group. Since grouping based on the similarity of rules extracted by rough set theory among customers increases the similarity of the rules which customers in the same group have, there is high possibility that new aesthetic designs synthesized by combining them reflect preferences of all customers in the group. In the case study, the proposed method was applied to a car exterior design to confirm its effectiveness.

**KEYWORDS**
Kansei engineering; Aesthetic design; Grouping; Hierarchical clustering analysis; Rough set theory

## 1. 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" [33].

In the field of kansei engineering [20][21] (referred to as affective or emotional engineering), methods for measuring and analyzing human's kansei and designing products based on them have been developed for years. In these methods, SD method [25] is widely used for measuring human's kansei quantitatively. Measured human's kansei is analyzed and utilized to a product design by various methods according to a purpose. Statistical techniques such as multivariate analysis and Hayashi's quantification methods, rough set theory [26] and artificial neural network are examples of analytical methods and design methods integrated with these analytical methods have been developed.

Most of industrial products are designed for many customers, not a single customer, and it is quite difficult to design products that satisfy all customers due to diversity of their kansei. To overcome the difficulty, the methods that group customers based on the similarity in their kansei and separately design products for each group have been proposed [14] [23] [30]. This paper also focuses on diversity of customers' kansei and proposes a new method for grouping of customers and aesthetic design based on rough set theory to reduce the impact of their diversity. In the proposed method, customers scores preference and impressions taken from existing products using pairs of kansei words and their evaluation scale. Evaluation results are analyzed by rough set theory and the rules that describe the relationships between customers' impressions and preference taken from existing products and their aesthetic features are extracted. Similarities of extracted rules among customers are then calculated and customers are classified into several groups based on the similarities. New aesthetic designs are finally generated by synthesizing extracted rules for each group. The feature of the proposed method is that both

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grouping and design are based on rough set theory. Since customers are grouped by the similarity of their extracted rules, the rules that customers in the same group have are quite similar. Therefore, there is a high possibility that all customers in the group are satisfied with the product designed by synthesizing their rules. On the other hand, since existing grouping methods are mainly based on the similarity of customers' kansei evaluation, there is no guarantee that the rules which customers in the same group have are similar. As a result, there is a possibility that the product that satisfies all customers in the same group cannot be obtained by synthesizing their rules.

The rest of this paper is organized as follows. Section 2 introduces overview of kansei engineering and related works. Section 3 explains the details of the proposed method. To confirm the effectiveness of the proposed method, it is applied to a car exterior design, as described in section 3. Finally, section 4 summarizes the results of this paper.

## 2. Related work

Kansei engineering is the field of engineering that aims to study a mechanism of humans' feeling & kansei and develop methods of measuring & analyzing humans' kansei and designing products which customers feel desirable and want.

For years, in the field of kansei engineering, various methods for measuring and analyzing human's kansei and designing products based on them have been developed. Measurement of human's kansei forms the basis of kansei engineering. Semantic differential method (SD method) [25] is the most widely used for measuring human's kansei quantitatively. In the SD method, subjects quantitatively score impressions which they receive from evaluation objects using adjective pairs of opposite meanings named "Kansei words" and their evaluation scales. Interviewing and measurement of bio-information such as electroencephalogram, brain activity and eye positions / movement are also used for measuring human's kansei.

Measured human's kansei is analyzed by various methods, for example, statistical techniques such as multivariate analysis and Hayashi's quantification methods, rough set theory and artificial neural network according to a purpose. Rough set theory [26] is the method that extracts decision rules that explains the relationships between decision and condition attributes from the information of the objects having multiple attributes. In kansei engineering, customer's preference of an existing product and its aesthetic elements are considered as decision and condition attributes respectively and rough set theory extracts decision rules that explain the relationships between customer's preference and aesthetic elements from the results of questionnaire using SD method. Artificial neural network is used mainly for analyzing the relationships between customers' impressions of products measured by SD method and parameters of aesthetic features. Once learning of a neural network is finished, customer's impressions taken from new products can be inferred by inputting parameters of their aesthetic elements.

Various methods for designing products based on analyzed human's kansei have been proposed. 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 using the methods described above. Tanaka et al. proposed the design support methods using interactive genetic algorithm [28]. Yanagisawa et al. proposed the design support methods using interactive reduct evolutionary computation [31]. Yamada et al. proposed the method to design an eyeglass frame using rough set theory [29]. Rough set theory was also used in various methods [13][22][24]. Hsiao et al. proposed the design support method using fuzzy theory and multidimensional scaling (MDS) method [5] and artificial neural network (NN) [6]. We proposed the design support method using self-organizing map (SOM), NN and genetic algorithm (GA) [11]. We also propose the method for selecting kansei words used for kansei evaluation [12]. In addition to product shape, the methods to design clothing pattern, texture of product surface, sound etc. have also been developed. Kamahara et al. proposed the method to design color and pattern of polka dots for clothing based on artificial neural network [9]. Akiyama et al. proposed the method to design wood grain patterns by using correlation analysis [2]. Since wood grain patterns give customers give impressions such as "peacefulness" and "composure", designed patterns are printed to product surfaces. Yanagisawa et al. proposed the method to design machine sound by using cluster analysis and correction analysis [32] Ito et al. proposed the method to design mascot characters by using rough set theory [8]. Most of industrial products are designed for many customers and it is quite difficult to design products that satisfy all customers due to diversity of their kansei. To overcome this problem, Lai et al. and Sutono et al. proposed robust design methods using taguchi's method [15], [27], while Kuroda et al., Yamamoto et al. and Oku proposed a method for grouping customers based on the similarity in their kansei evaluation [14] [23] [30].

In the field of CG or CAD, the concept of aesthetic curves and surfaces is proposed by Harada et al. [4], [5] and their formulation and application of aesthetic curves and surfaces have been studied [18], [35]. Gianninia et al. identified and classified styling properties and features that affect product aesthetics [3].

## 3. Proposed method

In order to reduce an adverse effect on diversity of customers' kansei and increase customer satisfaction with industrial mass productions, this paper proposes a new method for grouping of customers and aesthetic design based on rough set theory. The proposed method consists of questionnaire investigation of existing products against customers, extraction of customers' decision rules by rough set theory, grouping of customers based on the similarities of their extracted decision rules and aesthetic design based on the synthesis of extracted decision rules. The feature of the proposed method is that both grouping and design are based on the results of rough set theory. The proposed method consists of the following 4 steps:

Step1: Questionnaire investigation

Step2: Rule extraction

Step3: Grouping

Step4: Aesthetic design

The rest of this section explains the detailed procedures of 4 steps.

### 3.1. Preparation of the proposed method

Since SD method is used to measure customers' kansei in the proposed method, questionnaire sheets are prepared in the preparatory step of the proposed method. A designer prepares photos of the same kind of existing products as the design target and selects adjective pairs of opposite meanings named "Kansei words" suited for representing impressions taken from the design target. A pair of words that describes the degree of customer's preference, for example, like – dislike, also needs to be selected as one of pairs of kansei words. A designer then makes questionnaire sheets using photos, pairs of kansei words and their $n$-point evaluation scales. A designer also selects aesthetic elements and their alternatives suited for representing aesthetics of the design target and the existing products and identifies aesthetic elements of the existing products. Since rough set theory is used in the proposed method, only aesthetic elements that can be represented by alternatives or discrete parameters can be selected.

### 3.2. Step1: Questionnaire investigation

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

### 3.3. Step2: Rule extraction

Based on the questionnaire results, rules that describe the relationships between customers' preference & impressions taken from existing products and their aesthetic elements, named decision rules, are extracted by using rough set theory.

By advance preparation and questionnaire investigation, information about measured values of kansei evaluation and identified alternatives of aesthetic elements are obtained for each existing product. These information are called attributes of existing products. More concretely, the former is assigned to decision attribute while the latter is assigned condition attribute respectively. Since preference & impressions are scored by using $n$-point evaluation scale, they have the values 1-n. Aesthetic elements have alternatives as the values. A table that shows these information is called decision table and decision rules are extracted from there. Decision rules explains the relationships between the values of decision and condition attributes in the form of If-then format. Since preference and impressions are scored by using $n$-point evaluation scale, decision rules explain the conditions where score of a certain pair of kansei words becomes a certain value. Since huge number of decision rules are extracted as the number of samples is increased, it is important to only extract rules that can explain decision conditions using necessary minimum condition attributes. For the detailed theory and procedure, please see the reference [26].

After decision rules are extracted, covering index (CI) is calculated for each extracted decision rule. CI is the ratio of the number of existing products which the decision rule matches.

### 3.4. Step3: Grouping

Since decision rules are extracted for each customer, similarity of the extracted decision rules among customers are calculated. $Score_{ij}$ or $S_{ij}$, similarity of the extracted decision rules between customer $i$ and $j$ is defined by the below equation.

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

Where, $N^{kl}{}_{i}$ is the number of customer $i$'s rules that describe the conditions where score of the pair of kansei word $l$ is $k$. $N^{kl}{}_{ij}$ is the number of rules that describe the conditions where score of the pair of kansei word $l$ is $k$ and which customer $i$ and $j$ have in common. $C^{lk}{}_{li}$ is the sum of CI of the rules that describe the conditions where score of the pair of kansei word $l$ is $k$ and which customer $i$ and $j$ have in common. $K$ and $L$ is the number of point scale and pairs of kansei words respectively.

After calculating similarities among all customers, the similarities are analyzed by using hierarchical clustering analysis and customers are classified into several groups based on the results. Hierarchical clustering analysis is one of the methods of cluster analysis and hierarchically groups objects based on the distance or similarity among them. When objects are given, HCA starts with each point in a cluster of its own. Distance or similarity among clusters is calculated based on the coordinates of objects belonging to the clusters and the closest pair of clusters are merged into a new cluster. This task is repeated until all objects are merged into one cluster. Obtained hierarchical structure is represented in the form of dendrogram shown in Fig. 1. In the figure, $O_i$ is $i$-th object and similarity of objects and clusters that are merged in a lower position of a dendrogram is high.

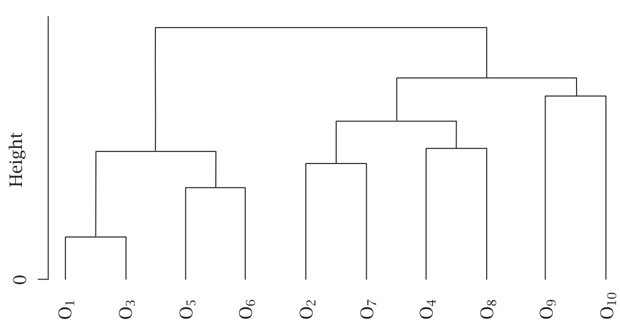


**Figure 1.** Dendrogram that shows the result of HCA.

Several method to calculate the distance or similarity among objects have been proposed, ward method is used in the proposed method. Ward method is based on the decrease in variance when clusters are merged. In particular, When 2 clusters are merged into new cluster, the similarity between the new cluster and the other existing clusters is calculated by the below equation.

$$S_{lk} = \frac{n_i + n_k}{n_i + n_j + n_k} S_{ik} + \frac{n_j + n_k}{n_i + n_j + n_k} S_{jk} - \frac{n_k}{n_i + n_j + n_k} S_{ij} \tag{2}$$

Where, the similarity between new cluster $l$ formed by merging cluster $i$ and $j$ and the other cluster $k$ is calculated. $S_{ij}$ is the similarity between cluster $i$ and $j$, $n_i$ is the number of objects in cluster $i$. In the proposed method, customers and the values obtained in Eqn. (3.1) correspond to objects and the similarities among objects respectively in HCA. After HCA, a designer decides the number of groups by considering the number of customers and the results of HCA.

### 3.5. Step4: Aesthetic design

Aesthetic design is carried out for each group based on the Mori's method [19]. In this step, only rules concerning the pair of the kansei words that describes the degree of customer's preference are used. Decision rule having high score of the pair of the kansei words that describes the degree of customer's preference is named "preference rule" while the rule having low score is named "non-preference rule" in the proposed method.

To begin with, $n$ preference rules are selected in a descending order of $CI$ for each customer. New rules are generated by selecting one preference rule from each

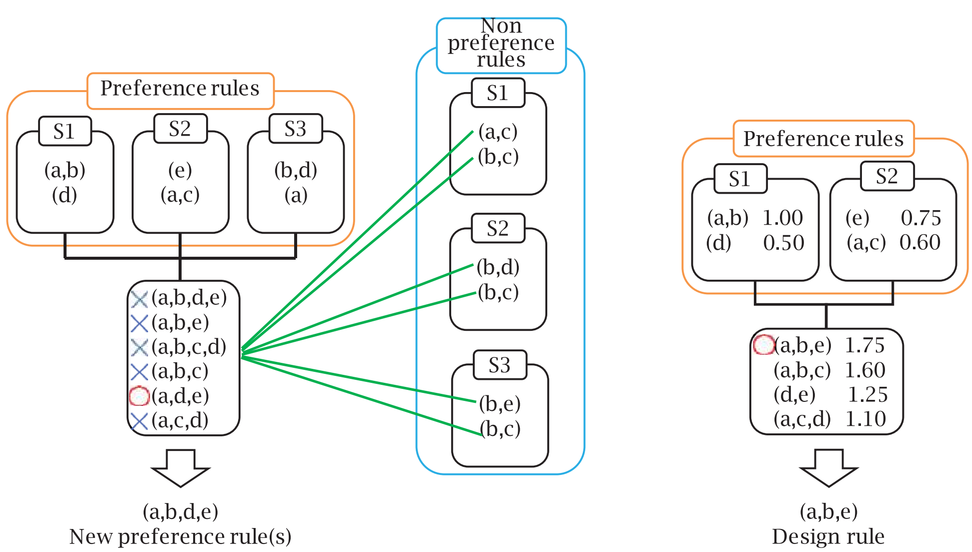


**Figure 2.** (a) Generation of new preference rules and (b) Evaluation and selection of new preference rules.

customer and combining them. Condition attributes of the new rule are a combination of the condition attributes of the selected rules. New rules are generated from all combinations of all customers' $n$ preference rules. Condition attributes of the newly 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 newly generated rules are calculated by adding together *CI* of the original rules. Finally, the rule having highest *CI* is adopted to a new aesthetic design. This rule is named "Design rule". Fig. 2 (a) and (b) illustrate the flow described above. Since the design rule may not contain several aesthetic elements in many cases, until alternatives of all aesthetic elements are decided by design rules, rules that do not conflict with the design rule are selected in descending order of *CI* and added to the design rule.

## 4. Case Study

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

### 4.1. Details of the case study

Eight male undergraduate and graduate students belonging to our institute were participated to the case study as subjects. Car exterior was selected as design target and 9 aesthetic elements (Shape of light, Shape, type and size of grill, Size of bonnet, Global shape and type of body, Gap between spokes of wheel, Orientation of side mirror) and their alternatives shown in Tab. 1 were configured. As shown in Tab. 1, each aesthetic element had 2 to 5 alternatives. 20 cars including sedans, compact cars, station wagons, sports cars, 1 box cars and SUVs were selected from existing commercial products, their phots are collected and alternatives of their aesthetic elements were identified. Since color was not selected as an aesthetic element, only photos of white cars are collected. "Attractive - Not attractive" was selected as a pair of kansei words to measure the degree of customers' preference and 9 pairs of kansei words (Stylish - Styless, Exciting - Quiet, Sharp - Rounded, Sporty - Unsporty, Popular - Unique, Luxurious - Cheap, Revolutionary -Retro, Adult - Childish, Intellectual - Wild) to measure customers' impressions were selected. Tab. 2 summarizes 10 pairs of kansei words. "Attractive - Not attractive" was evaluated by 3-point scale while others were evaluated by 5-point scale.

Fig. 3 shows an example of questionnaire sheets. Since the case study was performed in Japan, questionnaire sheets was written in Japanese. English words correspond to Japanese kansei words are also written in the figure.

**Table 1.** Aesthetic elements and their alternatives.

| | | | | |
|---|---|---|---|---|
| Front | Light | Shape | Wide rectangle | a1 |
| | | | Round | a2 |
| | | | Trapezoid | a3 |
| | Grill | Shape | Trapezoid | b1 |
| | | | Rectangle | b2 |
| | | | Polygonal shape | b3 |
| | | Type | Mesh | c1 |
| | | | Black out | c2 |
| | | | Horizontal lined | c3 |
| | | | Vertical lined | c4 |
| | | Size | Large | d1 |
| | | | Medium | d2 |
| | | | Small | d3 |
| | Bonnet | Size | Large | e1 |
| | | | Medium | e2 |
| | | | Small | e3 |
| Side | Body | Global shape | Rounded | f1 |
| | | | Rectilinear | f2 |
| | | Type | SUV | g1 |
| | | | Sedsan | g2 |
| | | | Mini-van | g3 |
| | | | Station wagon | g4 |
| | | | Hatchback | g5 |
| | Wheel | Gap between spokes | Wide | h1 |
| | | | Medium | h2 |
| | | | Narrow | h3 |
| | Side mirror | Orientation | Vertically | i1 |
| | | | Horizontally | i2 |
| | | | Slantwise | i3 |

**Table 2.** Pairs of kansei words for preference (Left) and impressions (Right).

| Attractive | Not attractive | Stylish | Styless |
|---|---|---|---|
| | | Exciting | Quiet |
| | | Sharp | Rounded |
| | | Sporty | Unsporty |
| | | Popular | Unique |
| | | Luxurious | Cheap |
| | | Revolutionary | Retro |
| | | Adult | Childish |
| | | Intellectual | Wild |

### 4.2. Results

8 subjects evaluated 20 cars using questionnaire sheets. Decision rules were extracted from their results and similarity of extracted decision rules among 8 subjects are calculated. Tab. 3 shows the calculated similarity among 8 subjects. In this table, $Si$ indicates subject $i$. This table shows that similarities between subject 1 and 4 and subject 2 and 3 are especially high while similarities between subject 1 and 2, subject 2 and 8, subject 3 and 5, subject 4 and 8 and subject 5 and 8 are high. HCA was then performed based on these calculated similarity. The dendrogram shown in Fig. 4 is the result of HCA. According to the result, we decided to divide 8 subjects into 3 groups as shown in Fig. 4. Group 1 consists of subject 1 and 4, group 2 consists of subject 2, 3, 5 and 8 while group 3 consist of subject 6 and 7.

After grouping, new rules having high score were explored by combining preference rules for each group.


**Figure 3.** Example of questionnaire sheets [17].

**Table 3.** Similarity between 8 subjects.

| | S1 | S2 | S3 | S4 | S5 | S6 | S7 | S8 |
|---|---|---|---|---|---|---|---|---|
| S1 | | 416.4 | 220.98 | 819.07 | 149.78 | 187.99 | 178.82 | 252.54 |
| S2 | | | 561.88 | 147.07 | 237.57 | 224.19 | 270.32 | 406.12 |
| S3 | | | | 327.57 | 398.93 | 119.28 | 283.6 | 304.41 |
| S4 | | | | | 328.18 | 152.24 | 283.6 | 455.97 |
| S5 | | | | | | 168.3 | 200.91 | 455.97 |
| S6 | | | | | | | 198.29 | 230.03 |
| S7 | | | | | | | | 268.42 |
| S8 | | | | | | | | |

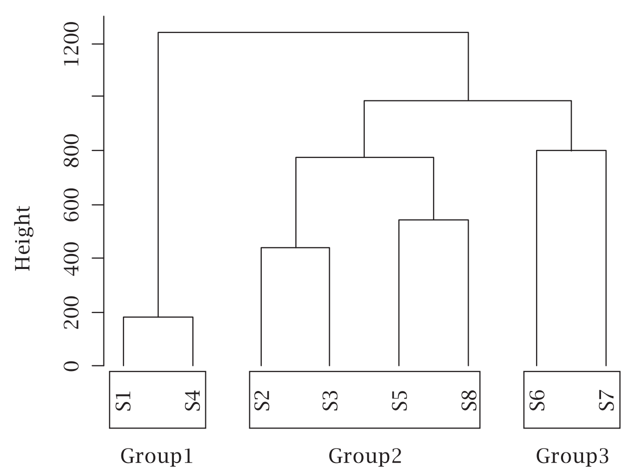


**Figure 4.** Results of HCA and grouping.

Tab. 4 shows the number of preference and non-preference rules extracted for each subject. Tab. 5 shows the rules having highest CI, the value of their CI and design rules for each group.

In order to evaluate the obtained design rules, we generated CG cars based on the obtained design rules using 3D tuning [1] and asked subjects to evaluate them. 3D tuning is the 3D car configurator containing CG models of existing cars and option parts of various manufactures. CG models of various option parts such as front and rear bumpers, grills, headlamps and tail lamps, spoilers, fenders, mirrors and intakes etc. are prepared and can be installed to car models. In the case study, we selected the cars that satisfy obtained design rules as much as possible and added option parts to improve matching degree of the selected cars with the design rules. The generated CG cars are shown in Fig. 5. Evaluation results are shown in the next section.

**Table 4.** The number of extracted rules.

| Group | Subject | Preference rules | Non preference rules |
|---|---|---|---|
| 1 | S1 | 78 | 61 |
| | S4 | 35 | 13 |
| 2 | S2 | 31 | 97 |
| | S3 | 81 | 57 |
| | S5 | 50 | 47 |
| | S8 | 64 | 60 |
| 3 | S6 | 85 | 52 |
| | S7 | 88 | 57 |

**Table 5.** Result of aesthetic design.

| | Group1 | Group2 | Group3 |
|---|---|---|---|
| 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 |

In order to confirm the effectiveness of grouping based on rough set theory, we grouped subjects using traditional grouping method and performed aesthetic design using step4 of the proposed method for each group. Traditional grouping method means that grouping was based on the similarity of evaluation scores of pairs of kansei words in questionnaire investigation. Fig. 6 shows the results of HCA. Based on the result, we divided 8 subjects into 2 groups as shown in Fig. 6. Group 1 consists of subject 1, 2, 4, 6 and 7 while group 2 consists of subject 3, 5 and 8. After grouping, new rules having high score were explored by combining preference rules for each group. Tab. 6 shows the rules having highest CI for each group, the value of their CI and design rules. After obtaining design rules, we also generated CG cars and asked subjects to evaluate them. Fig. 7 shows CG car which we generated based on the obtained design rules.

### 4.3. Discussion

In order to verify the effectiveness of the proposed method, especially in grouping based on rough set theory, we asked subjects to evaluate the cars designed by two methods on a 5-pint scale. Fig. 8 shows the evaluation scores. Since the cars were generated for each group,

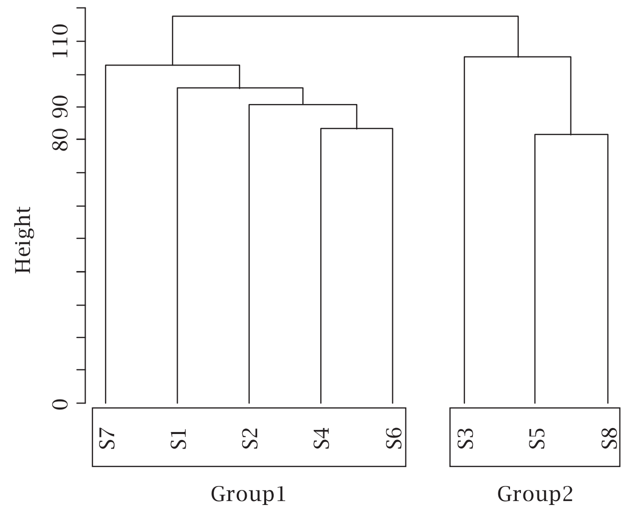


**Figure 6.** Result of HCA.

**Table 6.** Result of aesthetic design.

| | Group1 | Group2 |
|---|---|---|
| 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 |

**Figure 7.** Car exterior generated by the design rules.

subjects only evaluated the cars generated for their own groups.

Evaluation score of subject 5 is quite low in both cases, which show subject 5 wasn't satisfied with both cars. Except for subject 5, score of all subjects is more than 3. The reason that scores of subjects 3, 5 and 8 were same in the both cases is that they belonged to the same group in the both cases and design rules obtained by 2 methods were identical. Except for the results of subject 3, 5 and 7 that are not appropriate for comparison, 4 subjects out of 5 preferred the cars designed by the proposed

**Figure 5.** Car exterior generated by the design rules.

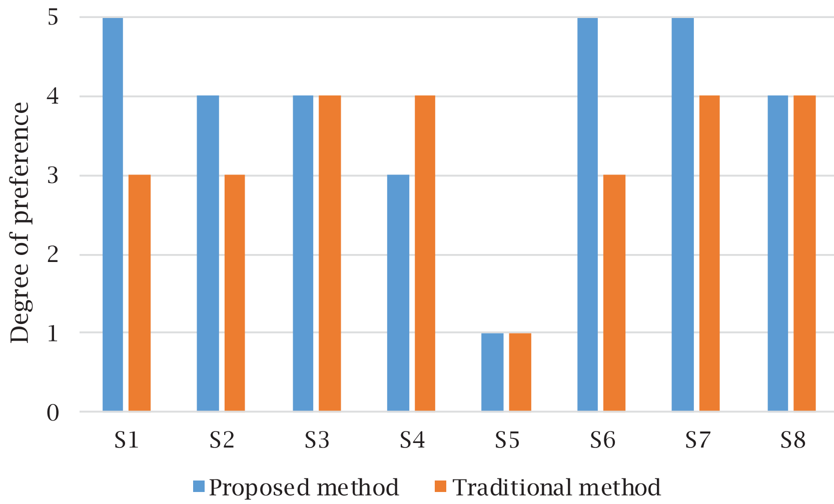


**Figure 8.** Evaluation results.

method rather than the cars designed by the traditional method. Only subject 4 preferred the car designed by the traditional method. Next, decision rules of each group obtained by 2 methods are compared. Since when the number of group members increases, the value of CI of synthesized decision rules tends to increase, use of CI per person is appropriate for comparing design rules in the case where the number of subjects is different in each group. CI per person listed in Tab. 5 and 6 shows that the value of CI per person of group 1 and 2 grouped by the proposed method is higher than the value of CI per person of group 1 and 2 grouped by the traditional method. Only the value of CI per person of group 3 grouped by the proposed method is quite low. This is because similarity between subject 6 and 8 was low and they were grouped at last as shown in. Fig. 4. CI per person of a decision rule is high shows that the decision rule can cover wider preferences of subjects in the same group. This is the effect of grouping based on rough set theory.

In the case study, car CG models were generated by using 3D tuning. Specifically, car CG models that satisfy obtained design rules the most were generated by selecting existing car models and adding option parts to them, as described above. Aesthetics of car exterior consist of not only aesthetic elements considered in the case study but also many other aesthetic elements and their impacts on overall impression of car exterior is also large. Therefore, when design rules of each group were embodied by using on different car models, there is a possibility that design quality of selected cars affects subject satisfaction. However, since comparison of CI per person also shows the effectiveness of the grouping method based on rough set theory as described above, the effectiveness of the proposed method can be confirmed by these comparisons.

## 5. Conclusions

Since customers' kansei is quite diverse, it is difficult to design industrial products that satisfy all targeted customers. To overcome such difficulty, the methods that group customers based on the similarity in their kansei and separately design products for each group have been proposed. This paper also focuses on their diversity and proposes a new method for grouping and aesthetic design based on rough set theory. In the proposed method, customers make kansei evaluation of existing products using SD method. Decision rules that describe the relationships between customers' preference & impressions and aesthetic elements are extracted from the results by using rough set theory. Customers are then grouped based on the similarities of their extracted rules. New aesthetic designs are finally synthesized by combining the extracted decision rules for each group. In aesthetic design based on rough set theory, products are designed by synthesizing decision rules extracted from the results of customers' kansei evaluation by rough set theory. Therefore, in the case where decision rules which customers have are diverse, there is high possibility that new products designed by synthesizing their rules don't reflect preferences of all customers. The problem of existing grouping methods based on the similarity of customers' kansei evaluation is that there is no guarantee that decision rules which customers in the same group have are similar. On the other hand, in the case where customers are grouped based on the similarity of their decision rules like the proposed method, since decision rules which customers in the same group have are similar, there is high possibility that the products that reflect preferences of all customers in the group can be obtained. This is a distinct feature of the proposed method.

To show the flow of the proposed method and its effectiveness, the proposed method was 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. However, due to the limitation of our resource, the number of subjects was limited to 8 and only one experiment was performed in the case study. For detailed verification of the proposed method, further experiments is expected.

Future direction of our research is support for a cloud of customers or big data. Actual industrial products are designed and sold for thousands, ten-thousand or more subjects unlike the case study. In such cases, since it is impractical to increase the number of groups without limit to maintain the similarity of customers in each group, it is inevitable to increase the number of customers per a group. As a result, it becomes difficult to obtain a new decision rule that doesn't conflict non-preference rules of subjects in the same group. To overcome this problem, further researches are required.

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