Title:
**Reuse of Kansei Evaluation Results for the Aesthetic Design of Different Types of Products**

Authors:
Masakazu Kobayashi, kobayashi@toyota-ti.ac.jp, Toyota Technological Institute
Fumi Shibata, sd13043@ toyota-ti.ac.jp, Toyota Technological Institute

Keywords:
Kansei Engineering, Aesthetic Design, Rough Set Theory

DOI: 10.14733/cadconfP.2018.16-20

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. In these methods, semantic differential (SD) method [7] is widely used. In addition, various aesthetic design methods based on analysis of measured customer kansei have also been developed. These methods analyze the relationships between kansei evaluation results of existing products and their aesthetic features and generates a new aesthetic design desired by customers. In these method, various analysis methods such as artificial neural network [2] [3], fuzzy set theory [1], interactive reduct evolutionary computation [10], multi-dimensional scaling [1], rough set theory [4-6] [8] [9], self-organizing map [3] etc. are used

The problem of the above methods is to require evaluation results of the same type of products as a design target. Since it is often rare that customers repeatedly buy the same type of products, customers need to perform kansei evaluation for each product and that is a heavy burden on customers. To reduce such customers' burden, this paper proposes a method for reusing past kansei evaluation results for the aesthetic design of new products. In the proposed method, a new product is designed based on kansei evaluation results previously performed to various types of products different from a design target. Therefore, once substantial evaluation results of various types of products are collected, it becomes possible to design new products without additional kansei evaluation.

Proposed method:
Before explaining the details of the proposed method, the considered assumptions are introduced here. Every product has various types of aesthetic features such as color, material, ornament etc. Each type of aesthetic feature has several options. For example, options of color are red, blue, black etc. A product type is a set of products having the same types of aesthetic features. In general terms, "sneaker" and "long wallet" are examples of product type. A lot of kansei evaluation are performed to various types of products in advance and their results are stored. However, evaluation results of the same type of product as a design target are not stored. This choice is aimed at showing the capabilities of our method since even existing methods can generate a new aesthetic design by using their results.

The proposed method is based on rough set theory as with existing methods. These methods extract decision rules that explain the relationships between customer's preference and aesthetic

features from the evaluation results of existing products by using rough set theory and generate a new design by combining them to maximize his/her preference. The novelty of the proposed method is the idea that the decision rules extracted from one type of product can be applied to others if they have the same aesthetic features. Based on the idea, in the proposed method, types of product that are different from a design target but have several same types pf aesthetic feature are selected, decision rules are extracted from their evaluation results and a new design is generated by combining them.

The proposed method consists of 4 steps. The rest of this section explains their details.

*Preparation of the proposed method*
Before executing the proposed method, customers evaluate preference of various types of products and their results are stored. Customers' preferences are scored on a 3-point scale (like, neither like nor dislike, dislike). Types of aesthetic features which each product type has are identified and their options are identified for each product. Decision rules that explain the relationships between customer's preference and aesthetic features are then extracted by using rough set theory. Since products are evaluated on a 3-point scale, 3 types of decision rules that explain customer's liking, neither like nor dislike and dislike are extracted. The rules that explain customer's liking and disliking are named "Preference" and "Non-Preference" decision rules respectively in the proposed method.

*Step1: Selection of product types from stored data*
Types of aesthetic features which a design target has are identified and product types that have some of them are selected from stored data. Every type of aesthetic feature which a design target has needs to be included in at least one of selected product types.

*Step2: Selection of prior aesthetic features*
Ratio of product types having the same type of aesthetic feature as a design target is calculated. This ratio is named credibility W. Credibility of aesthetic feature $i$, $W_i$ is defined by the below equation.

$$W_i = \frac{n_i}{N}$$

Where, $n_i$ is the number of product types having aesthetic feature $i$ of a design target as their own feature, $N$ is the total number of product types. Options of credible aesthetic features or aesthetic features included in a lot of product types can be precisely decided based on their evaluation results. Credible aesthetic features are selected and named priority aesthetic features.

*Step3: Acquisition of a candidate decision rule*
Preference decision rules relating to the priority aesthetic features are selected and their contribution ratio $S$ is calculated. Specifically, $S_{ij}$ is the contribution ratio of decision rule $i$ to aesthetic feature $j$ and defined by the below equation.

$$S_{ij} = \frac{l_i}{m_j} \sum_k CI_{ik}$$

Where, $m_j$ is the number of product types having aesthetic feature $j$ of the design target as their own feature, $l_i$ is the number of product types where decision rule $i$ is extracted, $CI_{ik}$ is the covering index of decision rule $i$ in product type $k$. Covering index is the ratio of the number of existing products which the decision rule matches. If product type $k$ doesn't have decision rule $i$, $CI_{ik}$ is 0.

After calculating contribution ratio $S$, until options of all prior aesthetic features are decided, decision rules are taken and combined one by one in descending order of $S$. If decision rules cannot coexist with each other or overlap non-preference decision rules extracted from all selected products, they are not selected. A new rule combining selected decision rules acquired by the above procedure is named a candidate decision rule.

*Step4: Acquisition of a final decision rule*
Preference decision rules that relate non-prior aesthetic features are collected and their contribution ratio $S$ is calculated using the same equation as the previous step. After calculating $S$, until options of

all non-prior aesthetic features are decided, decision rules are taken and added to a candidate decision rule one by one in descending order of *S*. If decision rules cannot coexist with each other or overlap non-preference decision rules of all products, they are not selected. Finally, the decision rule in which options of all aesthetic feature are decided is obtained and named a final decision rule.

Case Study:
To confirm the effectiveness of the proposed method, two case studies were performed. Based on the evaluation results of penny loafers, high heels and sneakers, low heel pumps and a long wallet were designed in case study 1 and 2 respectively. 5 female undergraduate students participated as subjects.

*Preparation of the case studies*
To perform kansei evaluation in advance preparation, 15 photos were collected for each of penny loafers, high heels and sneakers. Tab.1 shows identified types of aesthetic features of penny loafers, high heels and sneakers and their possible options. Participants evaluated their preference of each shoes on a 3-point scale.

| Penny loafers | High heels | Sneakers | | | |
|---|---|---|---|---|---|
| ✓ | ✓ | ✓ | Tip shape | Rounded | a1 |
| | | | | Pointy-toed | a2 |
| ✓ | ✓ | ✓ | Ribbon | No ribbon | b1 |
| | | | | Wide ribbon | b2 |
| | | | | Narrow ribbon | b3 |
| ✓ | ✓ | ✓ | Sole color | Black | c1 |
| | | | | Beige | c2 |
| ✓ | ✓ | ✓ | Insole color | Black | d1 |
| | | | | Beige | d2 |
| | | | | Red | d3 |
| | | | | Blue | d4 |
| ✓ | ✓ | | Glossiness of leather | Glossy | e1 |
| | | | | Matte | e2 |
| | ✓ | | Strap | No strap | f1 |
| | | | | With strap | f2 |
| ✓ | | | Tassel | No tassel | g1 |
| | | | | With tassel | g2 |
| | ✓ | | Heel shape | Pin shape | h1 |
| | | | | Wegde shape | h2 |
| | | ✓ | The number of strap holes | Many | i1 |
| | | | | A few | i2 |
| | | ✓ | Strap color | Black | j1 |
| | | | | White | j2 |

Tab.1: Types of aesthetic features of penny loafers, high heels and sneakers and their possible options.

*Case study 1: Design of low heel pumps*
According to our identification, low heel pumps have 7 types of aesthetic features as shown in Tab.2. This table also shows which types of aesthetic features which penny loafers, high heels and sneakers have. Tab.3 shows final decision rules and Fig.1 shows their CG generated by [11].

| Low heel pumps | | | | Penny loafers | High heels | Sneakers |
|---|---|---|---|---|---|---|
| ✓ | Tip shape | A | Tip shape | ✓ | ✓ | ✓ |
| ✓ | Ribbon | B | Ribbon | ✓ | ✓ | ✓ |
| ✓ | Sole color | C | Sole color | ✓ | ✓ | ✓ |
| ✓ | Insole color | D | Insole color | ✓ | ✓ | ✓ |
| ✓ | Glossiness of leather | E | Glossiness of leather | ✓ | ✓ | |
| ✓ | Strap | F | Strap | | ✓ | |
| ✓ | Tassel | G | Tassel | ✓ | | |

Tab.2: Aesthetic features included in low heel pumps.

| Subject1 | Subject2 | Subject3 | Subject4 | Subject5 |
|---|---|---|---|---|
| a2b2c1d1f2g1 | c2b2c1df1g1 | a2b1c1d3f1g1 | a1b1c2d3f2g1 | a1b3c2d3f1g1 |

Tab.3: Final decision rules for 5 subjects.

Fig.1: Low heel pumps designed for 5 subjects.

*Case study 2: Design of a long wallet*
5 types of aesthetic features of a long wallet were identified. Different from case study 1, a long wallet and 3 types of shoes have no same type of aesthetic feature except glossiness of leather. Therefore, similar types of aesthetic features are related between them. Tab.4 shows their relationships. Tab.5 shows final decision rules and Fig.2 shows their CG generated by [12].

| Long wallet | | | | Penny loafers | High heels | Sneakers |
|---|---|---|---|---|---|---|
| ✓ | Corner shape | A | Tip shape | ✓ | ✓ | ✓ |
| ✓ | Shape of decoration | B | Ribbon | ✓ | ✓ | ✓ |
| ✓ | Edge color | C | Sole color | ✓ | ✓ | ✓ |
| ✓ | Lining color | D | Insole color | ✓ | ✓ | ✓ |
| ✓ | Glossiness of leather | E | Glossiness of leather | ✓ | ✓ | |

Tab.4: Relationships of aesthetic features between a long wallet and 3 types of shoes.

| Subject1 | Subject2 | Subject3 | Subject4 | Subject5 |
|---|---|---|---|---|
| a2b2c1d1e2 | a2b2c1d2e1 | a2b1c1d3e1 | a1b1c2d4e2 | a1b3c2d3e2 |

Tab.5: Final decision rules.

Fig.2: Long wallets desgined for 5 subjects.

*Discussion*
To confirm the effectiveness of the proposed method, we asked 5 subjects to evaluate obtained low heel pumps and long wallet on a 5-point scale. Tab.6 shows their evaluation scores. The results show that most subjects satisfied both types of obtained products. The results also shows that average score of low heel pumps is higher than one of long wallets. Since types of aesthetic features of low heel pumps and 3 types of shoes were identical, subjects' preference for low heel pumps can be precisely estimated from evaluation results of 3 types of shoes. On the other hand, since most types of aesthetic features of a long wallet are different from ones of 3 types of shoes and similar types of aesthetic features are related to each other, estimation accuracy was degraded.

| | Like very much | Like | Neither like nor dislike | dislike | Dislike very much |
|---|---|---|---|---|---|
| Low heel pumps | 3 | 2 | 0 | 0 | 0 |
| Long wallets | 1 | 3 | 1 | 0 | 0 |

Tab. 6: Evaluation scores.

Conclusion:

Most of existing aesthetic design methods are based on analysis of the relationships between customers' preferences of the same type of existing products as a design target and their aesthetics. Therefore, customers need to evaluate a lot of existing products for each design. To reduce customers' burden of kansei evaluation, this paper proposes a method for designing a new type of product by reusing kansei evaluation results previously performed to various types of products. In the proposed method, since it is not necessary to evaluate the same type of existing products as a design target, once substantial evaluation results are stored, it becomes possible to design a new type of product without additional kansei evaluation.

To confirm the effectiveness of the proposed method, 2 case studies were performed. Based on the evaluation results of penny loafers, high heels and sneakers, low heel pumps and a long wallet were designed2. Though preference score of generated long wallets is a little bit lower than one of low heel pumps, most subjects prefers both generated low heel pumps and long wallets.

References:

[1] Hsiao, S.W.; Huang, H.C.: Applying the semantic transformation method to product form design, Design Studies, 19(3), 1998, 309-330. http://dx.doi.org/10.1016/S0142-694X(98)00009-X

[2] Hsiao, S.W.; Huang, H.C.: A neural network based approach for product form design, Design Studies, 23(1), 2002, 67-84. http://dx.doi.org/10.1016/S0142-694X(01)00015-1

[3] Kobayashi, M.; Kinumura, T.; Higashi, M.: A Method for Supporting Aesthetic Design Based on the Analysis of the Relationships Between Customer Kansei and Aesthetic Element, Computer-Aided Design & Applications, 13(3), 2015, 281-288. http://dx.doi.org/10.1080/16864360.2015.1114385

[4] Kobayashi, M., Niwa, K.: Method for Grouping of Customers and Aesthetic Design Based on Rough set theory, Computer-Aided Design & Applications, 15(4), 2018, 565-574. http://dx.doi.org/10.1080/16864360.2017.1419644

[5] Kuramaru, K.; Takanashi, R.; Mori, N.: The Method of Design Project Based on the Declaration of Checking Preference and Non-preference with the Product, Journal of Japan Society of Kansei Engineering, 1(1), 2001, 65-72. http://doi.org/10.5057/jjske2001.1.65

[6] Ohki, M.; Harada, T.; Inuiguchi, M.: Decision Rule Visualization System for Knowledge Discovery by Means of the Rough Set Approach, Journal of Japan Society for Fuzzy Theory and Intelligent Informatics, 24(2), 2012, 660-670. http://doi.org/10.3156/jsoft.24.660

[7] Osgood C.E.; Suci G.J.; Tannenbaum P.: The Measurement of Meaning, University of Illinois Press, 1967.

[8] Pawlak, Z.: Raugh Sets, International journal of Information Computer Science, 11(5), 1982, 341-356. http://doi.org/10.1007/BF01001956

[9] Yamada, K.; Moroga, U.; Unehara, M.: Design Support for Generating Novelty with Rough Sets Theory and Conceptual Hierarchy, Transactions of Japan Society of Kansei Engineering, 11(1), 2012, 17-26. http://dx.doi.org/10.5057/jjske.11.17

[10] Yanagisawa, H.; Fukuda, S.: Kansei Design by Interactive Reduct Evolutionary Computation: With Attention Paid to Favored Feature of Design, Transactions of the Japan Society of Mechanical Engineers. C, 70(694), 2004, 1802-1809. http://dx.doi.org/10.1299/kikaic.70.1802

[11] https://www.shoesofprey.com/

[12] https://joggo.me/