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CMP Appearance Modeling Design Taking Into Account Virtual Reality

Sanders Onesmus

Yousef Haj-Ahmad Department of Engineering, Faculty of Mathematics and Science, Brock University, 1812 Sir Isaac Brock Way, L2S 3A1 St. Catharines, ON, Canada

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Abstract: Styling design is a very important part of construction machinery product (CMP) design process, which is one of the important factors to improve the market competitiveness of CMPs, and is also the external embodiment of the connotation of CMPs. Because the manufacturing industry ignores the in-depth discussion on the appearance of CMP design, which affects the market competitiveness of CMPs. Therefore, this paper takes product styling design as an effective means of competition among engineering machinery manufacturing enterprises, plays the role of virtual reality (VR) technology in industrial product styling design, takes excavator appearance styling design as an example, uses cluster analysis and factor analysis to extract excavator styling style, and then can develop a styling design plan that meets market demand according to excavator styling style.

1. Introduction

With the rapid development of industrial manufacturing industry, China's construction machinery industry is undergoing a critical transformation period. The future trend of CMPs is to establish intelligent factories of construction machinery with high adaptability, high resource efficiency, harmonious human-machine collaboration and human aesthetic requirements. This requires not only the development of new CMP technology, but also the optimization of CMPs in appearance and shape design [1]. The effective connection between technology and artistic shape is one of the development and requirements of today's time.

Foreign countries attach great importance to CMP modeling, and computer technology and VR technology were introduced into the product design process at an early stage, which essentially improves the product modeling aesthetics. VOLVO and CATERPILLAR, for example, although their technology and production process and its functions have undergone great changes, their early product modeling design elements and basic modeling have been used to date, and it is worth

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studying [2]. There are still some problems to be solved in the domestic construction machinery, the construction machinery industry in order to be able to catch up with the market progress, thus speeding up the manufacturing pace of enterprises, eliminating some necessary forms and proportional push link, making the low quality of modeling design. However, with the development of technology, technology transparency triggered by the serious homogenization of products, making technology is no longer the only factor related to product success or failure. Therefore, the appearance of CMP modeling design is increasingly important in the increasingly fierce market competition, should have attracted the great attention of major enterprises [3-4]. Although there is relatively little research on styling design using scientific methods in China, foreign research experience has passed opportunities for China's machinery manufacturing enterprises.

In this paper, we first analyze the application value of CMP appearance modeling in many perspectives such as the function and technical level of the product, then apply VR technology to CMP modeling design and put forward four basic elements of product modeling design; finally, we determine three design schemes according to the appearance modeling design style of such products as excavators.

2. Product Modeling Design

2.1. CMP Appearance Modeling Analysis

The appearance modeling of CMPs is an energetic process, reflecting the function, technical level, socio-economic and cultural connotation of the product as a whole [5]. From the perspective of product function, product shape reflects the external shape required by functional structure; from the perspective of product technology level, product shape reflects the operation mode and material process limited by product technology level; from the perspective of social economy, product shape reflects user demand and market trend; from the perspective of cultural connotation, product shape reflects user aesthetics and social background [6-7]. China's construction machinery industry has formed an important industry with a wide range of product categories, which can basically meet the domestic market demand and partly radiate the international market, and has a certain scale and market potential.

2.2. Cluster Analysis Method

The process of dividing a collection of abstract objects into similar objects is called clustering [8]. Assuming that the center of clustering is represented by the distance between data points xi and xj, then for any data point xi local density e_i is defined as

$$e_i = \sum_{j \in \boldsymbol{I}_S \setminus \{i\}} \lambda(d_{ij} - d_n) \tag{1}$$

$$\lambda(x) = \begin{cases} 1, x < 0 \\ 0, x \geq 0 \end{cases} \tag{2}$$

Where d_n denotes the truncation distance, d_{ij} denotes the distance between samples i and j, and λ denotes the clustering function.

In this paper, we use the cluster analysis method to extract the engineering machinery product

samples, and the sample products with high similarity are clustered into one category, and then the clustering results are used to find the representative samples of each group category, which are the product samples we want to extract [9].

3. Application of VR in Mechanical Product Modeling Design

3.1. Application Status

VR technology-aided industrial design software system is a platform system that provides automated support for industrial products from the product concept design stage process of product morphology design, color design, decoration, human-machine environment, etc. It is one of the effective tools to support innovative product design, and in recent years VR technology-aided industrial design technology has become one of the hot spots of innovation design and styling design research today [10-11].

3.2. Design of Product Appearance Modeling Elements Based on Virtual Reality Technology

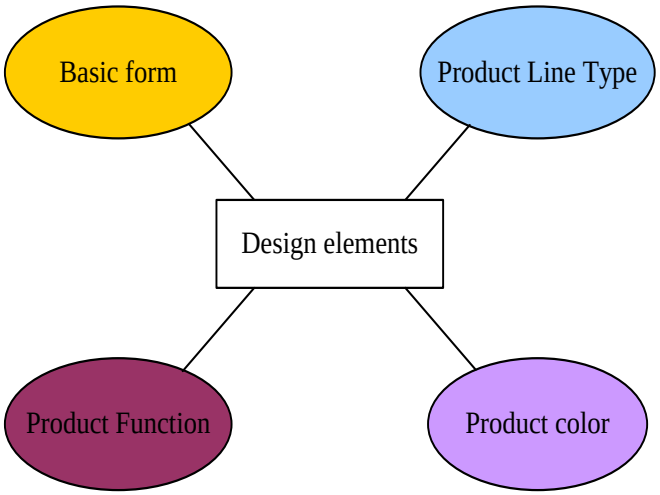


Figure 1. Design elements

This paper with the help of VR technology can simulate the design process of CMP appearance modeling, during which it is necessary to will pay attention to the four design elements of the product, as shown in Figure 1.

(1) the basic form

Most of the forms of CMPs are based on geometric forms, combining flat shapes with three-dimensional shapes. Take excavator as an example, triangle, quadrilateral, three-dimensional circle, three-dimensional quadrilateral, etc. become the main shapes that can constitute the product, and are applied to each part of the product, forming a beautiful and simple shape, the structure of the complete CMPs. The parts together play the working performance of the product and increase the geometric three-dimensional sense and mechanical texture of the product [12].

(2) Product line shape

The form of CMPs has its common characteristics, and with the development of manufacturing technology and consumers' aesthetic interests, the form of CMPs has changed from the past "straight" shape to the shape of curved form. Product form can fully reflect the market needs of

users, such as the popularity of product modeling, corporate style unity, corporate planning concepts and other information. In order to apply the modern design trend elements to the CMPs, so that more products use this large chamfer design techniques, so that the original mechanical hard products look more humane [13]. For example, the mechanical arm and other working devices are not exactly a single linear shape, the use of curved lines at the junction of various parts to transition, get rid of the stiffness of the mechanical arm, giving it flexibility and strength [14].

(3) Product function

In the design of CMPs, the function of the product must always be one of the primary considerations in product design, and must be considered at the beginning of the design on the function and structural characteristics of the product, and it can be judged by looking at its main function according to the use. Excavator is one of the main CMPs in engineering construction, and when people see this product for cognitive judgment, the basic cognitive problem of functionality arises [15]. The basic function of the excavator is composed of several important elements, the most important of which is the excavation function, but the excavation function alone does not constitute a CMP, it must also have a walking function, that is, a crawler walking mechanism or wheeled walking mechanism, and must also have a driving control function, taking into account the above product functions and can fully reflect the various functional attributes of the product in the product modeling design [16].

(4) Product color

CMPs more brightness, lower purity of yellow as the main color, black as a secondary color, play a warning role [17]. High brightness yellow is more distinctive and warm color, the most common excavators in life mostly use yellow as the main color.

4. Excavator Appearance Modeling Design Example Analysis

4.1. Extraction of Representative Excavator Samples

Take the excavator as an example of CMPs, design the appearance of the excavator modeling. In order to simplify the number of samples and obtain the representative excavator samples, the 20 excavator images numbered 01-20 were filtered out by cluster analysis method to find the representative modeling samples. In this paper, the semantic difference method is used to filter the semantic genes that match the styling of CMPs. The semantic difference method usually uses stylistic imagery words related to the research target to depict the image style of the research target, such as "interesting" and "uninteresting", "harmonious" and "noisy", and "noisy". "noisy", "traditional" and "modern", and so on, to describe the stylistic style of excavators from multiple perspectives [18].

(1) Selection of the sample. The sample of this step is 20 excavator pictures and 7 pairs of adjectives describing the appearance of the excavator. The seven pairs of adjectives include "streamlined" and "geometric", "conservative" and "avant-garde", "mass" and "individual", "static" and "dynamic", "traditional" and "modern", "complex" and "simple", and "monotonous" and "varied".

(2) Selection of subjects. The subjects were three industrial design majors and two mechanical graduate students.

(3) Representative excavator sample extraction. Firstly, five subjects were asked to compare 20 excavator samples two by two and score the similarity. The scores were 0-5. Then with a score of 10 as the cut-off point, cluster analysis was performed on the score data using SPSS software, then the 20 excavator samples would be divided into 5 categories. The results are shown in Table 1. The

first category is for samples numbered 03, 08, and 12; the second category is for samples numbered 10, 15, 16, 17, and 20; the third category is for samples numbered 01 and 07; the fourth category is for samples numbered 04, 11, 13, and 19; and the fifth category is for samples numbered 02, 05, 06, 09, 14, and 18. In these five categories of samples, the representative sample numbers are 12, 15, 07, 11, 14. Then these five representative excavator sample pictures were screened and renumbered 01-05.

Table 1. Cluster analysis results

	Sample number	Number of samples	Representative samples
1	03, 08, 12	3	12
2	10, 15, 16, 17, 20	5	15
3	01, 07	2	07
4	04, 11, 13, 19	4	11
5	02, 05, 06, 09, 14, 18	6	14

4.2 Extraction of Semantic Genes for Excavator Modeling

(1) Selection of samples. The 7 pairs of adjectives representing stylistic styles and 5 representative excavator samples derived above.

(2) Selection of subjects. Ten subjects were selected, five graduate students in industrial design and five graduate students in mechanical engineering who had professional internship experience.

(3) Statistical analysis: The 10 participants rated each of the 7 pairs of stylistic adjectives on a scale of -3 to 3 for each of the 5 representative excavator samples. The mean value was then calculated by each respondent's rating of the stylistic style semantics for each sample, as shown in Table 2.

Table 2. mean values of stylistic style semantics

	01	02	03	04	05
Streamline-Geometry	2.3	1.5	-0.6	0.9	1.2
Conservative-Avant Garde	-1.3	-2.4	1.6	2.7	0.5
Volkswagen - Individuality	-1.8	2.1	0.9	1.2	1.7
Static - Dynamic	-2.5	-0.3	1.4	2.5	2.6
Traditional - Modern	-2.5	2.7	-1.1	-2.0	1.4
Complexity - Simplicity	2.8	-2.6	-2.2	1.6	0.5
Monotonous-variation	1.6	1.3	2.4	0.7	-2.8

The semantic genes representing the excavator styling style were selected by using factor analysis, and the mean values of the styling style semantics in Table 2 were input into SPSS software for factor analysis, and then the 7 pairs of styling style semantics were simplified. The results are shown in Figure 2, and there are 2 factors with factor eigenvalues greater than 1.

According to the analysis of SPSS software, the analysis of stylistic style semantic factor loadings, whether positive or negative, the larger the absolute value, the higher the correlation with that factor. As shown in Table 3.

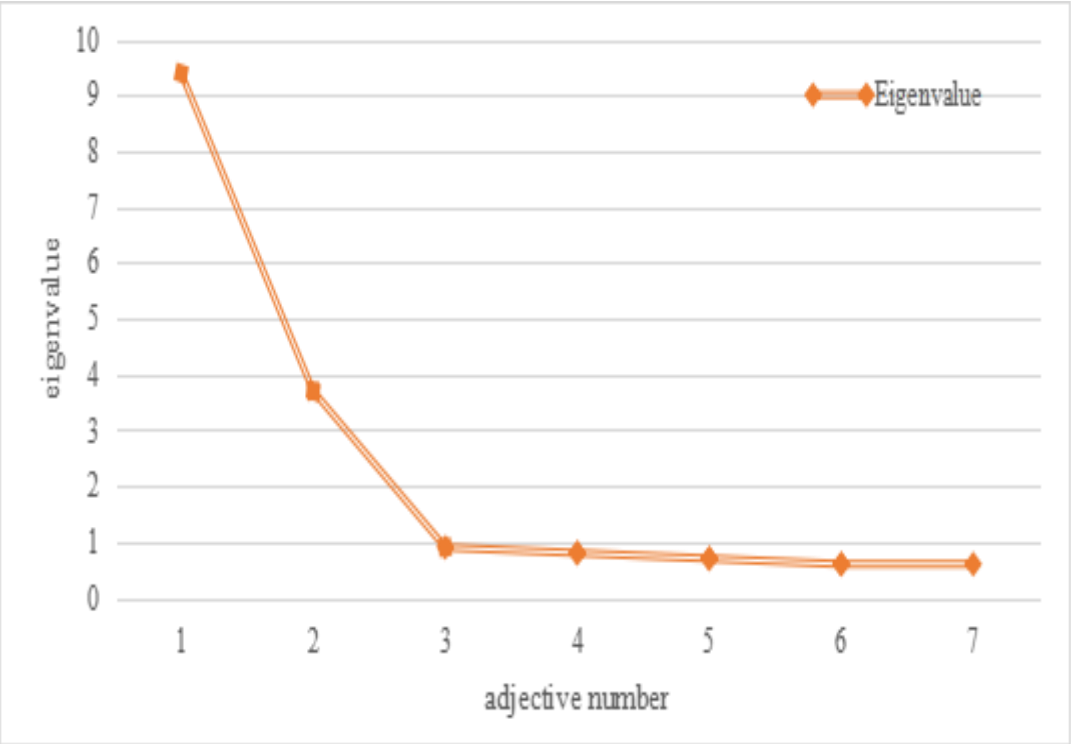


Figure 2. Factor steep slope diagram

Table 3. Factor loadings analysis

	01	02
Streamline-Geometry	0.972	-0.351
Conservative-Avant Garde	-0.956	0.533
Volkswagen - Individuality	0.427	0.345
Static - Dynamic	0.815	0.406
Traditional - Modern	0.528	-0.257
Complexity - Simplicity	0.374	0.962
Monotonous-variation	0.629	0.938

According to the results in Table 3, it can be seen that the semantic factors with absolute values of loadings over 0.9 are streamlined-geometric, conservative-avant-garde, complex-simple, monotonous-variable, so the excavator can be designed according to these stylistic descriptions.

4.3 Excavator Appearance Modeling Design Scheme

According to the above analysis of excavator modeling style, this paper gives three excavator appearance modeling design options, respectively, as follows.

Program one mainly adopts the geometric line of straight lines, upright, hard and straight, the whole vehicle is mainly yellow, the cab is gray, supplemented by local gray color band. The position of the heat dissipation grille is determined by the C line, which is the golden line of the power unit, so the horizontal ratio between the heat dissipation grille and the rest of the power unit

is 0.618; the heat dissipation grille is divided into two parts, A and B, and the ratio of the height of A and B is close to the golden ratio. The cab split line extends out to be tangent to the front of the track and the top of the power unit, and is proportional to the slope of the top of the cab. Cab handles are mostly diamond-shaped and triangular, reflecting the flexibility of the cab.

Option 2 adopts the geometric lines of horizontal straight lines and oblique tangent lines, forming a hard and strong, angular design style. The whole vehicle is mainly yellow, and the body is supplemented by a partial gray color band. The front handrail of the cab is designed with an external hitch, which not only meets the functional requirements, but also echoes the geometric form of the cab fender handrail. The cab is connected diagonally to the outer cut rectangle, the cab and the power unit are designed with integral steel plates, the upper part of the cab is widened backward, and the power unit forms a golden section rectangle.

Scheme three has a rounded overall shape and better visual stability. The body adopts strong and powerful arc shape, making the side shape vivid and tense. The outer cab front handle is in line with the visual balance, and the inner cab handle is diamond-shaped, which not only meets the functional requirements but also gives flexibility to the form; the connection between the cab and the fuselage is natural and smooth, which reduces the visual center of gravity of the cab and gives people a stronger sense of stability. The design of the heat dissipation grille is novel, with grid-like heat dissipation holes designed to improve the effect of heat dissipation, making the shape of the solution not only majestic but also agile.

5. Conclusion

In order to improve the competitiveness of CMPs in the market, the appearance and design of CMPs can not simply rely on imitation design, can not always stay in the shape of dull, single tone of the public perception, but to keep up with the requirements of the development of the times, understanding the user's psychology, the use of industrial design ideas and methods, using the theoretical basis of modeling design, from the perspective of CMPs "shape" and "meaning", to explore the theoretical methods suitable for CMP modeling design, to create a diversified form and rich connotation of CMPs.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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