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Study on a Correlation Model between the Kansei Image and the Texture Harmony

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Abstract

Texture harmony pursues a suitable texture matching to meet the customers Kansei image requirements. The texture harmony method which is based on Kansei Engineer is developed. Several questionnaires are made to obtain the Kansei words, design elements and texture factors. The representative Kansei words, representative design elements and the representative texture factors are selected using Pareto Diagram, Likert scale, multidimensional scaling analysis and cluster analysis. After developing the virtual samples, the respondents are asked to evaluate the Kansei image score of each sample according to the different Kansei image word. The Kansei image evaluating matrix is obtained by combining the Kansei image score with the texture combination code. The multiple linear regression model is supposed to explain the relationship of the Kansei image score and the texture factors. Based on the Kansei image evaluate matrix, the hypothesis is verified using the SPSS software. The case of electric kettle texture harmony design is studied to verify the method. The method can facilitate designers work, and lay a foundation of computer aided texture design system.

Keywords: *texture harmony, Kansei image, multiple linear regression, cluster analysis*

1. Introduction

Texture, color and form are three key elements of product identity [1]. The texture is one of the important factors of product identity which the product style depends on. The reasonable texture harmony contributes to the establishment of product brand identity [2]. The accurate expression of products kansei image, on the other hand, can help the nondestructive information dissemination between the designer encoding and consumer decoding, and it becomes one of hot issues in the design field [3]. Hsiao and Chen have discussed the relationship between product identity and form & color using different methods [4-10]. Most of the scholars focus on the kansei image based on the single texture instead of the view of the whole products. Karana and Sun have also discussed the relationship between different textures and kansei properties [11-14]. The study on how to scientifically and rationally use a set of texture in harmony way to meet target product kansei image is still lack.

In order to assist designer, the steps are deployed to build a correlation model between the texture kansei image and the texture harmony as follows: quantitatively analyzing of texture kansei semantics, adopting scientific method to extract the texture harmony elements, building the correlation model using multiple linear regression analysis method. The results of the study will promote the progress of the design

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method, and lay the combination foundation of the method and the computer aided systems.

2. Conception of the Texture Matching & Texture Harmony

Matching up more than two textures for a certain visual effect, was defined as texture matching. The texture harmony pursues the harmony and reasonable Kansei image for a given product. Texture harmony is based on the texture matching, and mainly solve how to fit the emotional semantic with the texture matching.

Generally, the designers match the textures based on their own experience. Harmony sense varies because of the different designer. What is most important is the difference of harmony sense between designer and consumer. The texture harmony mainly focuses on the how to meet the needs of customers' Kansei image.

3. The Method of Building a Correlation Model between the Texture Kansei Image and the Texture Harmony

The method quantifies the kansei cognition of product texture, obtains the facts of product texture harmony designing through the Pareto diagram, and builds a correlation model between the texture Kansei image and the texture harmony based on the multiple linear regression analysis.

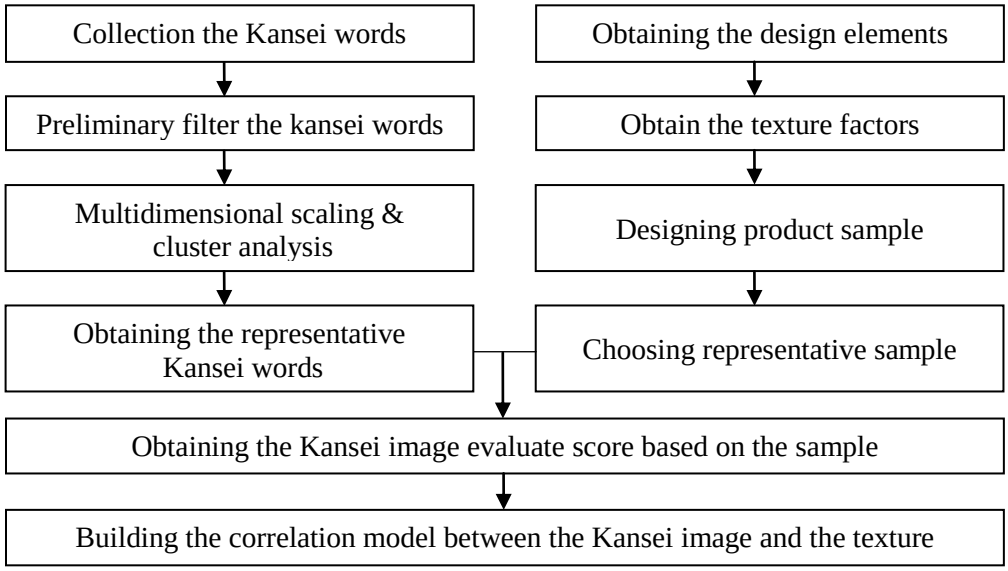

Figure 1. The Flow Chat of the Method

3.1. Obtaining the Representative Items of the Product Texture Kansei Image

The team investigated the adjective which suits to describe the target product texture on the web site, magazine and product booklet. After designing research and Pareto diagram analysis, n texture harmony Kansei image items were listed. The experts in this field was invited to group *n* words according the meaning into 2~6 groups. The number of words in each group can be different, but it should cover all the words without repeating. Counting the frequency of two words appears in the same group, and a similar frequency matrix $A_{n\times n}(a_{ij})$

was obtained as shown in formula 1. Where a_{ij} is the frequency of word i and j appearing in the same group.

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & a_{ij} & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix} \quad \cdots\cdots(1)$$

To verify whether it is suitable for the multidimensional scaling analysis, the matrix is inputted into SPSS software (Statistical Product and Service Solutions software, IBM). Based operation above, the multidimensional scaling analysis module is run. If it achieves a successful result, the factor's matrix A can be transferred into the same space coordinate values using the formula 2. Using the coordinate values do the clustering analysis in the SPSS software to obtain k groups, and name the group by the closest to the "0" word. The group name is the representative word of the product texture Kansei image.

$$D(X_i, X_j) = \left[\sum_{k=1}^{r} (X_{ik} - X_{jk})^2 \right]^{1/2} \quad \cdots\cdots(2)$$

Where, $D(X_i, X_j)$ is the distance of i^{th} and j^{th} Kansei word, r is the number of the dimension, X_{ik} and X_{jk} are the coordinate of i^{th} and j^{th} Kansei word on k^{th} dimension.

3.2. Exacting the Designing Factors of the Texture Harmony

Product contains many parts, and each part can use different textures. The product is divided into different parts called design elements. A questionnaire is designed to survey the most important one or more elements in the target product. Then, the elements frequency is counted, and the result is ordered descend. Based on results above, the cumulative frequency is computed. With referred the Pareto law (20/80 law), the elements' cumulative frequency within 80% section are selected as the main elements, and the rests are regarded as the secondary elements. The main elements are defined as the most representative texture harmony design elements (E_i). The texture harmonic space (P) is constitute by the typical design elements (E_i), and let $P=(E_1,E_2,\ldots,E_n)$. Each design element (E_i) contains several texture factors (T_{ij}), and let $E_i=(T_{i1}, T_{i2},\ldots, T_{ik})$, where the T_{ij} indicates the j^{th} texture factors of i^{th} elements. The texture harmony space is shown in formula 3.

$$P = \begin{pmatrix} E_1 \\ \vdots \\ E_n \end{pmatrix} = \begin{pmatrix} T_{11} & \cdots & T_{1k} \\ \vdots & \vdots & \vdots \\ T_{n1} & \cdots & T_{nk} \end{pmatrix} \quad \cdots\cdots(3)$$

3.3. Building the Correlation Model between the Texture Kansei Image and the Texture Harmony

Virtual experiment models are designed by the 3D software, and rendered using different texture matching at the same angle. The results pictures are used as the test samples.

The texture combination code is used to describe a set of texture factors in the different design elements.

Respondents are asked to evaluate the representative Kansei image words of all virtual samples. Each sample evaluating score of the different representative Kansei image word is computed. The Kansei evaluation matrix is obtained by combination the Kansei evaluate scores with the texture combination code of all the samples. Inputted the matrix into the multiple linear regression analysis module of SPSS software, the partial correlation

coefficients between the evaluate scores and the design elements and the partial correlation coefficients between the evaluate scores and the texture combination code can be calculated. Defined the evaluating values as the dependent variables, and also taken the texture factors as the independent variables, the correlation model between the texture Kansei image and the texture harmony can be obtained via formula 4.

$$y_i = \sum_{j=1}^{r} \sum_{k=1}^{t_j} a_{ijk} \cdot x_{jk} + c_i \quad \cdots\cdots(4)$$

Where, y_i is the score of i^{th} Kansei image words, r means the number of the design elements, t_j indicates the texture factors number of the j^{th} design element, a_{ijk} is the partial correlation coefficients between i^{th} Kansei image words score of the k^{th} texture factor of the j^{th} design elements, and c_j is the constant term. The partial correlation coefficients a_{ijk} means the important level of the each texture factors. Finally, significant test of the model is carried out to verify the results.

The method proposed can help the designer find the most suitable texture matching for the certain Kansei image and product, and acquire the texture harmony effect.

4. Case Study

4.1. Choosing of the Kansei Image Words of the Product

4.1.1. Collecting the Kansei words: 101 adjective which is suitable to describe the texture were selected on the design web site, book about the product design and material science, advertise and magazine as shown in Table 1.

Table 1. 101 Kansei Image Words for Product Texture

Modern	Gorgeous	Fine	Warm	Lightness	Hard
Expensive	Elegant	Warm	Fresh	Strong	Simple
Beautiful	Romantic	Clean	Loose	Simple	Pop
Monotonous	Bright	Close	Simple	Avant-garde	Brilliant
Lightweight	Soft	Concise	Modern	Rough	elegant
Natural	Flexibility	Soft	Classic	Quaint	Smooth
Vulnerable	Moderate	Traditions	Inexpensive	Smooth	Movement
Neutral	Conservative	Public	Sleek	Movement	Pure
Unique	Cheap	Smooth	Stationary	Transparent	Practical
Rustic	Mellow	Rationality	Transparent	Durable	Pleasant
Dim	Solemn	Clean	Cute	Rough	Flow
Sensibility	Eye-catching	Heavy	Bright	Thick	Publicity
Low-profile	Old-fashioned	Deep	Serious	Vitality	Technology
Chic	Artificial	Refreshing	Leisure	Safety	Cordial
Bold	Complex	Stable	Simple	Fashion	Fantasy
Delicate	Cold	Comfortable	Easily	Tough	Vitality
Future	Bright	Indifference	Luxury	Personality	

4.1.2. Preliminary Filtering: A questionnaire is made to survey the appropriate degree level between the Kansei image words and the material texture semantics. In order to obtain more professional and scientific data, 10 industrial design post-graduates and tutors were asked to fill the questionnaire. The respondents scored each Kansei words with 1-5 referred to the 5

level Likert Scale. The results are passed the analysis of the Reliability and validity, and 19 Kansei image words are selected according to the average score. 19 Kansei image words are listed in Table 2.

Table 2. Numbered 19 Kansei Image Words

No.	Kansei word	No.	Kansei word	No.	Kansei word
No.1	Technology	No.8	Clean	No.15	Strong
No.2	Fine	No.9	Fashion	No.16	Simple
No.3	Rationality	No.10	Beautiful	No.17	Refreshing
No.4	Monotonous	No.11	Stable	No.18	Soft
No.5	Modern	No.12	Concise	No.19	Rustic
No.6	Mellow	No.13	Bright		
No.7	Durable	No.14	Delicate		

4.1.3. Grouping the Words: 2 post-graduate tutors, 10 industrial design post-graduate and 13 consumers are invited to be the respondents. A questionnaire to group the 19 words was made. The respondents were asked to group the 19 words into 2-6 groups on the base of similarity. The words must be used and no-repeated. Similar frequency matrix $A_{19\times 19}$ was built. The Kruskal stress is 0.000, and the determination coefficient (RSQ) is 1.000 through calculating the matrix by the multidimensional scaling analysis in SPSS software. The results show that the data is suitable to running multidimensional scaling analysis. The matrix $A_{19\times 19}$ was transferred into the coordinates of the same space (as shown in Table 3) using the multidimensional scaling analysis module in the SPSS. The 19 words were carried out the clustering analysis based on the coordinates and the SPSS. Finally, the 19 words were grouped into 5 clusters based on the criterion that the Kruskal stress was lowest and the RSQ was biggest at the state of 5 clusters. The representative words or names of each cluster are No. 5 "modern", No. 13 "bright", No. 15 "strong", No. 12 "concise" and No. 14 "subtle".

Table 3. The Result of Cluster Analysis

Cluster I		Cluster II		Cluster III		Cluster IV		Cluster V	
No.	distance	No.	distance	No.	distance	No.	distance	No.	distance
5	0.005	13	0.015	15	0.660	12	0.170	14	0.069
9	0.005	17	0.015	3	0.689	16	0.182	6	0.086
1	0.009			7	0.707	4	0.243	18	0.109
				11	0.748	8	0.273	2	0.115
						19	0.539	10	0.190

4.2. Choosing the Texture Harmony Designing Elements

4.2.1. Choosing the Sample Product: Taken electric kettle as an example, the kettle can be divide into 7 parts including body, handle, lid, heating base, electric switch, spout and light.

4.2.2. Analyzing the Representative Densign Elements: The respondents consist of 5 industrial post-graduate tutors, 10 industrial post-graduates, 15 industrial designers and 20 consumers. Following the step described in Section 3.2, the survey collected 50

questionnaires and obtained 4 most representative texture harmony design elements including body, handle, heating base and lid as shown in Table 4 and Figure 2.

Table 4. The Survey Results of Texture Harmony Design Elements

No.	Design factor	Frequency	Frequency rate (%)	Cumulative frequency (%)
				0
1	body	49	23.9	23.9
2	handle	44	21.5	45.4
3	Heating base	37	18.0	63.4
4	lid	35	17.1	80.5
5	electric switch	19	9.3	89.8
6	spout	12	5.9	95.7
7	light	9	4.3	100
total		205	100	

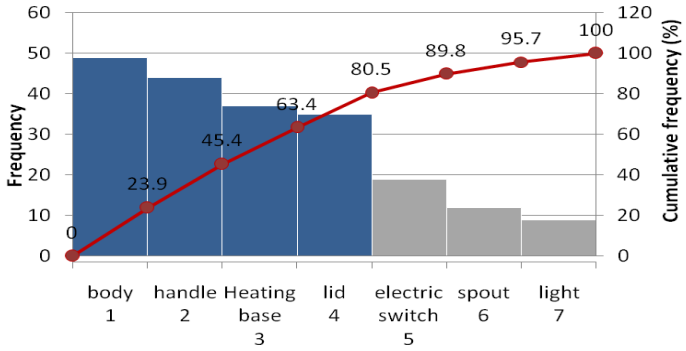

Figure 2. Pareto Diagram

4.3. Designing the Experience Sample

52 kettle samples were modeled by the PTC Creo Parametric 2.0 and rendered by Keyshot 3.0 according to available texture matching of kettle in the sale. Considering the research object, all the kettle samples were decolorized, and used the same form. Following the step in section 3.3, 20 industrial designers were asked to score the samples. As a result, 27 texture factors were selected as the representative textures. All representative design elements and their representative textures were cataloged as shown in Table 5, and which is called texture harmony space.

Table 5. Texture Harmony Space

Design elements	Texture factors					
Body (E_1)						
	T_{11} Mirror	T_{12} Frosted	T_{13} ABS	T_{14} Metallic	T_{15} Ceramic	T_{16} Stalinite

	stainless steel	surface		paint		
handle (E_2)						
	T_{21} ABS	T_{22} Frosted surface	T_{23} Ceramic			
lid (E_3)						
	T_{31} ABS	T_{32} Frosted surface	T_{33} Metallic paint			
Heating base (E_4)						
	T_{41} ABS	T_{42} Frosted surface	T_{43} Ceramic	T_{44} Metallic paint		

4.4. Building the Correlation Model between the Texture Kansei Image and the Texture Harmony

4.4.1. Evaluating the Samples: The survey was conducted in the E-prime software. Figure 3 shows the configure in the E-prime software. Using the questionnaire in Table 6, 10 industrial design post-graduates and tutors, 10 industrial designers and 20 consumers were asked to score each sample according to different representative Kansei image words within 5 level Likert scale.

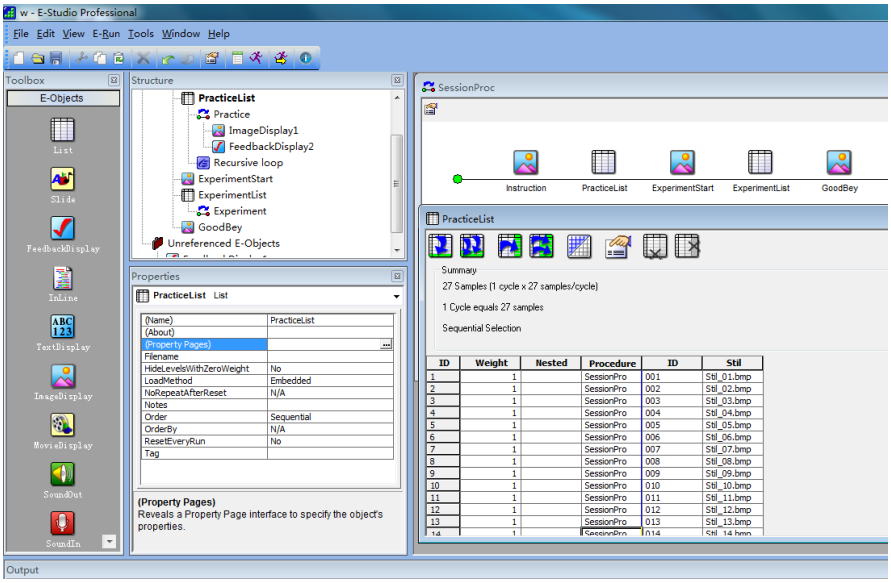

Figure 3. Configure in the E-prime Software

Table 6. Kansei Words Evaluative Table

No.	sample	Texture Body/ handle/ heating base / lid	modern	bright	strong	concise	subtle
2		ABS/ABS/ ABS/ ABS	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5

Removing the data which the reaction time is more than 2s in E-prime experiment, 35 copies of effective questionnaire were filtered out. Deployment the method stated in Section 2.3, each kettle sample's Kansei evaluating scores and their texture combination code are listed in Table 7, and which is called Kansei evaluating matrix.

Table 7. Kansei Evaluating Matrix

Samples		Kansei Evaluate Scroe					Design Elements															
							E_1						E_2			E_3			E_4			
No.	Figure	Modern	Bright	Strong	Simple	Delicate	T_{11}	T_{12}	T_{13}	T_{14}	T_{15}	T_{16}	T_{21}	T_{22}	T_{23}	T_{31}	T_{32}	T_{33}	T_{41}	T_{42}	T_{43}	T_{44}
1		3.83	3.97	4.25	3.43	3.56	1	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0
2		3.4	3.2	2.84	3.83	3.18	0	0	1	0	0	0	1	0	0	1	0	0	1	0	0	0
...	... ...	... ...	... ...	... ...	... ...	... ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
27		3.47	3.13	2.96	3.56	3.11	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	1

4.4.2. Calculating the Partial Correlation Coefficients: Using multidimensional analysis module in SPSS, the partial correlation coefficients between the evaluate scores and the design elements and the partial correlation coefficients between the scores and the texture factors were calculated as shown in Table 8 (taking "concise" as an example). Texture Factor score values of positive and negative means concise and not concise of the Kansei image.

Table 8. The Partial Correlation Coefficients (Taking "Concise" as an Example)

Design element	Texture factor	Score	Partial correlation coefficient
Body (E_1)	T_{11} Mirror stainless steel T_{12} Frosted surface T_{13} ABS T_{14} Metallic paint T_{15} Ceramic T_{16} Stalinite	Excluded 0.201 0.398 -0.239 -1.97 -0.48	0.775
handle (E_2)	T_{21} ABS T_{22} Frosted surface	0.187 -0.015	0.314

	T_{23} Ceramic	Excluded	
lid (E_3)	T_{31} ABS T_{32} Frosted surface T_{33} Metallic paint	0.034 Excluded 0.029	0.227
Heating base (E_4)	T_{41} ABS T_{42} Frosted surface T_{43} Ceramic T_{44} Metallic paint	-0.067 Excluded -0.517 -0.198	0.403

And the determination coefficients (RSQ) corresponding to 5 representatives Kansei image words are shown in table 9. All the value of RSQ is not less than 0.7, so the data can be trusted.

Table 9. Determination Coefficients

Kansei word	RSQ
modern	0.995
bright	0.992
strong	0.993
concise	0.866
subtle	0.916

Table 10 shows the partial correlation coefficients between 5 representative Kansei image words and the design elements. Table 11 shows the constant corresponding to each Kansei image words by SPSS's calculation.

Table 10. Partial Correlation Coefficients of 5 Kansei Words

Kansei word	Partial correlation coefficients of 5 Kansei words			
	Body (E_1)	handle (E_2)	lid (E_3)	Heating base (E_4)
modern	0.717	0.851	0.075	0.852
bright	0.988	0.177	0.175	0.210
strong	0.897	0.501	0.189	0.474
concise	0.775	0.314	0.227	0.403
subtle	0.878	0.448	0.309	0.453

Table 11. Constant Corresponding to the 5 Kansei Words

Kansei word	constant
modern	3.811
bright	4.003
strong	4.156
concise	3.420
subtle	3.574

4.4.3. Building the Regression Model: Taking Kansei image word "concise" as an example, the multiple linear regression model between the Kansei image and the texture factors is as follows.

$$y_{(\text{concise})}=0.201T_{12}+0.398T_{13}-0.239T_{14}-1.97T_{15}-0.48T_{16}+0.187T_{21}-0.015T_{22}+0.034T_{31}+0.029T_{33}-0.067T_{41}-0.517T_{43}-0.198T_{44}+3.420$$

4.4.4. The Significance Test of Regression Equation: Another experiment was carried out to verify the conclusion above. Making a set of new sample evaluates the Kansei image "concise" in the same way and builds another multiple linear regression model. T test is adopted to test the results of two experiments. If $P>0.05$, it indicates that there are no significant difference between two experiments results. The rest Kansei image is evaluated in the same way, and the result is also satisfactory. So, the result of the method is reliable and reasonable.

4.5 Analysis

The case study indicates that in the condition of Kansei image "concise", the biggest contribution design elements is the pot body, and the biggest contribution texture factors is ABS. It means that it is more likely to form "concise" Kansei image using ABS pot body in kettle design. The study also shows that the most "concise" kettle texture harmony case is ABS pot body + ABS handle + ABS heating base + ABS lid.

5. Conclusion

The study intends to raise the product texture harmony designing conception, build the multiple linear regression models between the texture harmony factors and the Kansei image. The model explains the mapping relationship between the texture and Kansei image. The result are verified by a case study of electric kettle.

The study is an attempt to texture harmony design, focusing on the relationship between the Kansei image and the texture harmony, based on the contribution degree of the single texture. The further research is going to explore the texture harmony based on the more complex condition and more detailed classification.

The study lays a foundation for texture designing decision system. The system aims at forming texture harmony under the assistant of computer, helping to meet the consumer's Kansei requirement more easily and goal-oriented, reducing the sense of uncertainty in texture design.

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