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AN APPROACH OF THE PRODUCT FORM DESIGN BASED ON GRA-FUZZY LOGIC MODEL: A CASE STUDY OF TRAIN SEATS

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Abstract. *In the process of product form design, the quantitative design method of combining the user-oriented Kansei images and product form design elements should be developed more objectively and logically. In order to satisfy the user perception of the Kansei image, this paper presents a new approach of the product form design based on Gray Relational Analysis (GRA) fuzzy theory. Firstly, GRA-Fuzzy logic model is used to effectively identify the form elements that influence the Kansei images. Secondly, according to the membership function that the input and output linguistic variables are determined based on the fuzzy theory, the fuzzy rules that associate product form elements with Kansei images are constructed. Thirdly, GRA-Fuzzy logic model is built to analyze and evaluate the product form design. The train seat form design is used as a case study. The result shows that the model is effective in predicting the product Kansei images, and it improves and optimizes the product form design process. Furthermore, GRA-Fuzzy logic model can be used, in conjunction with computer aided design system or X Reality technology, to build a 3-D model for promoting the design process of products.*
Keywords: GRA-Fuzzy logic model, Product form design, Kansei image, Train seats

1. **Introduction.** With the rapid economic growth and people's living standard improving, in the new era of the consumption style, user-oriented design has been developed in recent years. As technology development advances rapidly, for users the essential physical function of a product is no longer the decisive factor that attracts them to buy. Users have a fixed preference model for the product form, if which can be analyzed, designers are able to figure out quickly whether the form designs satisfy the target groups or not [1]. For designers, if you can understand the user psychology and explore in depth the relationship between the user perception, requirement and the design elements, you will design a good product successfully [2]. Form design matched with the product image is based on cognitive thinking of the user and designer [3]. Kansei image of the user and designer is taken as the fundamental starting point, with product form and design elements

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as the object of the research. A product design methodology with quantifying the Kansei image is used to help the product designers effectively obtain the ideal product form [4].

The different forms make the different feelings on human cognition, so the discussion of consumers' cognition of the forms is often conducted by image vocabularies depending on Kansei engineering. It is often assisted by the semantic differential scale, morphological analysis, Likert scale, and so on to construct a Computer Aided Design (CAD) system to generate product forms intended by users [5]. Lai et al. applied the grey relational analysis model to defining the relationship between the product form elements with the product Kansei images [6]. In addition, Myszkowski and Storme performed several Visual Aesthetic Sensitivity Test (VAST) to explore the visual aesthetics on 2D images and also seek for numerical approaches to aesthetic problems [7]. Yan et al. dealt with Kansei evaluation focusing on users' psychological needs and personal taste. The results showed that the fuzzy rule-based model had a better performance in predicting the usability of a new product than a linear regression model [8]. Based on the Kansei engineering theory, correlation analysis, factor analysis and cluster analysis were applied to analyzing the measurement results of Kansei image. The fuzzy evaluation method was applied to checking the membership degree of the design scheme [9]. By using the fuzzy analytical hierarchy process theory, the qualitative problems are combined with the user's requirements in product design. A comprehensive analysis and evaluation of the product is used to meet the psychological needs of users and has a good use of products. The Delphi survey methods are used to analyze the needs of users and the market to come up with the design scheme. The evaluation factors of the product are constructed. A hierarchical analysis model is established using the method of fuzzy mathematics to evaluate the various factors [10].

The previous studies lacked the numerical analysis and sequencing of influence values for different form elements that matched with the specific Kansei image, including the numerical comparison of influence on each form element affecting the particular Kansei image. They are the numerical data source of determining the most influential form elements of GRA-Fuzzy logic model. Moreover, the product design model system involved with product form design elements and Kansei images is equally necessary for user and designer to work collectively and efficiently.

Therefore, in the current article, we propose a new GRA-Fuzzy logic approach to analyze the relationship between the form elements of products and the specific product images. Based on Kansei engineering theory, the user perception of product image is transferred into the design elements of product. Firstly, the influence of various form elements affecting the product image is analyzed through the Gray Relational Analysis (GRA) and the most influential form elements for achieving the desirable product images are effectively identified. Secondly, the membership functions of the input and output linguistic variables are determined according to the fuzzy theory. As suggested in our previous study [11], the fuzzy logic model with fuzzy rules can be constructed to determine the value of the Kansei image for a given product. In line with the results of our previous research, we construct the fuzzy rules of GRA-Fuzzy logic model with the most influential form design elements for the specific product images in this paper. Finally, GRA-Fuzzy logic model is built objectively to facilitate and optimize the product form design in the product design process, and the case study shows the effectiveness of the proposed methods.

The organization of the remaining sections is as follows. Section 2 introduces the research methodology from the experimental preparation and statistics. GRA-Fuzzy logic modeling and testing phase are proposed in Section 3. Section 4 represents the case study on train seat image database construction and GRA-Fuzzy logic model using the new

GRA-Fuzzy logic approach. Section 5 discusses the conjunction between the GRA-Fuzzy logic model and the computer aided design system or X Reality technology. Finally, Section 6 concludes the proposed work.

2. **Experimental Preparation and Statistics Phase.** This section includes the preparation phase and statistics phase. Preparation phase comprises selecting the experimental subject, extracting the representative product samples, morphological analysis of the product form design elements and selecting the image words for describing the user perception of the product image. Statistics phase is through Kansei image evaluation of the experimental subjects to the product samples, collecting the evaluated data and building the product image database. The concrete steps of these two phases are as follows.

2.1. **Experimental preparation.** Firstly, the experimental study involved the experimental subjects, divided into 3 groups according to the different age, gender and experience: the first group (expert users), the second group (professional product designers) and the third group (general users) as Figure 1. The expert users of the first group are responsible for selecting the experimental samples. The professional product designers of the second group are asked to perform the morphological analysis in order to extract the form design elements of the products. The general users of the third group evaluate the product image matched with the experimental samples.

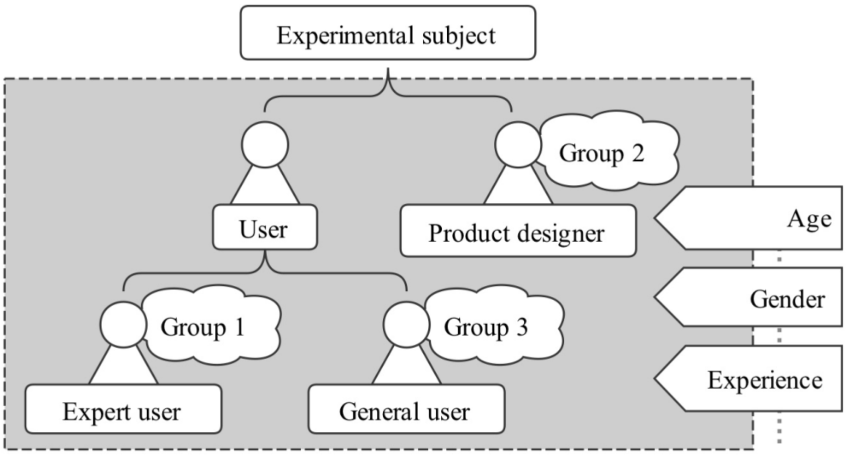


Figure 1. The group overview of experimental subject

We then selected the products of various models and makers. We asked the subjects of the first group to classify the selected products based on their similarity degree, using the Kawakita Jiro method [12]. Afterwards, the Multidimensional Scaling (MDS) analysis and the clustering analysis are applied to the classification results [13]; therefore, the representative experimental samples are extracted. A morphological analysis is used to extract the product form design elements of the representative experimental samples. Firstly, the subjects of the second group are asked to write down the main form design elements individually, according to their professional knowledge and practical experience. Secondly, the product designers form a focus group to combine similar opinions of the survey results [14]. After the discussion and analysis by the focus group, the form design elements of products are summarized and the result of the morphological analysis is obtained. The above process is shown in Figure 2.

The psychological perception of users about the product image can be described by the pairs of Kansei words, such as rustic-handsome, traditional-modern and simple-magnificent. We use the following 4 steps to extract the representative Kansei word

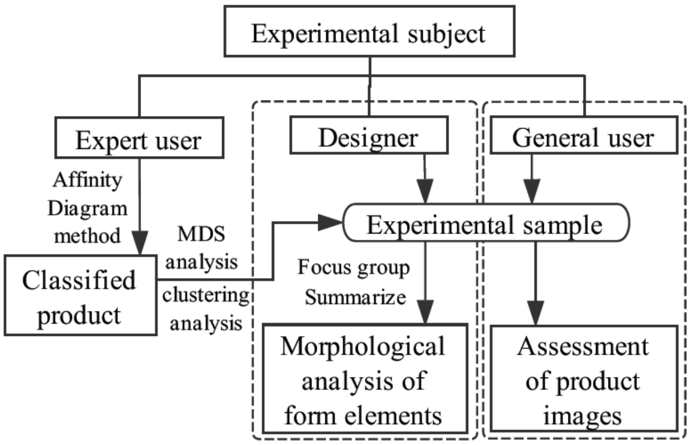


FIGURE 2. The flowchart of morphological analysis in product form design

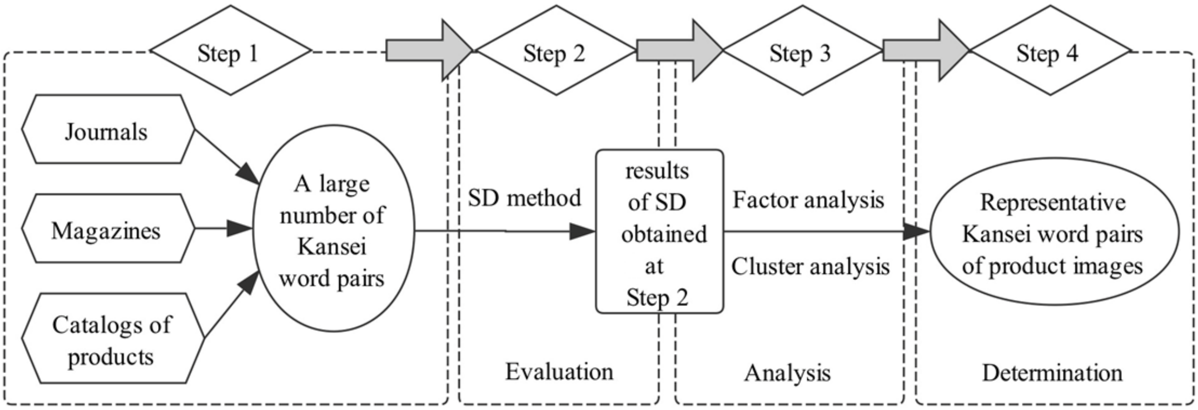


FIGURE 3. The 4 steps to extract the representative Kansei word pairs of product images

pairs for describing the user perception of the product image as Figure 3. Step 1: A large number of Kansei word pairs are collected from the journals, magazines and catalogs of products. Step 2: Evaluate the collected Kansei word pairs using the Semantic Differentials (SD) method [15]. Step 3: The results of SD achieved at Step 2 are analyzed by the factor analysis and cluster analysis. Step 4: The representative Kansei word pairs of the product images can be determined based on the analysis of Step 3 [16].

2.2. **Product image database.** We asked the subjects of the third group to assess the product form of the representative experimental samples on a seven-point scale of the SD method. The statistics phase provides the numerical database of product image for constructing the fuzzy rules of GRA-Fuzzy logic model. The process is illustrated in Figure 4.

3. **GRA-Fuzzy Logic Model.** This section explains the GRA-Fuzzy logic modeling phase and testing phase. Building a GRA-Fuzzy logic model involves the GRA and the GRA-Fuzzy logic modeling. To begin with, the form design elements which affect the product image are identified by GRA; subsequently the most influential form elements for the product image are obtained. Next, the input and output linguistic variables are defined, and after that their membership functions are determined. We constructed the fuzzy rules with the most influential form design elements for the product images, so

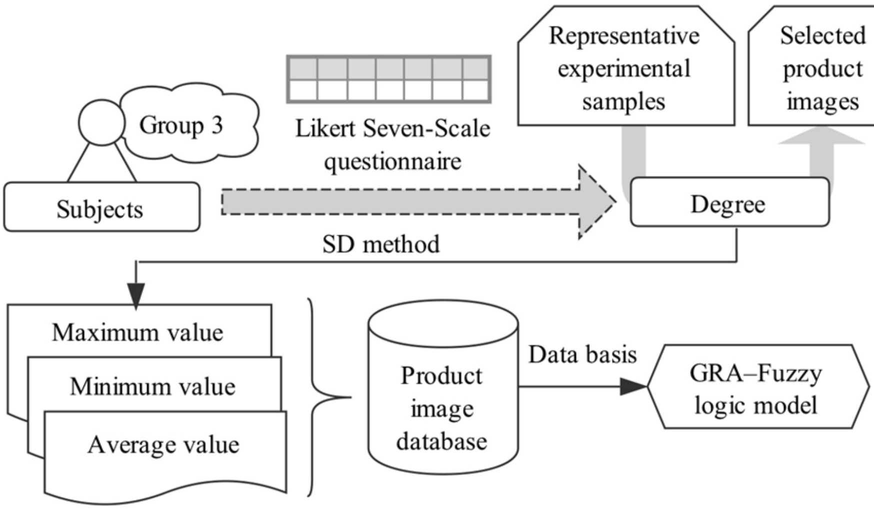


FIGURE 4. The flowchart of product image database establishment

GRA-Fuzzy logic model of product design is built. The last phase is to evaluate the performance of GRA-Fuzzy logic model.

3.1. **Grey relational analysis.** Grey Relational Analysis (GRA) is an important approach of the grey theory, because GRA not only applies to clustering the data which has same features with other clustering methods, but also measures their relationships [17]. The grey correlation coefficient $r\left(x_0(k), x_i(k)\right)$ is defined as follows:

$$r\left(x_0(k), x_i(k)\right) = \frac{\min_i \min_k |x_0(k) - x_i(k)| + \xi \max_i \max_k |x_0(k) - x_i(k)|}{|x_0(k) - x_i(k)| + \xi \max_i \max_k |x_0(k) - x_i(k)|} \tag{1}$$

$$k = 1, 2, \ldots, n \quad i = 1, 2, \ldots, m$$

The form design elements for the product images are identified by GRA. The product images are used as the reference sequence, and the form design elements used as the comparison sequence. The grey relational degree of each form design element to the product image is obtained, and the corresponding grey relational degrees of different form elements are different. If $r\left(x_0, x_i\right) > r\left(x_0, x_j\right)$, it manifests that the element x_i is closer to the reference element x_0 than the element x_j. In this study, it represents the form element x_i makes more influence on the product image x_0 than the form element x_j. Therefore, the higher the $r\left(x_0, x_i\right)$ value, the more influential the form design element x_i [18].

3.2. **GRA-Fuzzy logic model.** The GRA-Fuzzy logic modeling process is shown in Figure 5. Based on GRA-Fuzzy theory, combined with Kansei engineering, first of all, the most influential form elements are selected by GRA, and the product images are evaluated used with Likert Seven-Scale. Afterwards, the most influential form elements selected by the subjects are taken as input fuzzy set, along with the evaluated values of product images as output fuzzy set. The triangular functions of the input and output linguistic variables are obtained. Subsequently, through the application fuzzy logic model in Matlab, fuzzy control data table and the fuzzy rules are constructed, and then the defuzzification of fuzzy numbers is used by CoM method. Finally, GRA-Fuzzy logic model is built to determine the value of the specific product images for a given product.

We use the triangular membership functions to represent the values of various form types of the key form design elements (as the input linguistic variables) used in the fuzzy rules of GRA-Fuzzy logic model. Equation (2) shows the membership function $\mu_A(x)$ of

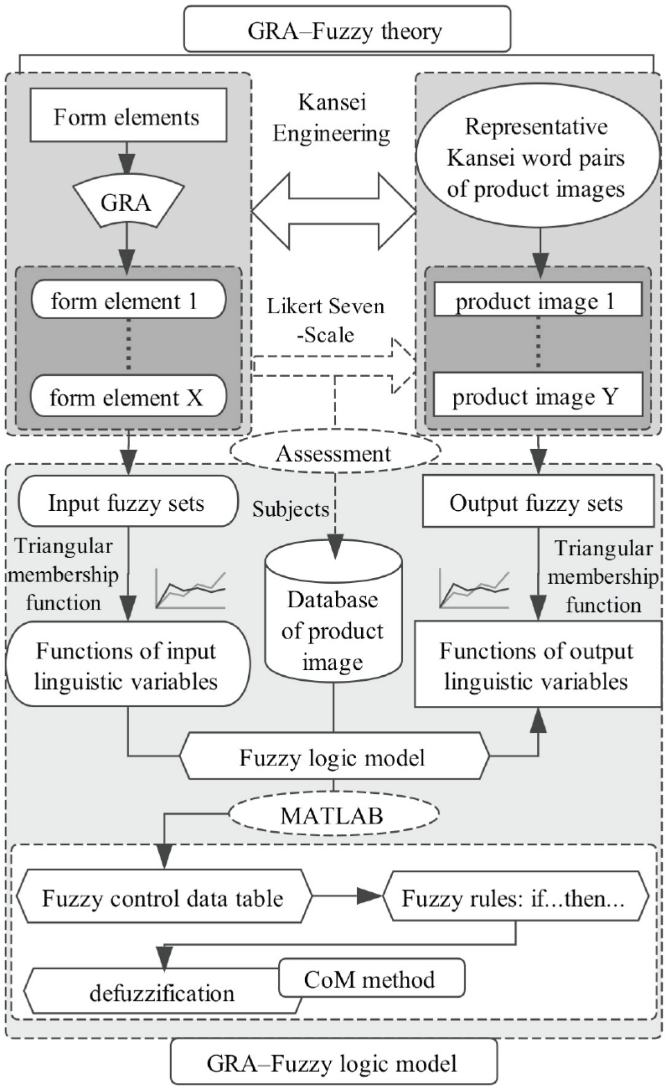


Figure 5. The flowchart of GRA-Fuzzy logic model phase in product form design

a triangular fuzzy number represented by a triple (a, b, c), where a, b, c are real numbers with $a \leq b \leq c$.

$$\mu_A(x) = \begin{cases} 0, & x < a \\ \dfrac{x-a}{b-a}, & a \leq x \leq b \\ \dfrac{x-c}{b-c}, & b \leq x \leq c \\ 0, & x > c \end{cases} \tag{2}$$

The triangular fuzzy number (a, b, c) can be used to give the approximate value range of a linguistic term. b is the most possible value of the term with a and c the lower and upper bounds respectively, used to reflect the fuzziness of the term.

To obtain the fuzzy rules in an objective manner, the subjects assess the product form of the representative train seat samples, as discussed in Section 2.2. Then the fuzzy rules of GRA-Fuzzy logic model are constructed. The multiple conditions fuzzy if-then rules can be used as follows:

$$\text{If } X_1 \text{ is } A_1 \text{ and } X_2 \text{ is } A_2 \cdots \text{ and } X_n \text{ is } A_n$$
$$\text{Then } Y_1 \text{ is } B_1 \text{ and } Y_2 \text{ is } B_2 \cdots \text{ and } Y_n \text{ is } B_n$$

where $A_1, A_2, \ldots, A_n$ and $B_1, B_2, \ldots B_n$ are the fuzzy linguistic terms, taken by the input linguistic variables $X_1, X_2, \ldots, X_n$ and the output linguistic variables $Y_1, Y_2, \ldots, Y_n$ respectively. Each fuzzy rule associates a given combination of product form elements with the corresponding value states of the product images.

Defuzzification is the process of converting the degrees of membership of output linguistic variables into numerical values [19]. We perform the most commonly used defuzzification technique, the Center of Maximus (CoM) method, calculated as:

$$y_{CoM} = \frac{\sum\limits_i [\mu(y_i) \times y_i]}{\sum\limits_i \mu(y_i)} \tag{3}$$

where i represents the linguistic term of a linguistic output variable; y_i is the maximum of each linguistic term i, and $\mu(y_i)$ is the aggregated output membership function.

3.3. **Performance evaluation and discussion.** To evaluate the performance of a model, the Root Mean Square Error (RMSE) is commonly used as follows:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n} (x_i - x_0)^2}{n}} \tag{4}$$

where x_i is the ith output value predicted by the model and x_0 is the expected value assessed by the subjects in the experiment. In this paper, to examine the prediction ability of the GRA-Fuzzy logic model, we compare its performance with the fuzzy logic model as Figure 6.

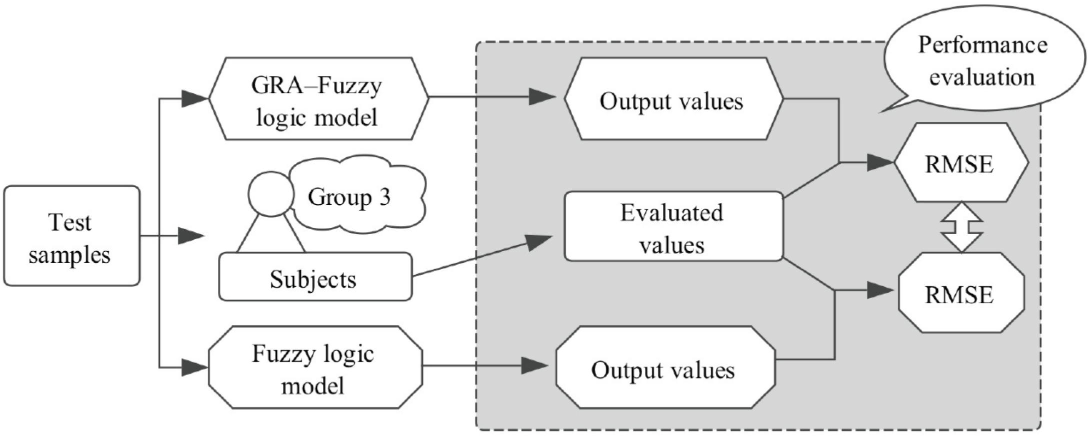


Figure 6. The RMSE of GRA-Fuzzy logic model and fuzzy logic model

4. **A Case Study of Train Seats.** In this section, the train seat form design is used as a case study. We present the case study of train seats based on GRA-Fuzzy logic model and its results in the context of the three primary phases as follows.

4.1. **Experimental preparation and product image database of train seat form design.** The experimental study involved 60 subjects, divided into three groups: the first group (13 males and 12 females with 36.8 average age), the second group (5 males and 5 females) and the third group (13 males and 12 females with 38.3 average age). Each subject of the first group had more than 80 times of train ride experience within 5 years. They are responsible for selecting the representative seat samples from 171 train seat pictures. The second group was composed of 10 professional product designers, which extracted the form elements of train seats through the morphological analysis. Every expert designer had at least 8 years' experience of product design. The subjects in the third group had more than 60 times of train ride experience within 5 years. They evaluated the product image of experimental samples, whose result is to be served as database for constructing GRA-Fuzzy logic model and testing the performance of the model.

The results of the morphological analysis were divided into two groups: form characteristics and form relation. The form characteristics group included the shape and size of the contour components of train seats, such as headrests, seat-backs, seats or handrails. The form relation group showed the relationship among the contour components, for instance, the combination relationship between the headrests and seat-backs, the proportion and angle between the seat-backs and seats. Finally, the focus group consisting of ten professional product designers analyzed and summarized the survey results. As a final result of morphological analysis, Table 1 shows the 9 form elements and their corresponding element types extracted from the 27 representative train seat samples. Each form element has different types, ranging from 2 to 5. For example, the 'headrest shape (x_2)' element has four types, including 'rectangle', 'semi-ellipse', 'ellipse' and 'irregular'.

Table 1. Morphological analysis of the form elements on the 27 representative train seat samples

	Form Elements	Type 1	Type 2	Type 3	Type 4	Type 5
1	Seat-back top shape (x_1)	Line (L)	Curve (C)	Arc (A)	Irregular (I)	
2	Headrest shape (x_2)	Rectangle (R)	Semi-Ellipse (SE)	Ellipse (E)	Irregular (I)	
3	Relationship between seat-back and headrest (x_3)	Integration (I)	Superposition (S)	Junction (J)		
4	Seat-back body shape (x_4)	Parallel Line (PL)	Raised Curve (RC)	Irregular Curve (IC)		
5	Seat-back waistline (x_5)	Straight Line (SL)	Polygonal Line (PL)	Arc Line (AL)	Curved Line (CL)	Irregular Line (IL)
6	Seat shape (x_6)	Cambered Face (CF)	Flat Face (FF)	Single-raised Face (SF)	Double-raised Face (DF)	
7	Seat handrail shape (x_7)	Straight Arm (SA)	Polygon Arm (PA)	Curved Arm (CA)	Large-area Arm (LA)	
8	Length ratio between seat-back and seat (x_8)	Slender Ratio 2:1 (SR)	Middle Ratio 1.65:1 (MR)	Wide Ratio 1.3:1 (WR)		
9	Seat-back slope angle (x_9)	Small Angle 90-100° (SA)	Large Angle 90-100° (LA)			

The 25 subjects of the third group evaluated the degree of 27 train seat samples matched to the product image. We finally picked out three representative Kansei word pairs for describing the product images of train seats, including traditional-modern (T-M), static-dynamic (S-D), common-outstanding (C-O). The traditional-modern (T-M) word pair was picked out as the primary Kansei image of train seats in order to construct the GRA-Fuzzy logic model. The other two Kansei word pairs were used to evaluate the performance of the GRA-Fuzzy logic model. We used a seven-point scale of the SD method to obtain the assessment value for the T-M image of a given train seat. The T-M value represents the degree to which the look of train seat samples matches the T-M image. We asked the 25 subjects of the third group to assess the T-M value of the 27 representative train seat samples on a tradition-modern scale of 1-7, where 1 and 7 represented the most traditional look and the most modern look, respectively.

The 25 subjects of the third group were involved to evaluate degree to which the 27 representative train seat samples match the T-M image. As shown in Figure 7, train seat no. 22 has the "modern" product image with an average T-M value of 5.33 as compared to other train seats, the maximum value of 7 and the minimum value of 3. Figure 7 provides the database for constructing the fuzzy rules to confirm the numerical value of the T-M image for a given train seat sample.

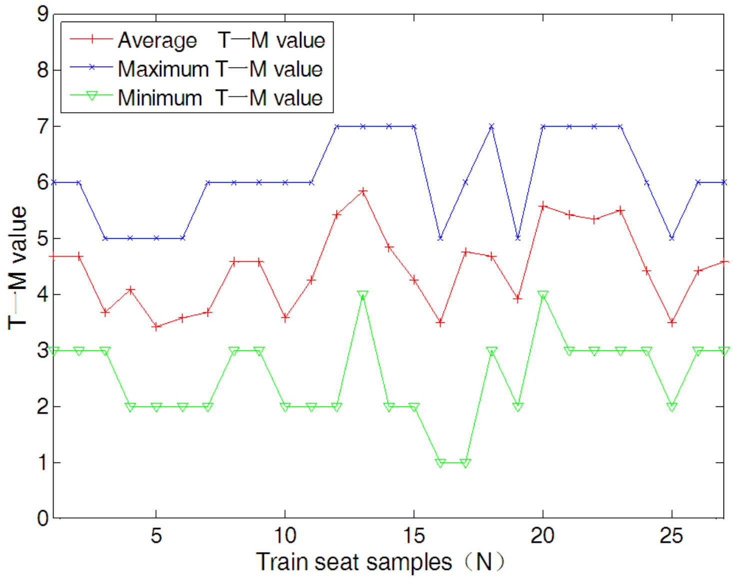


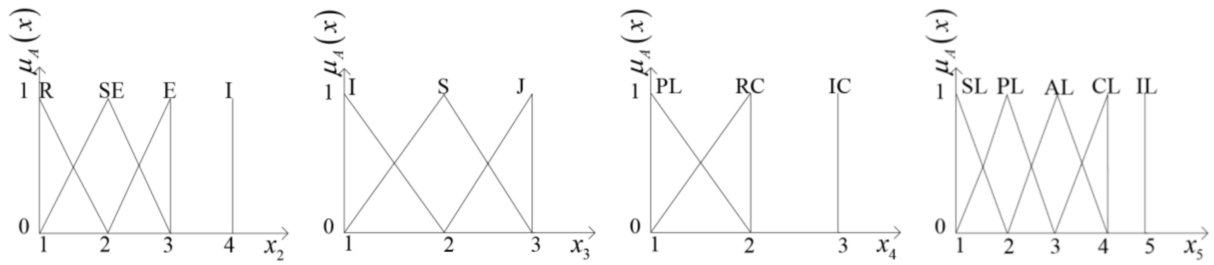
FIGURE 7. The T-M values of the 27 representative train seat samples

4.2. **GRA-Fuzzy logic model of train seat form design.** The grey correlation coefficient $r(x_0, x_i)$ between the T-M image (x_0) and the form element (x_i) of train seats can be obtained according to Equation (1) as Table 2.

TABLE 2. The numerical values of $r(x_0, x_i)$

$r(x_0, x_1) = 0.722$	$r(x_0, x_2) = 0.812$	$r(x_0, x_3) = 0.794$
$r(x_0, x_4) = 0.833$	$r(x_0, x_5) = 0.844$	$r(x_0, x_6) = 0.515$
$r(x_0, x_7) = 0.772$	$r(x_0, x_8) = 0.798$	$r(x_0, x_9) = 0.787$

As suggested in our previous research, we construct the fuzzy rules of GRA-Fuzzy logic model by using the six most influential form elements of train seats for the T-M image. We use the triangular membership functions to represent the values of the element types of the key six form elements, as shown in Figure 8. For example, "headrest shape" (x_2) has four types (rectangle, semi-ellipse, ellipse and irregular). Therefore, four linguistic terms are defined by four triangular fuzzy numbers as illustrated in Figure 8(a). The scale value of 1-3 is given for a specific value of "headrest shape" to describe the degree to which it matches the first three types as defined by the corresponding terms (rectangle, semi-ellipse and ellipse), respectively. For instance, a value of 2.5 indicates the actual "headrest shape" is a combination of 50% of the Type 2 (semi-ellipse) and 50% of the Type 3 (ellipse) of the "headrest shape" element shown in Table 1. We set the "irregular" type as a single value of 4, to indicate that this shape type has no association with the

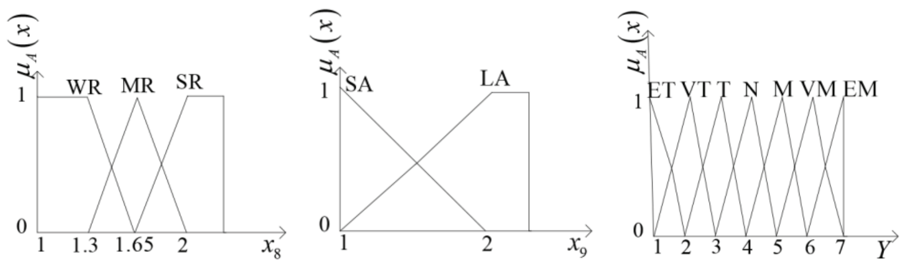


(a) Headrest shape (x_2)

(b) Relationship between seat-back and headrest (x_3)

(c) Seat-back body shape (x_4)

(d) Seat-back waistline (x_5)



(e) Length ratio between seat-back and seat (x_8)

(f) Seat-back slope angle (x_9)

(g) T-M value (Y)

FIGURE 8. Membership functions of the linguistic terms for the linguistic variables used in the GRA-Fuzzy logic model

first three types. As suggested in Section 4.1, the 25 subjects used the Likert Seven-Scale questionnaire of the SD method to assess the matching degree between the look of each of the 27 representative train seat samples and the T-M image.

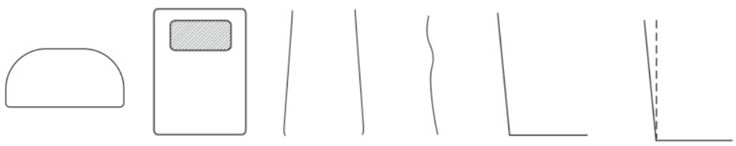
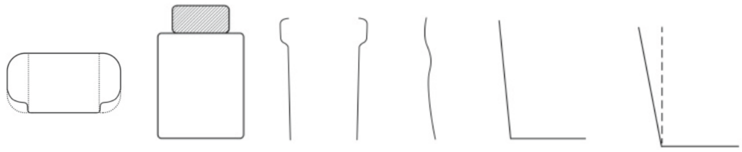
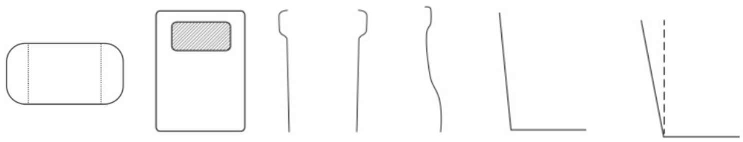
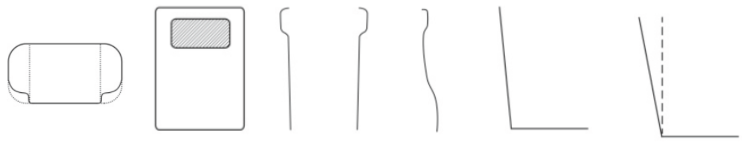
With the experimental study on the 27 representative train seat samples, a set of 54 ($27 \times 2 = 54$) fuzzy rules is constructed. For example, Rule 1 states that: if "headrest shape" (x_2) is irregular (I), "relationship between seat-back and headrest" (x_3) is superposition (S), "seat-back body shape" (x_4) is Irregular Curve (IC), "seat-back waistline" (x_5) is Irregular Line (IL), "l length ratio between seat-back and seat" (x_8) is Middle Ratio (MR), and "seat-back slope angle" (x_9) is Small Angle (SA), then the T-M value is "M" (Modern) with a Degree of Support (DoS) of 0.67.

4.3. **Performance evaluation of GRA-Fuzzy logic model.** In order to verify the prediction ability of GRA-Fuzzy logic model of train seats, we use the five test samples shown in Table 3. Then we compare the performance with the fuzzy logic and GRA-Fuzzy logic model on the basis of our previous studies.

The second row of Table 4 shows the average T-M value of the five test samples assessed by the 25 subjects of the third group. Table 4 shows the corresponding T-M value predicted by the GRA-Fuzzy logic model and fuzzy logic model, respectively. The result shows that the GRA-Fuzzy logic model has the highest consistency for predicting the value of the T-M image.

Table 4 shows the average values of static-dynamic (S-D) and common-outstanding (C-O) images assessed by the 25 subjects of the third group for the five test samples, as well as the values predicted by using the fuzzy logic and GRA-Fuzzy logic models, respectively. The results show that the GRA-Fuzzy logic model also has the lower RMSE. Accordingly, GRA-Fuzzy logic model is an effective mechanism for matching a combination of the product form elements with the specific product images.

TABLE 3. Input and output values of the five test samples

Sample	x_2	x_3	x_4	x_5	x_8	x_9	Y (T-M value)
1	 (SE)	(S)	(RC)	(CL)	(MR)	(SA)	4.16
2	 (I)	(J)	(IC)	(CL)	(MR)	(LA)	5.41
3	 (E)	(S)	(IC)	(IL)	(MR)	(LA)	4.00
4	 (I)	(S)	(IC)	(IL)	(MR)	(LA)	4.00
5	 (SE)	(I)	(PL)	(FL)	(SR)	(SA)	3.69

5. **Discussion.** GRA-Fuzzy logic model can be used in conjunction with Computer Aided Design (CAD) system or X Reality (XR or Cross Reality) technology to build 3-D model of product to promote and simulate the design process [20]. CAD is the use of computer systems to aid in the creation, modification, analysis, or optimization of a design. Designers usually start with the draft, and the work of turning a draft into a work map can be done by CAD software. It can be used to edit, enlarge, reduce, shift and rotate graphics data processing. Combining CAD with GRA-Fuzzy logic model, the design elements are sketched and modeled with CAD software to facilitate the product designers to evaluate the design more intuitively, adjust the combination of design elements, and obtain more accurate results with the GRA-Fuzzy logic model.

For example, Figure 9 illustrates the design sketches, 3-D model and rendering of the train seat no. 4 in Table 3. Moreover, model the form design elements of product with CAD system, respectively, and then carry out different combinations of 3-D models of the form design elements. The values of product images with different combinations are obtained by GRA-Fuzzy logic model. The product designers may conceive and create the new product 3-D model intuitively with the new combination of the form elements 3-D models matched with the ideal product images.

Table 4. The RMSE results of the GRA-Fuzzy logic and fuzzy logic models

	Test sample 1	Test sample 2	Test sample 3	Test sample 4	Test sample 5	RMSE
T-M value						
Assessment by subjects	4.75	5.33	4.92	4.00	3.42	
The GRA-Fuzzy logic model	4.16	5.41	4.00	4.00	3.69	0.5047
The fuzzy logic model	4.42	4.00	4.08	4.42	4.24	1.8526
S-D value						
Assessment by subjects	4.80	5.08	3.80	4.24	3.72	
The GRA-Fuzzy logic model	4.24	4.48	4.68	4.79	4.39	0.6632
The fuzzy logic model	4.00	3.32	2.76	3.25	2.52	1.2033
C-O value						
Assessment by subjects	5.53	6.22	5.80	4.10	3.73	
The GRA-Fuzzy logic model	4.79	5.48	5.08	4.95	4.63	0.7932
The fuzzy logic model	4.13	4.22	4.00	2.90	2.02	1.6471

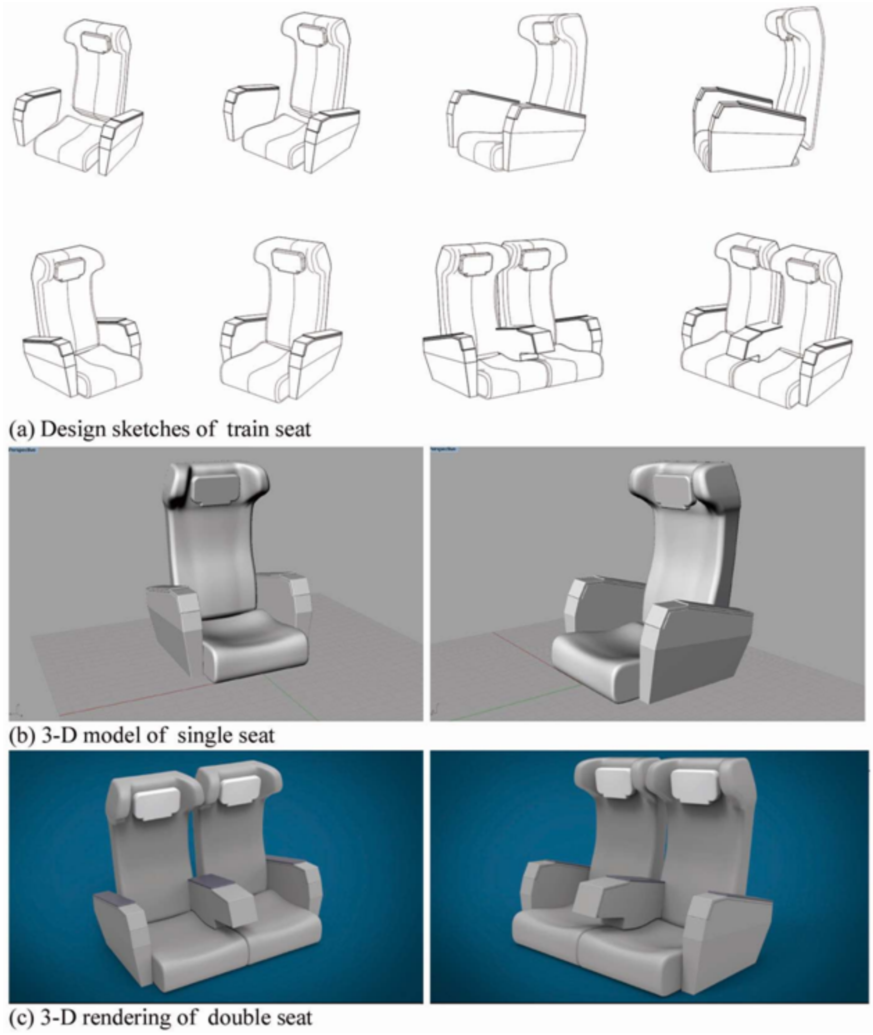


Figure 9. The design sketches, 3-D model and rendering with the CAD system of the train seat no. 4

XR technology consists of technology-mediated experiences that combine digital and biological realities. It encompasses a wide spectrum of hardware and software, including sensory interfaces, applications, and infrastructures, that enable content creation for Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR), and more [21].

VR, AR and MR can cooperatively work with GRA-Fuzzy logic model, enhance the visualization of product design, which make the designers and users perform the design result more efficiently. In the model phase, VR, AR and MR technology can change the traditional display mode to refine the design for form, function and structure in GRA-Fuzzy logic model. For example, VR can simulate real product using environment, enable the users to experience, use and evaluate the product in virtual space. AR may help the product designers to perform the design process in real products using environment, and modify the combination of the form elements until a satisfied value of GRA-Fuzzy logic model is obtained. Users can evaluate the product performance with the most intuitive feelings in the real-world environment. MR may further enhance the interaction between designer, user and product.

6. **Conclusion.** In this paper, we have proposed a GRA-Fuzzy logic method for transforming user' perception into product form elements, with an experimental study of train seats. The approach of the product form design based on GRA-Fuzzy logic model helps the product designers focus on the most influential form design elements for achieving the desirable product images. To illustrate the approach, we have performed an experimental study on train seats based on the process of user-oriented design. Using GRA-Fuzzy logic model, we have constructed the fuzzy rules generated objectively based on the subjects' assessments, make the product images predicted quickly through the product form. The approach proposed in this paper helps the designers focus on the product forms that contribute most to the desirable product image.

The experimental result has demonstrated that GRA-Fuzzy logic model has a better performance. It is an effective mechanism for improving and optimizing the product form design process. The following research direction is to link the influence of the product color, material, surface texture and tactile impression with the user's feeling of the products. Moreover, we can even continue to explore the influence of the static environment, dynamic environment, or the environmental color of the product on product image. Therefore, GRA-Fuzzy logic model of product design process involved with multiple product design elements and product images can be further improved and developed in the future.

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