# Research on the Style of Product Shape Based on NURBS Curve

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**Abstract.** To further study on the relationship between users' perception of style image and product shape features, a research method of product feature image based on the NURBS curve was proposed. The experimental study was conducted with the example of goblet. Firstly, the key control points impacting the shape features were extracted and a plurality of products 3D models were constructed. Secondly, five representative products and three key images were selected by the methods of hierarchical clustering and factor analysis. Then, the Kansei Engineering evaluation system of goblet was established, with which the subjects conducted Semantic Differential experiment for a thirty-three products with different shapes, and the data were analyzed by multiple regression analysis as well. Finally, the mapping model between the control points and Kansei images was constructed and its reliability was verified. This mapping model accurately reflected the relationship between the various control points and different style images, this research method can be applied to the modelling design of other products, which can help the designers grasp the product style accurately. This paper would play an important guiding role on product development and creative design.

**Keywords:** Style image · Shape features · NURBS curve · Semantic Differential

## 1 Introduction

As the key of emotional cognition of product design, style image becomes an important factor in the consumer markets, and it is of great significance to industrial product design [1]. In recent years, the perceptual technology based on semantic difference method has been widely used [2–5]. McCormack carried out a detailed method to evaluate the style of different kinds of industrial products [6]. Demirbilek discussed the key role of product characteristics and user emotions during the process of design [7]. Huang et al. studied the application of perceptual technology in aided product design system and developed a prototype system about self-adaptive product design on modularity [8]. Analysis plays a significant role during product design. Belaziz analyzed product shape by Kansei words and presented a form of features based tool to aid the integration of analysis during the design process [9].


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Besides, in previous Kansei Engineering studies, many researchers generally employed the concept of "items" and "categories" to develop a qualitative description of the overall product form in terms of its basic design features. Jindo describes the research and development work done on a design support system intended for use as a support tool in designing office chairs. Subjective evaluations were conducted using the semantic differential (SD) method to examine the relationship between users' personal assessments of office chairs and design elements [10]. Lai presented a new approach to determining the best design combination of product form elements for matching a given product image represented by a word pair. Grey relational analysis (GRA) model was used to examine the relationship between product form elements and product image [11].

However, the research of style image perception mostly stays on the entirety of products, lacking the study of points and lines which are the basic components of a product.

## 2 Background

In this paper, we studied the mapping mechanism between initial points and goblet style image based on NURBS curve. Firstly, the key control points impacting the shape features were extracted and a plurality of products 3D models were constructed. After that, five representative products and three key images were selected by the methods of hierarchical clustering and factor analysis. Then, the Kansei Engineering evaluation system of goblet was established, with which the subjects conducted Semantic Differential experiment for a thirty-three products with different shapes, and the data were analyzed by multiple regression analysis method. Finally, the mapping model between the control points and Kansei images was constructed and its reliability was verified.

The research of product design showed that lines are the key factor to determine the final shape of product. Therefore, we can control the shapes of product by adjusting the structural points which compose those lines. We took the shape of goblet as an example. According to the basic features and the design standard of goblet, the 3D models of goblet was created by 3D software and the NURBS curve was extracted as well. Figure 1 shows the nine control points which determine the shape of goblet. As the figure shows, P1, P2, P3 and P4 mainly control the shape of goblet head, while P5, P6 and P7 mainly control the shape of goblet body and P8 and P9 mainly control the shape of goblet foot. Obviously, these control points in the two-dimensional space are defined by X axis and Y axis. Any change of X or Y coordinates could lead to the change of product modeling.

## 3 Method

### 3.1 Create 3D Models

We invited five designers who have experience of more than six years of product design to adjust those nine control points to create a number of different goblet samples

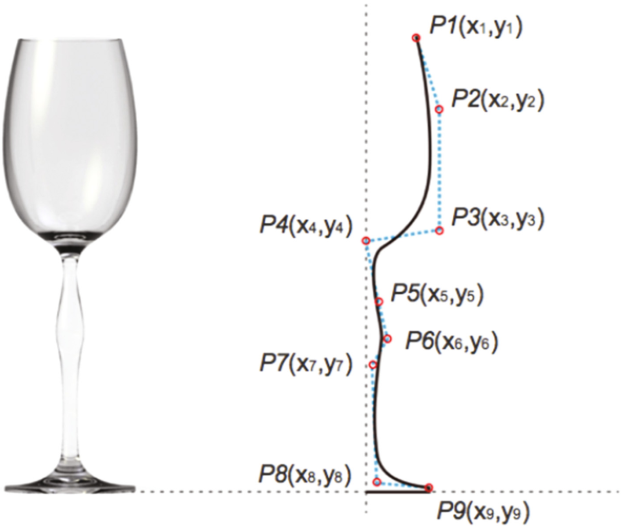



**Fig. 1.** The NURBS curve and control points of goblet

based on the numerical definition of the generic goblet form presented in Fig. 1. Five designers created total of fifty-nine 3D models with Rhinoceros 4.0 software developed by McNeel company. Figure 2 shows the total of thirty-three goblet samples we used in the experiment. User's image perception would be affected by different factors such as shape, texture, color, light, scene etc. [12, 13]. In order to exclude the influence of other factors we rendered those samples by applying the same color and texture in one scene.

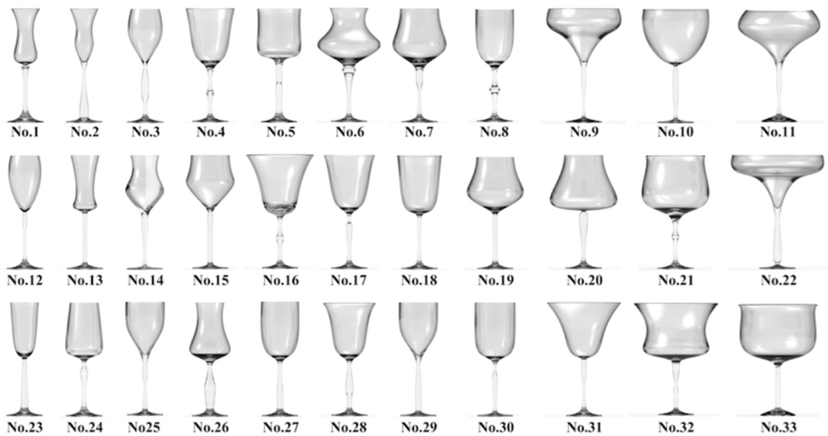



**Fig. 2.** The goblet samples used in the experiment

### 3.2 Select Appropriate Product Samples

Hierarchical Clustering was used to select appropriate product samples among so many models. As a result, all the samples were classified into five different groups and five representative samples were selected according to the Euclidean Distance. Figure 3 shows that No.29 was selected as the representative sample in the first group, No.16 was selected as the representative sample in the second group, No.23 was selected as the representative sample in the third group, No.11 was selected as the representative sample in the fourth group, and No.7 was selected as the representative sample in the last group.

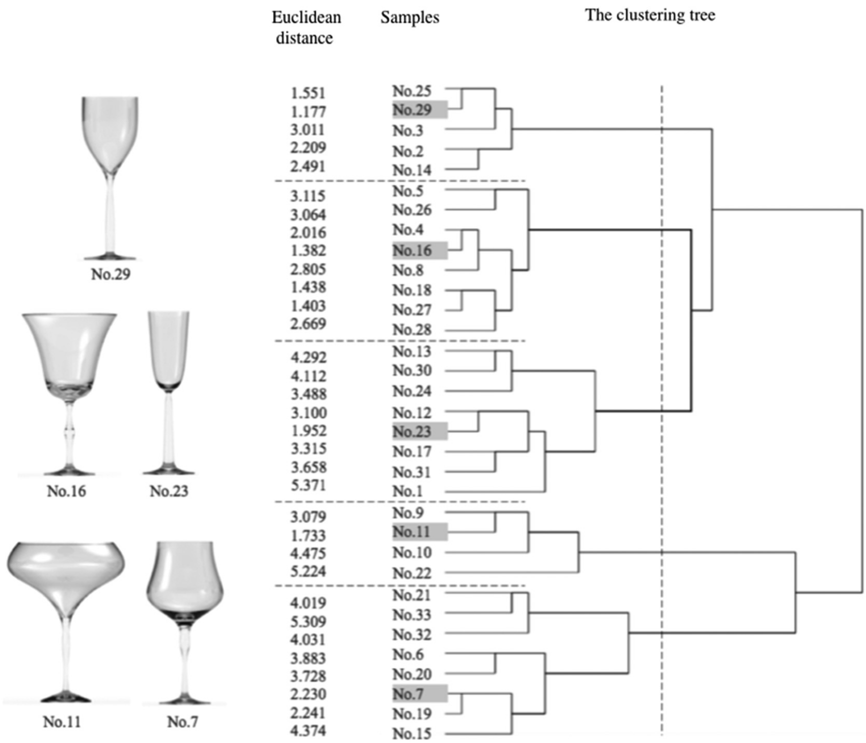



**Fig. 3.** Representative samples of five groups

### 3.3 Select Appropriate Product Image Descriptors

Consumers commonly use simple adjectives to express their perceptions of a product's image. As a result of consumers' personal values or preferences, these adjectives can provide an explicit representation of users' emotional response to a product's form [15]. Therefore, approximately one hundred adjectives in Chinese pertaining to goblets' form were collected from websites, magazines, papers and books. These adjectives were then sieved and twenty-six product image descriptors remained. As Table 1 shows, finally, the method of Principal Component Analysis was used to classify twenty-six adjectives into three style imageries (feeling of delicacy, feeling of unique and feeling of modern).

**Table 1.** The explained variance of 26 image descriptors

| Product image | Factor A | Factor B | Factor C |
|---|---|---|---|
| *Feeling of delicacy* | | | |
| Luxury | **0.953** | 0.237 | 0.103 |
| Fancy | **0.869** | −0.214 | 0.430 |
| Kingly | **0.816** | 0.116 | 0.339 |
| Ordinary | **−0.829** | −0.527 | −0.176 |
| Metabolic | **0.900** | 0.114 | 0.421 |
| Dexterous | **−0.901** | −0.056 | −0.168 |
| Emotional | **0.922** | 0.207 | 0.326 |
| Elegant | **0.932** | −0.635 | 0.139 |
| Simple | **−0.982** | −0.172 | 0.077 |
| Dynamic | **0.864** | 0.008 | 0.476 |
| Passionate | **0.929** | 0.356 | −0.006 |
| Gentle | **0.765** | −0.231 | 0.465 |
| *Feeling of unique* | | | |
| Individual | 0.293 | **0.955** | 0.025 |
| Innovative | 0.224 | **0.945** | 0.219 |
| Exaggerated | 0.340 | **0.933** | −0.031 |
| Odd | 0.144 | **0.914** | −0.373 |
| Fresh | 0.455 | **0.881** | −0.125 |
| Solemn | −0.524 | **−0.847** | 0.065 |
| Lovely | 0.102 | **0.788** | 0.583 |
| *Feeling of modern* | | | |
| Modern | −0.424 | 0.171 | **0.811** |
| Popular | 0.342 | −0.420 | **0.840** |
| Rounded | 0.455 | −0.088 | **0.726** |
| Refined | 0.212 | −0.477 | **0.697** |
| Powerful | −0.418 | 0.044 | **−0.893** |
| Plump | 0.556 | −0.220 | **0.760** |
| Classic | 0.573 | 0.450 | **−0.643** |
| **Explained variables** | **45.25%** | **29.23%** | **22.11%** |
| **Total explained variables** | **45.25%** | **74.48%** | **96.59%** |

## 3.4 Image Perception Evaluation of Goblet Form

Thirty-six graduate students who major in product design were invited to evaluate all the thirty-three samples by the three style imageries in Kansei Engineering Evaluation System. As Fig. 4 shows, participants only need to observe the form of goblet model on the left side of the system interface, and then select a proper value of each image which represent their emotional response to the product's form. The data of each product sample data will be recorded automatically.


**Fig. 4.** Goblet Kansei engineering evaluation system

**Table 2.** Results of multiple linear regression analysis

| Product form image | Unstandardized coefficients | Standardized deviation | Standardized coefficients | P value | Tolerance | Variance inflation factor |
|---|---|---|---|---|---|---|
| Delicate constant | 5.144 | 0.555 | | 0.000 | | |
| X2 | −0.382 | 0.066 | −0.914 | 0.000 | 0.450 | 2.223 |
| X3 | −0.186 | 0.049 | −0.476 | 0.001 | 0.727 | 1.376 |
| Y3 | 0.197 | 0.051 | 0.488 | 0.001 | 0.698 | 1.432 |
| X5 | −1.064 | 0.417 | −0.352 | 0.017 | 0.598 | 1.671 |
| X7 | −0.867 | 0.389 | −0.263 | 0.035 | 0.818 | 1.223 |
| Y8 | 1.243 | 0.510 | 0.325 | 0.022 | 0.638 | 1.567 |
| Unique constant | −1.945 | 0.253 | | 0.000 | | |
| X1 | 0.428 | 0.122 | 0.647 | 0.002 | 0.433 | 2.322 |
| X2 | −0.434 | 0.113 | −0.809 | 0.001 | 0.533 | 3.006 |
| Y3 | 0.369 | 0.074 | 0.712 | 0.000 | 0.730 | 1.370 |
| Y5 | 0.205 | 0.101 | 0.258 | 0.043 | 0.912 | 1.096 |
| X6 | 1.212 | 0.423 | 0.381 | 0.008 | 0.832 | 1.202 |
| Y8 | 1.811 | 0.729 | 0.369 | 0.020 | 0.668 | 1.497 |
| Modern constant | 7.229 | 1.115 | | 0.000 | | |
| X1 | −0.214 | 0.057 | −0.406 | 0.001 | 0.803 | 1.246 |
| Y2 | −0.144 | 0.070 | −0.228 | 0.041 | 0.789 | 1.268 |
| X3 | −0.116 | 0.047 | −0.289 | 0.021 | 0.687 | 1.456 |
| Y3 | 0.183 | 0.042 | 0.443 | 0.000 | 0.907 | 1.103 |
| X5 | −0.814 | 0.373 | −0.262 | 0.038 | 0.659 | 1.518 |
| X6 | −0.871 | 0.269 | −0.343 | 0.003 | 0.846 | 1.181 |

## 4 Results

Multiple linear regression is a generalization of linear regression by considering more than one independent variable, and a specific case of general linear models formed by restricting the number of dependent variables to one. It was used to explain the linear relationship between independent variables and dependent variables. The data presented within the Unstandardized Coefficients (UC) column of Table 2 can be used to construct functional models relating the design variables of the goblet form to an evaluative rating in each of the three product image perception domains. As Table 2 shows, X2, X3, Y3, X5, X7 and Y8 significantly affected the feeling of delicacy, X1, X2, Y3, Y5, X6 and Y8 significantly affected the feeling of unique, and X1, Y2, X3, Y3, X5 and X6 significantly affected the feeling of modern. The functional models for each product image perception domain can be formulated as follows:

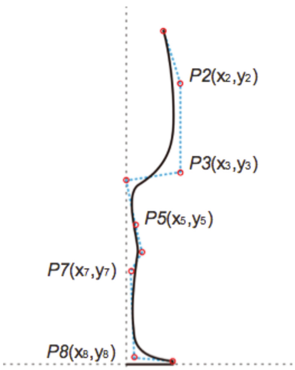
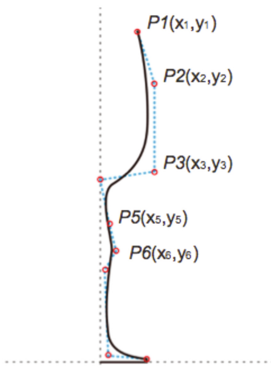
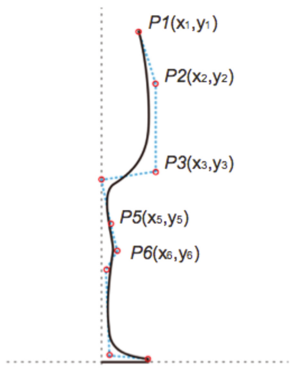
"Delicate" image = 5.14-0.382X2-0.186X3+0.197Y3-1.064X5-0.867X7+1.243Y8

"Unique" image = -1.945+0.382X1-0.434X2+0.369Y3+0.205Y5+1.212X6+1.811Y8

"Modern" image = 7.229-0.214X1-0.144Y2-0.116X3+0.183Y3-0.814X5-0.871X6

Finally, as Table 3 shows, the mapping model between control points of NURBS curve and product style image was built, which means we could change specific control points to change the style image of goblets.

**Table 3.** The mapping relationship between control points and image

| Form image | | |
|---|---|---|
| **Delicate** | **Unique** | **Modern** |
|  |  |  |
| With the decrease of $X_2$ $X_3$ $X_5$ $X_7$, the feeling of delicate increases. | With the decrease of $X_2$, the feeling of unique increases. | With the decrease of $X_1$ $Y_2$ $X_3$ $X_5$ $X_6$, the feeling of unique increases. |
| With the increase of $Y_3$ $Y_8$, the feeling of delicate also increases. | With the increase of $X_1$ $Y_3$ $Y_5$ $X_6$ $Y_8$, the feeling of delicate also increases. | With the increase of $Y_3$ , the feeling of delicate also increases. |

## 5 Conclusion

We proposed a numerical modelling method to define the mapping relationship between product form and style image. Taking goblets as example, we built the mapping model between the control points of NURBS curve and product style image. This model can accurately reflect the influence of each style image in the process of product modelling. It is also applicable to other product design area. This method can help designers to grasp better product style, which plays a crucial role in product development field.

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