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Computer-Aided Design AND APPLICATIONS

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

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ABSTRACT

Most of aesthetic design methods proposed in the field of kansei engineering ask customers to evaluate the same type of existing products as a design target, analyze the relationships between their results and aesthetic features and generate a new design desired by customers. Therefore, customers need to conduct a lot of kansei evaluations for each design and those evaluations become their heavy burden. To reduce customers' burden, this paper proposes a method for reusing kansei evaluation results for the aesthetic design of different types of products. The basic idea of the proposed method is that the decision rules extracted from one type of product can be applied to others if they have the same aesthetic features. Therefore, once kansei evaluation results of various types of products are sufficiently collected, it becomes possible to design new products without additional kansei evaluation. In the case study, to demonstrate a design flow using the proposed method, low heel pumps and a long wallet were designed based on kansei evaluation results of penny loafers, high heels and sneakers. Low heel pumps are a type of women's shoes like penny loafers, high heels and sneakers while a long wallet is different from them. The obtained designs were evaluated by subjects to reveal the properties / effectiveness of the proposed method.

Keywords: Kansei Engineering, Aesthetic Design, Rough Set Theory.
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1 INTRODUCTION

Due to maturation of science and technology, it becomes increasingly difficult for companies to differentiate their products in terms of objective and concrete qualities such as 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" [13]. The engineering field to study about humans' kansei is named "kansei engineering"

In the field of kansei engineering [6][7] (referred to as affective or emotional engineering), various methods for supporting aesthetic design have been developed [1-5], [8], [11], [12] for years. These methods measure impressions / preferences which customers receive from existing products, analyze the relationships between customers' evaluation results and aesthetic features of existing products and generate a new aesthetic design

desired by customers. In these methods, semantic differential method (SD method) [9] is the most widely used to measure customers' impressions. 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. On the other hand, various analysis methods such as artificial neural network [2], fuzzy set theory [1], interactive reduct evolutionary computation [12], multidimensional scaling [1], rough set theory [5], [8], [11] etc. are used to analyze the relationships. Our methods are based on self-organizing map & neural network [3] and rough set theory [4].

Since aesthetic design methods described above suggest options / parameters of aesthetic features that improve customers' preferences / give certain impressions to customers, designers can proceed aesthetic design more efficiently and effectively by using those information. On the other side, these methods have the problem that they require a lot of kansei evaluations of the same type of existing products as a design target for each design. This is because they generate a new design by analyzing the the relationships between customers' impressions / preferences received from them and their aesthetic features. Customers don't have much opportunity to repeatedly buy the same type of products except like commodities, so it is rare that a lot of collected kansei evaluation results can be reused. To reduce such type of customers' burden, this paper proposes a method for reusing customers' kansei evaluation results for the aesthetic design of different types of products. In the proposed method, a new type of product is designed based on the kansei evaluation results performed to various types of products different from a design target. Therefore, once evaluation results of various types of products are sufficiently collected, it becomes possible to design new products without any further kansei evaluation.

The rest of this paper is organized as follows. Section 2 explains the details of the proposed method. To demonstrate a design flow using the proposed method and reveal its properties, it is applied to designs of low heel pumps and a long wallet, as described in section 3. Finally, section 4 summarizes the results of this paper.

2 PROPOSED METHOD

Since most of traditional aesthetic design methods generate a new design by analyzing the relationships between customers' impressions / preferences received from the same type of existing products as a design target and their aesthetic features, customers are asked to make a lot of kansei valuation for each design and such customers' burden inhibits the spread of existing aesthetic design methods. Therefore, to reduce their burden in traditional methods, the proposed method reuse kansei evaluation results previously performed to various types of products different from a design target to generate a new design. Once evaluation results of various types of products are sufficiently collected, the proposed method don't require any further kansei evaluation to generate a new design. As a result, customers can easily utilize the proposed method to buy any types of products.

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 and ornament. 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 same types of aesthetic features. In general terms, "sneaker" and "leather 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, the results of kansei evaluation performed to the same type of product as the 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.

2.1 Flow of the proposed method

The proposed method is based on rough set theory [10] as with a lot of existing methods. Rough set theory 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 impressions / preferences of existing products and their aesthetic elements are considered as decision and condition attributes respectively and rough set theory extracts decision rules that explain the relationships between customer's impressions / preferences and aesthetic elements from questionnaire results. The methods based on rough set theory generate a new design by combining extracted decision rules to maximize his / her preference. The novelty of the proposed method compared to the existing one 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 the following 4 steps. The rest of this section explains the detailed procedures of 4 steps.

Step1: Selection of product types from stored data

Step2: Selection of prior aesthetic features

Step3: Acquisition of a candidate design

Step4: Acquisition of a final design

2.2 Preparation of the proposed method

Before applying 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 options of 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. The rules explain customer's neither like nor dislike are not used in the proposed method.

2.3 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. Tab. 1 illustrates aesthetic features which selected product types have. Every type of aesthetic feature which a design target has needs to be included in at least one of selected product types. It is desirable that aesthetic feature types of a design target are included in more than one selected product types.

Design target	Product type1	Product type2	Product type3
A	✓	✓	✓
B	✓	✓	✓
C	✓	✓	
D	✓		
E			✓

Table 1: Aesthetic features included in each product type.

2.4 Step2: Selection of prior aesthetic features

Ratio of product types that have the same aesthetic feature types as a design target has is calculated for each aesthetic feature type of a design target and named credibility. Specifically, credibility of aesthetic feature type i, W_i is defined by the below equation.

$$W_i = \frac{n_i}{N} \tag{2.1}$$

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. Tab. 2 illustrates a calculation example. In the case of Tab. 2, credibility of aesthetic feature A, B and C is high while credibility of aesthetic feature D and E is low. Since there are many kansei evaluation results concerning aesthetic feature types included in a lot of product types and their relationships with customers' preferences can be precisely predicted, their options should be preferentially decided. Therefore, credible aesthetic features are preferentially selected and named "prior aesthetic features". In the case of Tab. 2, aesthetic feature A, B and C are selected as prior ones.

Design target	Product type1	Product type2	Product type3	
A	✓	✓	✓	W_A=1
B	✓	✓	✓	W_B=1
C	✓	✓		W_C=0.66
D	✓			W_D=0.33
E			✓	W_E=0.33

Table 2: Calculation of credibility W

2.5 Step3: Acquisition of a candidate design

Preference decision rules relating to the prior aesthetic features are selected and their contribution ratio is calculated. Specifically, the contribution ratio of decision rule i to aesthetic feature j, S_{ij} is defined by the below equation.

$$S_{ij} = \frac{l_i}{m_j} \sum_k CI_{ik} \tag{2.2}$$

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, decision rules are taken and combined one by one in descending order of S until options of all prior aesthetic features are decided. 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 design". Fig. 1 illustrates the flow of Step3. In this example, aesthetic features A, B and C are prior ones. "Preference" and "non-preference" decision rules relating to aesthetic features A, B and C and their CI are shown in the table inside the figure. A candidate design "a1b1c1" is obtained.

2.6 Step4: Acquisition of a final design

Preference decision rules that relate non-prior aesthetic features and can coexist with the candidate design obtained in Step3 are collected and their contribution ratio S is calculated using Eqn. (2.2). After calculating contribution ratio S, decision rules are selected and added to the candidate design one by one in descending order of S until options of all non-prior aesthetic features are decided. 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 design". Fig. 2 illustrates the flow of Step4. This example is a continuation of Fig. 1 and aesthetic features D and E are non-prior ones. d1 and e1 are selected and a final design "a1b1c1d1e1" is obtained.

3 CASE STUDY

To demonstrate a design flow using the proposed method and reveal its properties, two case studies were performed. Based on the evaluation results of penny loafers, high heels and sneakers, low heel pumps were designed in case study 1 while a long wallet was designed in case study 2. Low heel pumps are similar to penny loafers, high heels and sneakers since all of them are types of women's shoes while a long wallet is different from them. 5 female undergraduate students participated as subjects to both case studies. Since the proposed method was only for single subject, case studies were independently applied for each participant.

3.1 Preparation of the case studies

To perform subjects' kansei evaluation of existing penny loafers, high heels and sneakers in advance preparation, 15 photos were collected for each of them. Since color of shoes was not used as an aesthetic feature, only photos of black shoes were collected. Tab. 3 shows identified aesthetic feature types of penny loafers, high heels and sneakers and their possible options. Participants evaluated their preference of each shoes on a 3-point scale using questionnaire sheets shown in Fig. 3.

1. Extract preference decision rules and calculate CI

Preference decision rules

Product type1		Product type2		Product type3	
a1b1	0.66	a1b1	0.66	a1b1	0.33
c1	0.66	c1	0.33	a2b2	0.125

2. Calculate contribution ratio

a1b1 $S_{a1b1} = \frac{3}{3}(0.66 + 0.66 + 0.33) = 1.65$

c2 $S_{c1} = \frac{2}{3}(0.66 + 0.33) = 0.66$

a2b2 $S_{a2b2} = \frac{1}{3}(0.125) = 0.0416$

3. Conbine decision rules with high contribution and compare non-preference decision rules

Non-preference decision rules

Product type1		Product type2		Product type3	
a2b2	0.66	b2	0.66	c2	0.33
c2	0.66	c2	0.33	a2c2	0.125
a2	0.33	a2	0.125	b2	0.125

4. Generate a candidate design

Candidate design: a1b1c1

Figure 1: Flow of Step3.

3.2 Case study 1: Design of low heel pumps

3.2.1 Step1: Selection of product types from stored data

As previously stated, low heel pumps were designed by reusing evaluation results of penny loafers, high heels and sneakers. According to our identification, low heel pumps had 7 aesthetic feature types as shown in Tab. 4. This table also shows which aesthetic feature types penny loafers, high heels and sneakers have.

3.2.2 Step2: Selection of prior aesthetic features

Credibility *W* is calculated for each aesthetic feature type. Tab. 5 shows their values. Based on them, aesthetic features A, B, C and D are selected as prior ones.

3.2.3 Step3: Acquisition of a candidate design

Preference decision rules relating prior aesthetic features were extracted from the evaluation results performed by 5 subjects by using rough set theory. Tab. 6 shows preference decision rules of subject 5 and their CI. As shown in this table, rule “a1c2” is included in 3 types of shoes while rule “d3” is included in 2 types of shoes.

Contribution ratio *S* was calculated for each decision rule. Tab. 7 shows partial list of their values of subject 5. True decision rule was generated by combining decision rules that have high contribution ratio, can coexist with each other and don’t overlap non-preference decision rules. Generated candidate design of subject 5 was a1b3c2d3. Tab. 8 shows true decision rules of every subjects.

1. Extract preference decision rules and calculate CI

Preference decision rules

Product type1		Product type3	
a1b1d1	0.66	a1b1e1	0.33
c1d1	0.66	c2e2*	0.33
a2b2d1*	0.33	c1e1	0.125
a1b1d2	0.125	a1b1e2	0.125

*They cannot coexist with a true decision rule

2. Calculate contribution ratio

D1 $S_{d1} = \frac{2}{1}(0.66 + 0.66)$=2.64

D2 $S_{d2} = \frac{1}{1}(0.125)$=0.125

E1 $S_{e1} = \frac{2}{1}(0.33 + 0.125)$=0.91

E2 $S_{e2} = \frac{1}{1}(0.125)$=0.125

3. Compare non-preference decision rules

Non-preference decision rules

Product type1		Product type3	
a2b2	0.66	b2c2	0.66
a1d2	0.33	a2b2d2	0.33
b2d2	0.125	c2d2	0.33
c1d2	0.125	c2	0.125

4. Generate a final design

Final design: a1b1c1d1e1

Figure 2: Flow of Step4.

3.2.4 Step4: Acquisition of a final design

By deciding options of non-prior aesthetic features, a final design was decided. Tab. 9 shows a final design of every subjects. Based on them, CGs of low heel pumps shown in Fig. 4 were generated by [15].

3.3 Case study 2: Design of a long wallet

5 aesthetic feature types were identified as ones of long wallet. Different from case study 1, a long wallet and 3 types of shoes had no same aesthetic feature type except “Glossiness of leather”. Therefore, similar aesthetic feature types were related between a long wallet and 3 types of shoes. Tab. 10 shows their relationships.

Since the flow of Step3 and 4 is mostly the same as case study 1, its details is omitted. Tab. 11 shows final design. Based on them, CGs of long wallets shown in Fig. 5 were generated by [16].

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

Table 3: Aesthetic feature types of penny loafers, high heels and sneakers and their possible options.

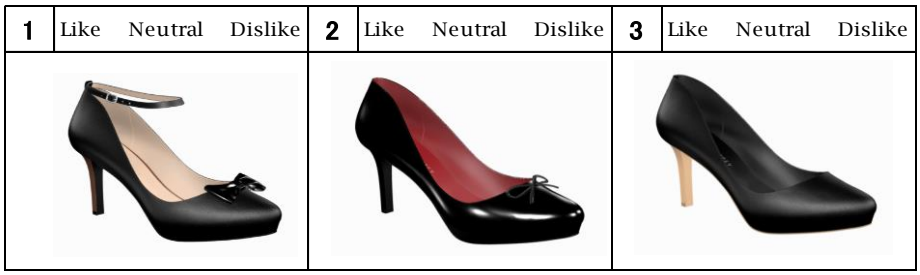

Figure 3: Example of questionnaire sheet.

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	✓		

Table 4: Aesthetic feature types included in low heel pumps.

Tip shape	W_A=1
Ribbon	W_B=1
Sole color	W_C=1
Insole color	W_D=1
Glossiness of leather	W_E=0.66
Strap	W_F=0.33
Tassel	W_G=0.33

Table 5: Credibility *W*.

Penny loafers		High heels		Sneakers	
d3	0.33	a1c2	0.5	a1c2	0.66
b3	0.33	b3d3	0.25	d3	0.33
a1c2	0.33	a1b1	0.25	b2	0.33
c2d1	0.33	a1d3	0.25	a1d2	0.33
		b1d1	0.25	c2d2	0.33
		c2d2	0.25	d4	0.16
		a1d1	0.25	a2c1d1	0.16
		c2d1	0.25		
		a1b2d2	0.25		

Table 6: Preference decision rules relating prior aesthetic features of subject 5.

Rule	a1c2	d3	b3d3	c2d1	b2	a1d2	c2d2	b3d3	a1b1	a1d3	⋯
S	1.5	0.44	0.11	0.11	0.11	0.11	0.11	0.083	0.083	0.083	⋯

Table 7: Partial list of contribution ratio S of subject 5.

Subject1	Subject2	Subject3	Subject4	Subject5
a2b2c1d1	c2b2c1d2	a2b1c1d3	a1b1c2d3	a1b3c2d3

Table 8: Candidate design of every subjects.

Subject1	Subject2	Subject3	Subject4	Subject5
a2b2c1d1f2g1	c2b2c1df1g1	a2b1c1d3f1g1	a1b1c2d3f2g1	a1b3c2d3f1g1

Tab. 9: Final designs.

Figure 4: Low heel pumps designed for 5 subjects.

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	✓	✓	

Table 10: Relationships of aesthetic features between a long wallet and 3 types of shoes.

Subject1	Subject2	Subject3	Subject4	Subject5
a2b2c1d1e2	a2b2c1d2e1	a2b1c1d3e1	a1b1c2d4e2	a1b3c2d3e2

Table 11: Final designs.

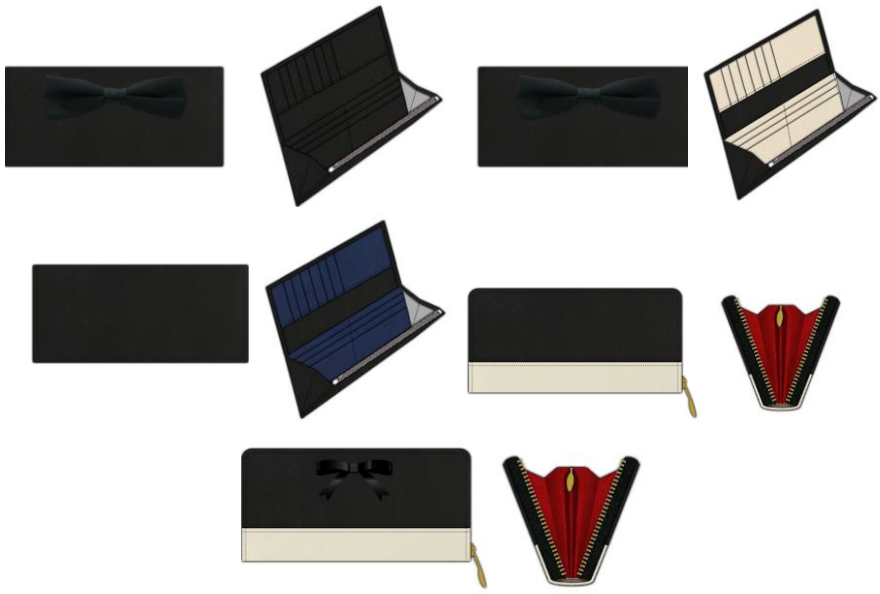

Figure 5: Long wallets desgined for 5 subjects.

3.4 Discussion

To confirm the properties / effectiveness of the proposed method, we asked 5 subjects to evaluate low heel pumps and long wallet obtained in case studies 1 and 2 on a 5-point scale. Tab. 12 shows their evaluation scores.

	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

Table 12: Evaluation scores.

The evaluation results show that most subjects satisfied both types of obtained products. Although it is difficult to verify the effectiveness of the proposed method from them due to a limitation of participants, they indicate its effectiveness to some extent. The results also shows that the average score of low heel pumps is higher than one of

long wallets. Since aesthetic feature types of low heel pumps and 3 types of shoes were identical, subjects' preference for low heel pumps can be precisely estimated from the evaluation results of 3 shoes types. On the other hand, since most aesthetic feature types of a long wallet are different from ones of 3 shoes types, similar aesthetic feature types need to be related to each other. Therefore, estimation accuracy was degraded.

4 CONCLUSION

Since most of existing aesthetic design methods generate a new design by analyzing the relationships between customers' preferences / impressions of the same type of existing products as a design target and their aesthetics, customers need to evaluate a lot of existing products for each design. To reduce such customers' burden, this paper proposes a method for designing a new type of product by reusing results of kansei evaluation 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 demonstrate a design flow using the proposed method and reveal its properties, 2 case studies were performed. Based on the evaluation results of penny loafers, high heels and sneakers, low heel pumps were designed in case study 1 while a long wallet was designed in case study 2. The obtained designs were evaluated by subjects and compared. Although 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.

As for future research, a large case study is planned to confirm the effectiveness of the proposed method. In addition, development of methods for selecting product types from stored data and relating similar aesthetic features belonging to different product types is also planned. Since a designer needs to manually conduct these processes based on his / her experience and intuition in the proposed method, those methods improve the practicality of the proposed method.

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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. 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] Nagamachi, M.: Kansei Engineering, Kaibundo Publishing, 1989.
[7] Nagamachi M.: Kansei Engineering: A New Ergonomic Consumer-Oriented Technology for Product Development, International Journal of Industrial Ergonomics, 15, 1995, 3-11. http://dx.doi.org/10.1016/0169-8141(94)00052-5
[8] 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
[9] Osgood C.E., Suci G.J., Tannenbaum P.: The Measurement of Meaning, University of Illinois Press, 1967.
[10] Pawlak, Z.: Raugh Sets, International journal of Information Computer Science, 11(5), 1982, 341-356.

[11] 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
[12] 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
[13] Yanagisawa, H., Kansei Quality in Product Design, Emotional Engineering, 2011, 289-310. http://dx.doi.org/10.1007/978-1-84996-423-4_16
[14] Yasuda, K.; Shiraki, W.: A study on scenery evaluation of girder bridges by rough sets, Journal of structural engineering, 57A, 2011, 221-231. http://dx.doi.org/10.11532/structcivil.57A.221
[15] https://www.shoesofprey.com/
[16] https://joggo.me/