SUV Front View Design Method Selected by Multiple Schemes

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Abstract. Based on the parametric sensibility engineering and computer-aided industrial design basis, the SUV forward-looking contour is used as a target to explore a preferred selection model for multiple design schemes under specific images. Samples of the SUV front view were collected, the design variables were defined using the Bézier curve, and representative samples were selected using multivariate analysis and cluster analysis. Through the questionnaire survey, the sensory image of SUV front view contour was screened to obtain pairs of representative images. Using semantic difference method to conduct perceptual image research and analysis of representative samples. According to the analysis results, the correlation models of perceptual images and related design variables are obtained. The effectiveness of the model is verified by the existing model design of the market. The conclusion proves that there is a correlation between the consumer's emotional image and the position of the SUV front-view contour feature point. The coordinates of the forward-looking contour control point of the design scheme are brought into the relevant consumer image correlation model, and the optimal image is obtained under the image. The design scheme improves the success rate of the front face design of the SUV.

1. Introduction
Modern product design centers on user expectation [1], based on human cognition, targeted the external form of the product, takes the consumer's perceptual image preference as the goal, and finally products that meet consumer expectations are designed [2]. In the design of automobile, whether the front face of a car meets the expectations of consumers has become an important factor in attracting consumers [3]. Chen Lingyan [4] analyzed the potential visual rules in the front face of the car and the organizational relationship among the various modeling elements from the Gestalt principle. McCormack et al. [5] used shape grammar to describe the continuity and evolutionary characteristics of Buick's front-face brand modeling genes. Focusing on the side and front face of the car, Zhu Wei et al. [6] established the mapping model of brand image and shape from the perspective of brand image. Based on the deductive Kansei Engineering theory, Li Shaobo et al. [7] qualitatively analyzed the mapping relationship between consumers' emotional image and the elements of automobile front face modeling. Deng Jianwei [8] obtained the contour shape by the feature matching theory experiment, which is the...
most obvious feature of consumers’ cognition style. The existing related studies mostly focus on the continuity of automobile modeling development from two aspects of consumer image or brand gene. However, designers often propose multiple design schemes for the same design task in the actual modeling design activities, and there is still a lack of a rational method to determine the consumer image and select the most appropriate scheme. Therefore, this paper combined parametric Kansei Engineering and Computer Aided Industrial Design (CAID) technology to find an effective forward-looking design choice method by analyzing the correlation between consumer image and SUV front-face modeling variables.

The conceptual expression of the designer and the modeling principle of computer graphics are based on the modeling feature line [9]. The modeling feature line in the SUV front-view modeling element includes the most information at the "minimum cost". Zhao Danhua [10] extracted 20 modeling feature lines, including the outline of the front face, the front windshield, the hood, the grille, the headlamp and the fog lamp, which have abundant morphological connotation information and the structure constraint information related to the modeling through the induction and classification of the feature lines. The expressions and meanings of these feature lines are essentially the same. The conclusion drawn from the study of one feature line which contains the most information can also be extended to other feature lines [11]. Through the questionnaire survey of professional designers, this paper explored the information contained in the forward-looking styling elements of the above six SUVs. The survey included a total of 50 students, including 40 graduate students majoring in industrial design and 10 automobile styling designers. Each respondent can select one or two of the six options that are considered to contain the most information. The results showed that 85% of the respondents believed that the forward-looking outline contained the most information on the front view angle of the car. The choice of grille and headlamp was 60% and 50% respectively, and the other options were all below 20% without consideration. The influence of grid and headlight on the shape is reflected in the mutual positional relationship and the change of its structure [6], which is difficult to describe with the characteristic line. Therefore, the SUV front view outer contour line was selected as the research object.

2. Research methods

2.1. Numerical definition of the sample

In the description of the styling, both qualitative and qualitative methods were used. This study used a more precise description of the digital method. In the digitalization of automobile modeling, Bézier curve can fully describe the change of shape with fewer points, simplify the data processing. By numerically defining the modeling curve, the shape curve can be transformed into a Bézier curve controlled by the curve anchor point (expressed as \(H_i, i = 1, 2...n\)) and curvature control point (represented as \(C_i, i = 1, 2...n\)), and then into a shape curve with the feature point coordinates as design variables, as shown in Fig. 1.

![Figure 1. Two expressions of styling feature lines](image-url)
In order to show the actual size of the sample and the position of the feature points, the sample was scaled by 1:25 scale and a two-dimensional standardized coordinate system was established. In this paper, the midpoint of the front bumper outer edge line was taken as the coordinate origin. Taking into account the consumer's perception of the SUV's forward-looking shape in real life, and following the principle of univariate design, the sample was added to the same rear-view mirror and tire alignment, as shown in Figure 2.

![Figure 2. Haval H6 front view outline Bézier curve expression](image)

The outer contour was defined numerically according to the description of Bézier curve, that was, the coordinates of the feature points on the line were marked. The forward-looking shape of an automobile was symmetrical, and only one side of the feature line needed to be defined. The numerical definition consisted of 8 curves, 23 points and a total of 42 variables in clockwise direction. \(H1x, C13y, H9x\) and \(H9y\) were constant terms and would not be studied.

2.2. Selection of representative samples

In order to ensure the validity of the research and the extensiveness of the sample, we selected the front-view picture of the SUV model with the domestic sales volume, including 85 models of more than 30 brands of domestic and joint ventures, and the actual size data were attached. The sample screening process was shown in Figure 3.

![Figure 3. Sample screening process](image)

Firstly, the KJ method was used to understand the differences between the subjects' perceptions of the appearance of the SUV's external contours. It was necessary to take the outline part of the sample as a silhouette processing in order to facilitate the subject's perception of the contours. The subjects of this experiment were composed of 50 industrial design students trained in modeling design, including 28 graduate students and 22 undergraduates. Subjects were asked to categorize the silhouettes of 85 samples according to their subjective feelings, and to divide the pictures into 10 to 14 groups according to their
personal feelings. In the light of the classification result, the dissimilarity matrix between the samples was calculated, and the sample dissimilarity matrix was passed through the multivariate scale method to understand the relationship between the samples and the sample and the whole. By changing the spatial dimension, the optimal spatial configuration was selected. The analysis results were shown in Table 1.

**Table 1.** Stress value and RSQ value of spatial configuration of each dimension

| Dimension | Dissimilarity matrix | Dimension | Dissimilarity matrix |
|-----------|----------------------|-----------|----------------------|
|           | Stress               |           | Stress               |
| 2         | 0.33242              | 5         | 0.12345              |
| 3         | 0.23031              | 6         | 0.09452              |
| 4         | 0.17098              |           | 0.69954              |
| 5         | 0.12345              |           | 0.78456              |

When the dimension was 6, the Stress value was less than 0.1, the RSQ value was greater than 0.85, and the conformity between the configuration space and the sample difference relationship can be accepted. Therefore, the space of 6 dimensions was selected to illustrate the difference relationship between the samples. The coordinates of samples in 6-dimensional space were taken as variables to carry out hierarchical cluster analysis, and the cluster tree structure was obtained. The samples were divided into 14 groups according to the number of clusters and the structure of tree graph. Fourteen averaging automobile samples were obtained according to their respective coordinates and the sum of points to points. As representative samples of the 85 samples, they were uniformly represented by the letter M. The representative sample front view outer contour line design variables were shown in Table 2.

**Table 2.** Represents sample front view contour quantization coordinates

|          | H1y   | C1x   | …    | C13x  |
|----------|-------|-------|------|-------|
| M1       | 144.04| 21.59 | …    | 27.77 |
| M2       | 141.06| 21.6  | …    | 27.67 |
| …        | …     | …     | …    | …     |
| M14      | 141.35| 22.91 | …    | 42.14 |

2.3. **Selection of perceptual Image Vocabulary**

From the relevant automotive networks, newspapers, books, etc., a total of 200 perceptual imagery words describing the SUV shape were collected. After choosing words with similar meanings and properties by focus group method, 12 pairs of words were obtained by matching the remaining words with antonyms. In order to reduce the experimental load of the subjects, the samples were divided into six groups by cluster analysis of tree graph structure. Six averaging samples were obtained according to coordinates, and a questionnaire survey was conducted with 12 pairs of image vocabulary to produce a 7th-order Semantic Difference (SD) scale. The average score matrix of perceptual evaluation was obtained. The subjects were 20 students majoring in industrial design, including 8 undergraduates and 12 postgraduates. The perceptual evaluation matrix was factored and three common factors were extracted to explain 86.78% of the variance. The contribution of the factors was 42.67%, 28.36%, 13.74% respectively, and the ratio was 3:2:1. The factor loading between each factor and the perceptual image is shown in Table 3.
Table 3. Perceptual image lexical factor load

|                     | Ingredient 1 | Ingredient 2 | Ingredient 3 | Ingredient 1 | Ingredient 2 | Ingredient 3 |
|---------------------|--------------|--------------|--------------|--------------|--------------|--------------|
| complex - concise   | -1.068       | 0.634        | -0.198       | -0.486       | 0.477        | 0.072        |
| personality - Popular | 0.968       | 0.311        | -0.076       | 0.226        | 0.307        | -0.189       |
| Leisure - business  | -0.904       | -0.489       | 0.226        | -0.177       | 0.276        | 0.844        |
| novel - conservative| 0.680        | -0.728       | 0.394        | 0.049        | 0.653        | -0.630       |
| Compact - Handsome  | -0.651       | 0.3819       | -0.182       | -0.012       | -0.062       | -0.286       |
| Dynamic - Solemn    | 0.515        | -0.949       | 0.394        | 42.67%       | 28.35%       | 13.74%       |
| Home-off - road     | 0.501        | 0.929        | 0.453        | Cumulative contribution 42.67% | 71.02% | 84.76% |

In order to select perceptual images more objectively, the factor load of 12 pairs of perceptual images in Table 4 was analyzed by hierarchical cluster analysis, and the perceptual image was divided into 6 groups according to the tree structure, according to the contribution ratio, 3, 2 and 1 perceptual images were selected from the three components, and the vocabulary selected was not in the same group. The final sensible imagery vocabulary was: leisure-business, home-off-road, personality-popular, dynamic-Solemn, tough-round.

2.4. Research on Sensual Images of Representative Samples

Questionnaire survey was conducted by making 14 representative samples and 6 pairs of representative sexual vocabulary words into a 7th-order semantic difference (SD) scale. In order to ensure the reliability of the survey, before the formal questionnaire survey, the reliability analysis of the questionnaire was carried out first, that was, the same person was surveyed twice by the same questionnaire, and the consistency of the two survey results was checked. The subjects were 30 students majoring in industrial design. The analysis result α coefficient value was 0.892, which was greater than 0.8, indicating that the questionnaire was reasonable and can be used.

The questionnaires were distributed simultaneously through the network and offline. A total of 60 copies were distributed, 55 questionnaires were retrieved, 3 questionnaires were scored without discrimination, and 52 valid questionnaires were obtained. 36 of the subjects had a design background and 16 had no design background. The questionnaire was 86.7% efficient. The perceptual assessment matrix of the average scores of 14 representative samples in 6 pairs of perceptual images was shown in Table 4.

Table 4. Inductive evaluation matrix of representative samples

|                     | home-off road | complex - concise | dynamic - solemn | tough - round | personality - popular | leisure - business |
|---------------------|--------------|-------------------|------------------|--------------|-----------------------|-------------------|
| M1                  | 4.91         | 3.05              | 4.64             | 4.68         | 4.91                  | 3.50              |
| M2                  | 4.64         | 3.05              | 4.77             | 4.18         | 5.45                  | 3.45              |
| …                   | …            | …                 | …                | …            | …                     | …                 |
| M1                  | 4.68         | 4.64              | 4.80             | 4.64         | 4.80                  | 4.68              |
2.5. Relevant Analysis of Consumer Image and Form Design Elements

The image adjective is defined as dependent variable and the shape design variable as independent variable, and the relationship model between them is established through regression analysis. Before regression analysis, correlation analysis is needed to test whether there is a correlation between independent variables and dependent variables. Taking the perceptual image vocabulary "popular" as an example, there were 12 morphological design variables which had significant correlation with "popular" image, as shown in Table 6.

| Table 5. "popular" image related analysis results |
|--------------------------------------------------|
| popular | Pearson Correlation Coefficient | popular | Pearson Correlation Coefficient | popular | Pearson Correlation Coefficient |
| C2x     | -0.711**                         | C5x     | -0.849**                         | C10x    | -0.779**                         |
| H3x     | -0.837**                         | C6x     | -0.744**                         | C11x    | -0.877**                         |
| C4x     | -0.893**                         | H5x     | -0.742**                         | C11y    | -0.626*                          |
| H4x     | -0.969**                         | C9y     | -0.715**                         | C13x    | -0.745**                         |

*Significantly at 0.05; ** Significantly at 0.01.

The larger the absolute value of Pearson coefficient is, the more correlated it is, the positive correlation is greater than 0, and the negative correlation is less than 0. The results showed that the variables were significant at 0.05 and most were very significant at 0.01. The correlation analysis of other vocabulary and design variables showed that there was a correlation and regression analysis can be performed. The study used linear multiple regression analysis, see formula (1):

\[ Y_i = \alpha + \beta_1 X_1 + \cdots + \beta_k X_k + \epsilon_i \]  

In formula: 
- \( Y_i \) — dependent variable;  
- \( \alpha \) — intercept;  
- \( \beta_1 \ldots \beta_k \) — regression coefficient;  
- \( X_1 \ldots X_k \) — Independent variable;  
- \( \epsilon_i \) — Uncertainty factor error.

In this study, since the variable was a perceptual image vocabulary, the independent variable was the horizontal and vertical coordinate values. Stepwise multivariate regression analysis was carried out on the data of tables 2 and 5. The results of the analysis are shown in Table 6.

| Table 6. Multiple regression analysis results |
|-----------------------------------------------|
| regression coefficient | home-off - | tough - | dynamic - | personality - | complex - | leisure - |
| \( \beta \) | road | round | solemn | popular | concise | business |
| C1x     | 1.420** | -2.171** | -0.991** | -1.231* | 2.211* | 0.914** |
| C2x     | 1.674** | 0.318* | 0.681* | -0.850* | -0.865* | -0.908* |
| H4y     | -1.564** | -3.311** | -1.038** | \( \) | -2.798* | -0.341** |
| H5x     | -0.840** | 0.211* | -1.982** | 2.200* | 0.164* | \( \) |
| C7x     | 1.438** | 2.579* | -3.485* | -1.482** | \( \) | \( \) |
| C8x     | 1.285** | -2.449** | -1.720* | 3.052* | -0.980** | \( \) |
| C9x     | -0.955* | \( \) | \( \) | \( \) | \( \) | \( \) |
| C10y    | 2.870** | -4.944** | -1.190** | -2.876* | 4.708* | -0.421* |
| C11y    | \( \) | 1.305** | -1.385* | \( \) | -1.670** | \( \) |
| H8x     | -0.815* | 1.534** | -0.413* | 2.762* | 1.794** | \( \) |
| H8y     | 1.496* | -1.426** | -1.660** | \( \) | \( \) | \( \) |
| C13x    | -0.697* | \( \) | \( \) | \( \) | -0.335* | \( \) |
| Constant | 4.339 | 23.238 | 28.098 | 8.148 | 7.606 | 6.240 |
| Adjusted R² | 0.819 | 0.862 | 0.898 | 0.876 | 0.920 | 0.974 |
3. Result Analysis

It can be seen from Table 7 that the explanatory power of the vocabulary "popular" is $R^2=0.876$, which indicates that the model has a high degree of fitting with the data and has reference value. The explanatory ability of other vocabulary $R^2$ is above 0.8, indicating that the analysis results are credible. The normalization coefficient $\beta$ indicates the degree of influence of the independent variable on the dependent variable. The larger the absolute value of $\beta$, the greater the influence on the perceptual image. The positive beta value is positively correlated with the negative correlation. According to the results of regression analysis, it is possible to construct an association model between the perceptual image and the corresponding design variables. These models can compare the perceptual image intensity of the design according to the design variables.

"Popular" imagery = $-0.1231 \times (C1x) - 0.85 \times (C2x) + 0.681 \times (C3x) - 1.982 \times (H5x) + 2.579 \times (C7x) - 1.720 \times (C8x) - 2.876 \times (C10y) - 1.385 \times (C11y) + 2.762 \times (H8x) + 8.148$  
"Off-road" imagery = $1.420 \times (C2x) - 1.564 \times (H4y) - 0.840 \times (H5x) + 1.285 \times (C8x) + 2.870 \times (C10y) - 0.815 \times (H8x) + 1.496 \times (H8y) - 0.697 \times (C13y) + 4.339$  
"Round" image = $-2.171 \times (C1x) + 1.674 \times (C3x) - 3.311 \times (H4y) + 1.438 \times (C7x) - 2.499 \times (C8x) - 0.955 \times (C9x) - 4.944 \times (C10y) + 1.534 \times (H8x) - 1.426 \times (H8y) + 23.238$  
"Solemn" image = $-0.991 \times (C1x) + 0.318 \times (C3x) - 1.038 \times (H4y) + 0.211 \times (H5x) - 1.190 \times (C10y) + 1.305 \times (C11y) - 0.413 \times (H8x) - 1.660 \times (H8y) + 28.098$  
"Concise" imagery = $2.211 \times (C1x) - 2.798 \times (H4y) + 2.200 \times (H5x) - 3.485 \times (C7x) + 3.052 \times (C8x) + 4.708 \times (C10y) + 7.606$  
"Business" image = $0.914 \times (C1x) - 0.865 \times (C2x) - 0.908 \times (C3x) - 0.421 \times (C10y) - 1.670 \times (C11y) + 1.794 \times (H8x) - 0.335 \times (C13x) + 6.240$  

When the perceptual image of "popular" is enhanced, the independent variable C1x decreases, point C1 moves left; C2x decreases, point C2 moves left; C3x increases, point C3 moves right; H5x decreases, point H5 moves left; C7x increases, point C7 moves right; C8x decreases, point C8 moves left; C10x decreases, point C10 moves left; point C11 moves left; H8x increases, point H8 moves right.

4. Method Verification

In order to verify the validity of the model, two models of Harvard H6 and Harvard H6coupe were selected to verify the model. Taking the image of “Solemn, popular, and round” as an example, regression analysis showed that the variables associated with these three images are C1x, C2x, C3x, H4y, H5x, C7x, C8x, C9x, C10y, C11y, H8x, H8y. The front view contours of these two models were numerically defined, the 12 variables were extracted, and the correlation models of three images were input respectively. The results showed that the image of Haval H6 was greater than Haval H6coupe in the “Solemn, popular, and rounded” image, and Market feedback was consistent. The other three image models were also validated by the same model, and the results showed that the model was effective. It was proved that this method can be applied to determine the consumer image and choose the design scheme of the front face of multiple SUVs.

5. Conclusion

Through the numerical definition of the front view of popular models in the domestic SUV market and the perceptual image survey of representative samples. Correlation analysis was used to prove that the shape of the SUV front-view outline was related to the consumer image. Finally, the validity of the model was verified by analyzing the market case. In this paper, a method of defining feature lines from point coordinates was proposed to determine the optimal design scheme under a specific image. Due to the diversity of consumer image and the complexity of automobile design, some non-linear analysis methods can be used to further improve the study of the relevance of modeling and imagery.
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