

# Computer-Aided Innovative Design of Appearance Modeling Based on Virtual Reality Human-Computer Interaction

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Abstract. Product shape design is a process of innovative design and optimal combination of product form, color, material, decoration and other elements according to certain requirements. It plays a very important role in the process of modern product innovation and development. With the emergence and development of computer application, art of design, artificial intelligence, cognitive psychology and other disciplines, the digital intelligent product modeling design system combining these disciplines has become a new research hotspot. Based on the analysis of computer-aided industrial product design, this paper constructs the framework of virtual reality human-computer interaction appearance modeling system from the perspective of appearance modeling. A new method of collaborative product appearance design based on virtual reality is proposed, and the overall structure of virtual reality design environment is given. The computeraided design model of collaborative appearance modeling under human-computer interaction is built, and the best design scheme is obtained through humancomputer interaction in virtual environment, and the design parameters are determined by knowledge description transformation again. The experimental results show that the realization of the system illustrates the modular product appearance design method, the system function test, performance test, verify the feasibility of the model.

**Keywords:** Virtual reality; Human-computer interaction; Computer-aided design; CAD

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#### **1 INTRODUCTION**

The wide application of computer technology in various fields, together with other components, creates the digital environment. The application of virtual reality technology creates a real environment similar to the real environment. Virtual reality technology is a comprehensive technology produced by the combination of human imagination and electronics, etc. It uses multimedia computer simulation technology to constitute a special environment, and users can naturally interact with this environment through various sensing systems [1]. In the digital environment, what the experience sees and feels is a thing constructed with digital virtual, and people's vision, hearing, taste, touch and other senses can be fully mobilized to obtain quite real feelings. The expression of virtual reality is beyond the reach of traditional artistic techniques. On the basis of intuition, it greatly expands the refraction of the artist's inner world and breaks through the surface perception of the experience for art. Digital environment achieves its goals from different perspectives with the help of a variety of devices, and users get deep experience and feelings during the use, which deepens people's understanding and thinking about artistic works [2]. VR technology has been widely used in many aspects. Through this technology, people can receive information in multiple dimensions, gain new sensory experience, truly appreciate the charm of the virtual world, and guide the public to explore deeper cultural treasures.

Human-computer interaction is a way of communication. The interaction of virtual reality art works integrates all the previous comprehensive interactive experience of human beings, including interactive experience, original interaction, tool and symbol interaction, interface interaction after the emergence of computers, and extended gesture, sound and motion sensing interaction. Virtual reality technology enables people's real environment and virtual environment to interact in a natural state. After users enter the virtual environment from the real environment, they can get all the experiences in the real environment in the virtual environment with the help of virtual reality technology brings a new perspective to observe and understand the "new world". In the process of interaction, the interactive content is digitally summarized and exported with the help of computer, so as to get the feeling of observation perspective, and based on this, the creation is carried out to obtain the demand of the public.

# 2 RELATED STUDIES

Computer-aided modeling design can effectively and comprehensively show the characteristics of industrial design products [4]. Generally speaking, industrial product modeling design refers to free surface design and sketch design. Sketch design and freeform surface design represent the main design research of computer-aided modeling technology, product modeling is people's intuitive understanding of the product, modeling determines business opportunities. Han et al. [5] proposed a method of product appearance design based on feature parts, which divided product appearance according to function, and used CAD to gather different functional units together to realize the diversity of product appearance design, evaluate different appearance, and get the design scheme that meets the designer's requirements. Huang et al. [6] comprehensively utilizes various virtual reality software and hardware technologies to build a simulation system for realtime human-computer interaction between human and virtual operation objects. Liu et al. [7] divided the knowledge in the process of product appearance design from the perspective of knowledge reuse, so as to obtain designers' design knowledge and users' demand knowledge. On this basis, the product appearance knowledge reuse prototype system is built and the design scheme is obtained. The design efficiency of this method is high, but it relies too much on prior knowledge, and the obtained results cannot meet the requirements of users. Kim et al. [8] proposed a Java-based product appearance design method, and introduced the appearance Synth that can change the skin into the product appearance design system, which can realize the product appearance design without programming. The design effect of this method is good, but the cost is

high. Dong [9] used the method of feature modeling to realize the parametric modeling of the disk body and the rapid parametric modeling of the overall structure, which is convenient for users to design and modify and provides an effective tool for users' design and processing.

Product design process is a complicated and uncertain reasoning process, which is widely used and involves most fields. Virtual reality human-computer interaction design is not only the promotion of industrial design, but also the new focus of product design research. In order to effectively realize personalized product appearance design, it is necessary to adopt a design method that is easy to change. The fundamental purpose of CACD system is to effectively support the innovative design of products.

#### 3 COMPUTER-AIDED DESIGN OF COLLABORATIVE APPEARANCE MODELING BASED ON VIRTUAL REALITY HUMAN-COMPUTER INTERACTION

#### 3.1 The Overall Architecture of Virtual Reality Design Environment

With the continuous progress of software and hardware technology related to virtual reality technology. The integration of product development, design and evaluation under virtual environment has become a hot issue in academia and industry. Whether the conceptual design can meet the needs of target users and guide the trend of consumption popularity. The most convenient method is to use a "seeing by seeing" surface or model. The research mainly includes two aspects: one is the modeling of object/scene; The second is the visualization of product concept. The development of VR technology provides a new way of human-computer interaction. 3d interaction, tactile perception, speech recognition, gesture recognition and other technologies can all be applied in conceptual design. The key to providing a multi-channel product appearance design in virtual reality environment is to shape the virtual environment for product model work. The overall structure of the designed virtual reality environment is shown in Figure 1.



Figure 1: Virtual reality design environment overall architecture diagram.

Virtual reality environment by virtual reality technology shaping 3D environment, access to 3D image reconstruction results through CAD technology for product appearance design, virtual reality technology was used to optimize the point cloud distribution of three-dimensional point cloud data field intensity, can design the model into a virtual reality environment, to adjust product appearance related parameters, After the designer gets the satisfactory design scheme, he can

exit the virtual reality environment and feedback the final design data to the CAD system, so as to realize the product appearance design.

#### **3.2 Computer-Aided Design of Collaborative Appearance Modeling Under Human-Computer Interaction**

CACD system will develop in the direction of digitization, centralization and network. The interaction will be more natural, enabling users and designers and design teams to participate in product innovation cooperatively and efficiently on the same platform; The conceptual design stage will be seamlessly integrated with other design stages, which will play an important role in the improvement of design efficiency, innovation and humanization of solutions in the process of product design. In the virtual environment, when the computer cannot effectively simulate human intelligence, it is necessary to combine man-machine interaction and cooperate with virtual reality technology to realize the design of product appearance [10]. Therefore, a collaborative product appearance modeling design method under human-computer interaction is proposed. The product appearance modeling design process is regarded as a computer-aided constraint judgment and solution process, and its functional model is shown in Figure 2.



Figure 2: Functional model diagram of human-computer interaction appearance.

In the design of product appearance, a large number of data sets are provided by output to people. The computer is mainly responsible for solving the scheme conforming to the constraints, and the complicated calculation work is handed over to the computer to deal with. Various data and analysis results are provided through the system and algorithm. The decision-making work is handed over to the designer, so that they can work together to design the appearance of the product and obtain the best design scheme.

# 3.3 Human-Computer Interaction System Framework for Virtual Reality

In view of the data acquisition, model construction and display, human-computer interaction and security control required by human-computer interaction and computer-aided system in virtual reality environment, this paper proposes a computer-aided framework model of human-computer interaction in virtual reality environment, as shown in Figure 3. Logically, the framework model includes four layers: system layer, logic layer, user layer and data layer. There are certain logic or business interaction relationships among these layers, and each layer contains several security

control mechanisms and methods, forming a complete set of human-computer interaction logic architecture system in virtual reality environment.



Figure 3: Computer aided framework model for human - computer interaction in virtual reality environment.

The system layer refers to the system software running on top of the hardware layer. It is the middle core layer of human-computer interaction and computer control system framework model in virtual reality environment. The main functions include data acquisition, communication management, model driven, 3D display, system security management, etc. The logical layer is the business logical relationship of the system. This layer mainly includes logic control of business process, data processing and algorithm optimization. The main modules are instruction execution, data processing, business interaction and so on.

# 3.4 Select Key Function Modules

Each function module, according to the size of its size, the different working range of motion and other factors, its impact on the overall appearance of the model is also different. Such as the detection module (sensor), its size is very small, the impact on the layout of the ability is very small, so it can be basically ignored. Therefore, before the module layout design, it is necessary to evaluate the influence of each functional module on the modeling, and select the most influential modules for layout design. Here the fuzzy comprehensive evaluation method is used to find the influence weight of each module on the layout.

Introduction comment set =[deep influence, deep influence, medium influence, not deep influence, no influence], and the values are x, respectively. Its positioning level vector C=y.

The evaluation matrix is determined as formula 1.

The appearance modeling is developed, and realized. In the data acquisition phase, data is obtained from the application and submitted to the application for final use by a high-level language programming interface. After data collection, 3D display is carried out. In the way of pre-modeling, 3D is used to draw the 3D model of elements. In order to realize wide-angle three-dimensional display and make people have a sense of immersion in the virtual reality environment, a 3D display system is developed based on VR display.

The research and development of pre-modeling technology, model 3D display technology, control command and communication technology have been equipped with the components of human-computer interaction and remote-control system in virtual reality environment. The integration of various technical elements constitutes a complete appearance and modeling system with a strong sense of three-dimensional and immersive, and the various functions of the system are verified by experiments. The appearance and modeling system integration of human-computer interaction in the established virtual reality environment is shown in Figure 4. The system is composed of data acquisition, model, 3D display, 3D interaction and other functional modules.

The data acquisition module and the communication module are connected by data cache file. The data acquisition module writes data to the data buffer file continuously, and the communication module reads data from the data cache file continuously. Communication module and model loading are connected to 3D display module and interactive module through data cache file. According to the same connection mode, the data collected by the visual data acquisition module is passed to the model loading and 3D display module through the cache file and communication module. The model loading and 3D display module loads the model according to the data of the cache file, builds the scene and displays it through the display hardware device.

$$\mathbf{R} = \begin{bmatrix} \mathbf{r}_{1} & \cdots & \mathbf{r}_{32} \\ \cdots & \cdots & \cdots \\ \mathbf{r}_{101} & \cdots & \mathbf{r}_{132} \end{bmatrix}$$
(1)

The method of expert scoring was adopted to obtain  $r_{ij}$ . K experts scored the evaluation level of each indicator respectively. It was assumed that there was one  $W_1$ -level comment in  $W_{I1}$  and two  $W_2$ -level comments in  $W_{I2}$ . The average value is given in formula 2.

Determination of weight vector A: As the influence degree of each module is different, the weight

VIRTUAL REALITY INTERACTIVE APPEARANCE MODELING SYSTEM INTEGRATION

$$\mathbf{r}_{ij} = \frac{\mathbf{W}}{\mathbf{k}} \tag{2}$$

After sorting out the scores of K experts, the evaluation matrix can be obtained:

vector is determined according to the influence degree of each module.

4

4.1

AND TESTING

Integration

 $\mathbf{R} = \begin{bmatrix} x_1 & \cdots & x_1 + 1 \\ \cdots & \cdots & \cdots \\ y_1 & \cdots & y_1 + 1 \end{bmatrix}$ (3)



**Figure 4:** The appearance modeling system integration diagram of human-computer interaction in virtual reality environment.

# 4.2 Virtual Reality Human-Computer Interaction Appearance Modeling System Integration

VR technology needs to be realized through computer technology, including simulation environment, perception, natural skills and sensing equipment data processing, and many other functions. The CPU of the PC is AMD FX-8350, the memory is 8 GB, the hard disk is 200 GB and the graphic display is HKC P4000 23.8-inch computer monitor. The core display card of THE VR system hardware is equipped with NVIDIA GeForceGTX1080Ti, DRAM of 11 GB, video memory bit width of 352-bit, core frequency of 1 480/1 733 MHz, and video memory frequency of 11 000 MHz. The desktop virtual environment uses Windows 10. The industrial simulation software Vega developed by Multi Gen-Paradigm of the United States is adopted as the system support platform. The development language is Visual C#. The 3d solid modeling software is Auto CAD.

#### 4.3 Functional Test

Login test the use case: Enter only the username, enter the correct user name and incorrect password, enter the correct general rights user name and password, and enter the administrator user name and password. The operation of 100 users is simulated, and the test results of the login interface of the system through use cases are shown in Figure 5.



Figure 5: The login page of the system passes the test result.

After the login interface of the system passes four use case tests, the measured results are consistent with the expected results. Because the system is divided into several modules, the system is statistically analyzed and described, and no abnormality is found in the test results. With the increase of the number of users browsing application forms, the system throughput has little change, that is, the number of requests processed by the server per minute is stable; The average value changes greatly, that is, the server's time for each request changes greatly. With the increase of the number of simultaneous users, the server's time for processing each request becomes longer, and the longest time is within 2s, which is within the acceptable range of users. The deviation value gradually increases with the increase of simultaneous login users, and the data distribution is uneven, which represents the change of system stability.

#### 4.4 Performance Test

The stress test is to test the response time and the carrying capacity of the system when the system accesses concurrently when the access volume exceeds the normal. The following is the test of the number of concurrent users. Under the premise that the software and hardware of the system are running normally, the system response time is obtained by testing the operations of different numbers of users, and the data is analyzed and counted, so as to infer the main test function points and result records of the system function test, as shown in Figure 6.



Figure 6: Main test function points and result record diagram of system functional test.

In the process of system test, under the condition of less concurrency, the system runs smoothly without adverse reactions. Under the condition of high concurrent access, the system still runs stably. The bearing capacity test is one of the important factors for system stability. It reflects the interface and function of the system, and the prompt information is comprehensive and has a certain carrying capacity.

Performance test is an important index to evaluate a software. Among the performance requirements, stability, support capacity and security are important, and the environment in which the module is operated in the system needs to be evaluated. In the process of performance testing, the impact of test environment and test data should be excluded first. Different test environment and test data will cause different interference to the performance of the application system. In the

performance test, each performance was tested in detail, mainly testing data collection, model and 3D display, AND 3D interaction. The performance test results are shown in Figure 7.

The test results show that the overall design test of the software system, the test of each module of the system and the program coding test are stable and reliable. The system design adopts the security technology with high reliability, the system structure design is reasonable, each module has a high degree of correlation, the code coding is correct, the operation is smooth, with stability, and meets the design requirements.



Figure 7: Performance test results.

# 5 CONCLUSION

With the development of information technology, the consumption concept of society is changing constantly, and the function of products is no longer the most important factor for consumers to decide to buy. More and more attention has been paid to the innovation, appearance, agreeableness, environmental protection and other factors of the products, which occupy a prominent position in the competition. Computer-aided design (CAD) can effectively combine the different functional characteristics of computers and humans. To construct the framework of virtual reality interactive appearance modeling system; A new method of collaborative product appearance design based on virtual reality is proposed, and the overall structure of virtual reality design environment is given. The computer-aided design model of collaborative appearance modeling under human-computer interaction is built, and the best design scheme is obtained through human-computer interaction in virtual environment, and the design parameters are determined by knowledge description transformation again. In the virtual reality technology, the user participates in the environment method to perform the task, realizes the interaction of the environment in the process of completing the task, and senses the virtual reality environment through special tools. A CAD method for the innovative design of product appearance and modeling is explored.

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