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Virtual Reality Visualization Customization Platform for Construction Machinery Products Based on Parametric Design

Aditya Ijaz

Department of Mechanical Engineering, Balochistan University of Information Technology, Engineering and Management Sciences (BUITEMS), Airport Road, Baleli, Quetta, Balochistan, Pakistan

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Abstract: Construction machinery products are bulky and complex in structure, which makes many difficulties in the process of product customization. The development of parametric design brings great convenience to product design and greatly improves the efficiency of product research and development. In order to solve the shortcomings of the existing research on the virtual reality visualization customization platform for construction machinery products, this paper discusses the parametric design function equations and the visualization and virtual reality feature parameterization of construction machinery products. The development tools and product configuration of the virtual reality visualization customization platform are briefly discussed. And design and discuss the process structure of the virtual reality visualization customization platform for construction machinery products proposed in this paper, and finally apply the virtual reality visualization customization platform for construction machinery products designed in this paper to mixing equipment, paver, and road roller in the collected highway engineering projects. Experimental test with dump truck mechanical products. The experimental data show that the parametric design achieves an average accuracy of about 95.7 in the configuration of product functions and prices in construction machinery products mixing equipment and paver, while the accuracy of product functions and price configuration in construction machinery products road rollers and dump trucks is about 95.7. The accuracy averages around 96.2. Therefore, it is verified that the virtual reality visualization customization platform for construction machinery products based on parametric design has good performance effects.

1. Introduction

The advancement of parametric technology can promote the improvement of the visualization

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level of the manufacturing industry, and can improve the scalability of the virtual reality visualization customization platform for construction machinery products. Parametric technology has become an important way to reduce product production costs.

Nowadays, more and more scholars pay attention to the research of various computer technologies and system tools in the virtual reality visualization customization platform of construction machinery products, and through practical research, they have also achieved certain research results. The purpose of Mahillo A is to design an IoT visualization-based customization platform for additive manufacturing products, creating a method for product customization that evolves from traditional construction machinery product customization to fully integrated virtual reality and parametric technology. This approach utilizes consistent products from market demand to design and develop factory product production to suit customer needs. The method utilizes virtual reality technology to control the sequence of operations and product designs of individual developments in a product factory setting. And use cloud computing storage, access and visualization technology to automate product configuration, and propose a method that can check the shape and size of products, which reduces the waste of product materials [1]. The heterogeneous and interdisciplinary technologies used by Kraft M provide an efficient platform for custom product development. It also describes the customization, configuration and development of DP method in automotive products to improve the scalability of traditional product customization platforms. Kraft M has developed a tool called Design Product Platform Manager to support visualization of custom platforms for automotive products. The Design Product Platform tool connects to the Product Data Management database. Finally, the design product tool was evaluated to improve the specific product application, and the expected effect was achieved [2]. Kraft M introduces a visualization for online luxury customization and implementation via a semi-immersive (VR) platform. The aim is to experiment with product models using techniques that vary in effectiveness, safety, and through perceived experience variables, to test the effect of the approach on luxury customization. The effects of product customization and user-customized products' individual requirements on the effect of this method are also tested. Data shows that perceived experience and value have a significant impact on the platform's performance [3]. Although the existing research on the virtual reality visualization customization platform for construction machinery products is very rich, the virtual reality visualization customization platform for construction machinery products based on parametric design still has certain limitations.

Therefore, in order to enrich the existing research on the virtual reality visualization customization platform for construction machinery products, this paper first introduces the parametric design function equation and the concepts of construction machinery product visualization and virtual reality feature parameterization, and then discusses the construction machinery product virtual reality proposed in this paper. The sample data, development tools and product configuration of the realistic visualization customization platform, and finally the process structure of the virtual reality visualization customization platform for construction machinery products based on parametric design is designed. The mechanical products in the highway engineering project are tested experimentally, and the final experiment shows the effectiveness of the virtual reality visualization customization platform for construction machinery products designed in this paper.

2. Virtual Reality Visualization Customization Platform for Construction Machinery Products Based on Parametric Design

2.1. Visualization of Construction Machinery Products

Traditional construction machinery products are order-oriented customization methods, and customers cannot see the real products customized. With the development of virtual reality technology, it is possible to visualize and customize network virtual 3D products [4]. The visualization requirements for customization of construction machinery products are mainly reflected in the following three aspects:

(1) Visualization requirements of custom objects

The structure of construction machinery products is complex, and it is simply displayed to customers with text or two-dimensional pictures, and it is difficult for customers to clearly identify the details of the product [5]. In the visualization of 3D products, information such as text and explanation of product performance can also be added, so that customers can customize products according to their real needs on the customization system [6].

(2) Visualization requirements of customized interface after the customer selects and completes the customized requirements, the system presents a 3D visualization product [7]. Therefore, considering the characteristics of a wide variety of construction machinery products and complex structures, the requirements for custom interface visualization are put forward for the construction machinery customization system [8].

(3) Visualization requirements of the display environment Construction machinery products are closely related to the working environment [9]. The displayed environment is close to the actual virtual scene, and the scene model is constructed by using virtual reality technology, and then the necessary lights and textures are added [10].

2.2. Virtual Reality Feature Parameterization of Construction Machinery Products

Using the idea of feature parameterization in the design process of virtual products, a product digital model with feature parameterization can be established [11]. When the user's design index changes, the characteristic parameterized design of virtual products has the following characteristics:

(1) It is suitable for product design with well-defined working principle and basic functions, for multi-variety, small batch or single-piece production and rapid response to market demand. Therefore, it has the characteristics of small design innovation space, but a very high degree of design automation [12].

(2) The product design knowledge is mature, has a relatively fixed and effective problem decomposition structure, and has previous successful design experience. Therefore, it has the characteristics that the design knowledge is not general enough, but the design of the domain-specific products is highly relevant [13].

The main parameters of product characteristics can be extracted according to the performance index, manufacturing cost, shape, size and weight required by users, and driven by the main parameters [14]. Design constraints such as standard part selection, manufacturing feasibility and cost are met until each part is described parametrically [15].

2.3. Parametric Design

The qualitative parameters are graded through their description content, and the dissimilarity between the qualitative parameters is given based on the difference of the levels, so as to obtain the overall similarity of the qualitative parameters [16].

(1)For the construction machinery product module IG_t^i and the construction machinery product module family GV^i, the dissimilarity f_a^t between the product parameters CV and IG is obtained according to the above parameterization technology. Similarity between:

$$H^u = 1 - \sum_{a=1}^{G} k_a^{ui} f_a^t \tag{1}$$

Matching product price parameters on the basis of product parameter similarity calculation, so as to obtain the overall product parameter similarity [17]. The calculation formula is:

$$H = H^u - \sum_{j=1}^{d} k_i^{li} \left| \frac{\max(CV_{tj}^{li}) - \min(CV_j^{li}, IG_{tj}^{li})}{\max(CV_j^{lj}, IG_{tj}^{li})} \right| \tag{2}$$

According to the similarity degree H, that is, the degree of parameter matching between the construction machinery product module IG_t^i and the construction machinery product module family GV^i, the closer H is to 1, the higher the matching degree of construction machinery products [18].

(3)Traverse all modules belonging to the construction machinery product module family GV^i in the module library, calculate the product function configuration, set the threshold θ, and take the $q(i)$ functions of the function configuration $H > \theta$ as the matching module set $\{IG_1^i, IG_2^i, ...IG_{r(i)}^i\}$ of the module family GV^i.

(4) Perform the calculation in step (3) for all product configuration module families, for product configuration module families GV^1 to GV^d. Get all matching module sets, namely:

$$V = \{IG_1^1, IG_2^1, ...IG_{r(1)}^1\}, \{IG_1^2, IG_2^2, ..., IG_{r(2)}^2\}, ... \{IG_1^d, IG_2^d, ...IG_{r(d)}^d\} \tag{3}$$

Finally, according to the requirements, a product configuration instance module is selected from each configuration set to form a product design scheme.

3. Investigation and Research on the Virtual Reality Visualization Customization Platform of Construction Machinery Products Based on Parametric Design

3.1. System Development Tools

In order to reduce the difficulty of system development and improve the efficiency of system development, consider the functional requirements and user requirements of the parametric design of the virtual reality visualization customization platform of construction machinery products for system development. Based on C++, Pascal, Script and other languages for programming, Oracle10g is used to organize and manage data. Table 1 lists various tool platforms required for

system development.

Table 1. Development tools

Tool	Function
1Pro/ENGINEER3.0 or above	Virtual Reality Visual Modeling Tool
Pro/TOOLKIT3.0 or above	Virtual Reality Drive Engine Toolbox
racle10g or above	Data Storage and Management
DelphiXE2 or above	Interface Development and Database
VisualStudio2010 or above	Interface Application
Python3.1.2 or above	Script Script Code

3.2. Configuration of Construction Machinery Products

This paper selects a section of highway with a length of 50km, a single road width of 10m, and a planned construction period of 60 days. According to the engineering overview of highway project construction, it can be determined that the required mechanical products include mixing equipment, paver, road roller and dump truck. Combined with the actual engineering volume, the required number of shifts can be determined. According to the unit price of different shifts of different manufacturers, this paper takes the compromise price for calculation. In this paper, two models of each mechanical product are selected for analysis and comparison, such as Table 2 shows:

Table 2. Construction machinery product configuration table

Product Category	Product number	Unit price	Total number of shifts
Mixing equipment	LB3000.	21568.8	16.23
	CCCC XizhuJD5000	24752.5	13.12
Paver	XCMGRP903	2541.3	16.78
	SUPER2100-21P	2635.65	13.25
Roller	STR130-5	242.34	21.9
	XCMGXD82E	185.11	19.24
Dump Truck	30ttruck	725.63	182
	35ttruck	264.94	215

4. Application Research of Virtual Reality Visualization Customization Platform for Construction Machinery Products Based on Parametric Design

4.1. The Overall Structure of the Virtual Reality Visualization Customization Platform for Construction Machinery Products Based on Parametric Design

The construction machinery product customization platform includes two subsystems: the client and the enterprise. It adopts a structural model combining visual customization, parametric design and virtual reality. The overall framework of the construction machinery product virtual reality visualization customization platform is shown in Figure 1:

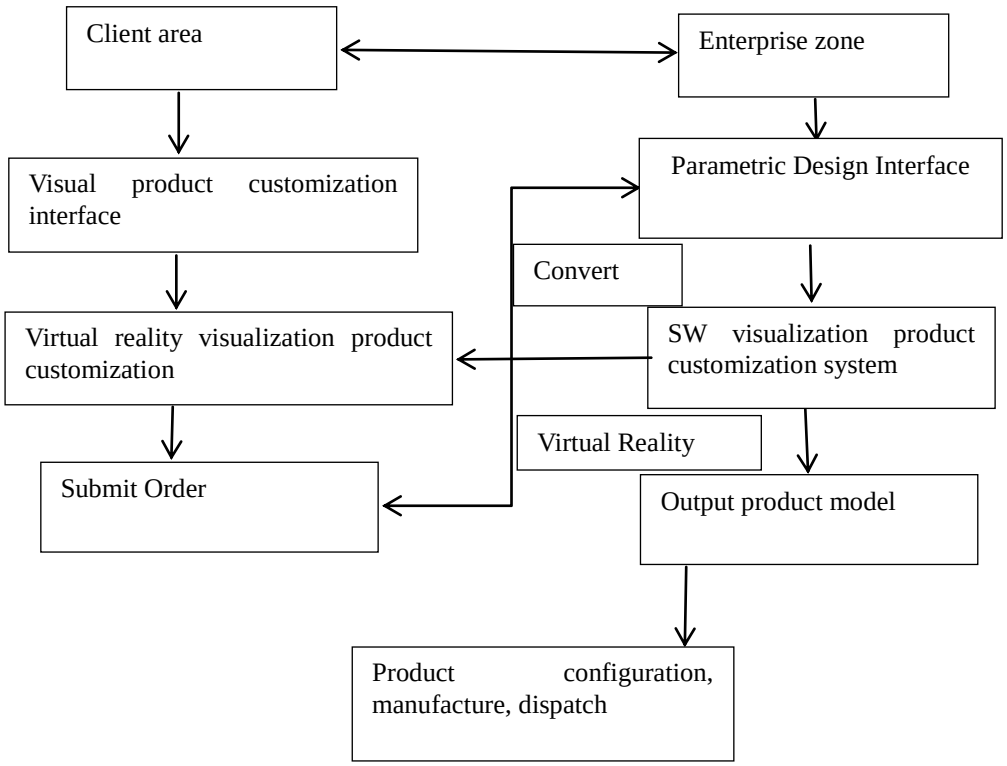


Figure 1. Structure of virtual reality visualization platform for construction machinery products

The specific operation process of the virtual reality visualization customization platform for construction machinery products based on parametric design is as follows:

(1) On the client side, the customer enters the demand information through the visual interface, enters the 3D visualization customization system developed based on the virtual reality platform, and comprehensively checks the performance, structure, appearance and other characteristics of the customized construction machinery products.

(2) On the enterprise side, designers input or import customized related parameters through the parametric design interface, and the parametric design drives the customized new construction machinery products in the developed SW system. Designers design other construction machinery products through the enterprise side according to actual needs.

(3) Import the designed new construction machinery products into the client, and enrich the model library of the client's visualization and customization. The 3D model in the visualization customization subsystem cannot be directly imported from the design system, and it needs to be converted into a format through virtual reality technology, and then add lights and textures to make the virtual products of construction machinery more vivid and realistic.

4.2. Application of Virtual Reality Visualization Customization Platform for Construction Machinery Products Based on Parametric Design

In order to verify the reliability of the virtual reality visualization customization platform for construction machinery products based on parametric design, the parametric design-based product customization platform is compared with the accuracy of parametric function and price configuration of construction machinery products. The mechanical products (mixing equipment,

paver, road roller and dump truck) in the highway engineering project are selected for experimental testing. The specific experimental results are shown in Table 3:

Table 3. Precision data for configuration

Product	Mixing equipment	Paver	Roller	Dump truck
Function	97.1%	94.2%	95.7%	96.8%
Price	95.2%	96.5%	94.9%	97.6%

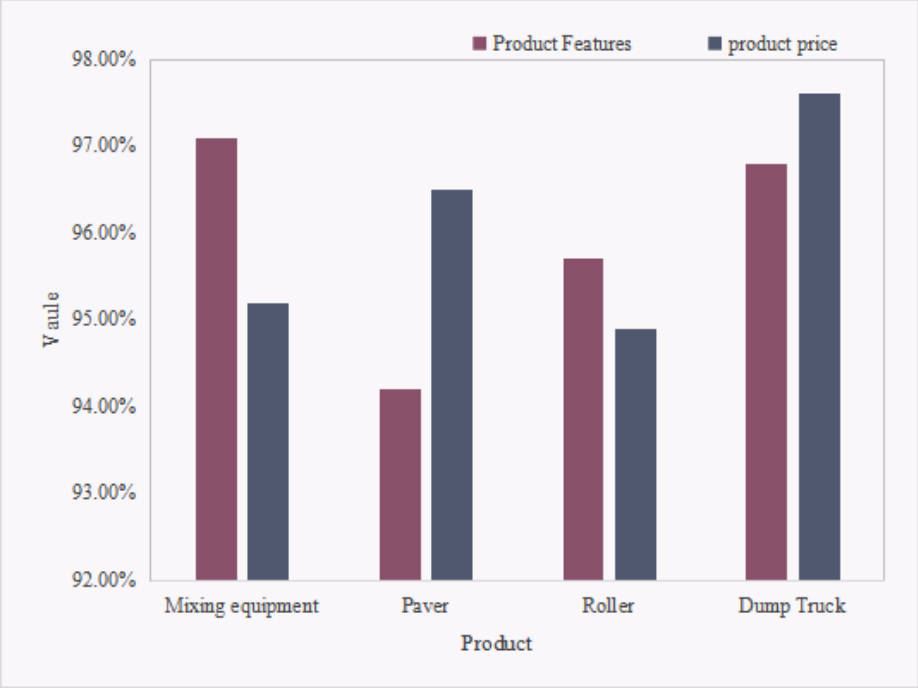


Figure 2. Accuracy comparison of product parameter configuration of construction machinery products

It can be seen from the data of the accuracy of parametric function and price configuration of construction machinery products in Figure 2 that the parametric design of construction machinery products in the virtual reality visualization customization platform for mixing equipment products The accuracy of parameterized function configuration and price configuration reached 97.1% and 95.2%, respectively. The accuracy of parameterized function configuration and price configuration of paver products reached 94.2% and 96.5% respectively. And the accuracy of parameterized function configuration and price configuration of roller products reached 95.7% and 94.9% respectively. The accuracy of parameterized function configuration and price configuration of dump truck products reached 96.8% and 97.6% respectively. From the overall point of view of the above data, the parametric design has high reliability for the product configuration in the virtual reality visualization platform of construction machinery products.

5. Conclusion

This paper specifically expounds the technical basis of the realization of the virtual reality visualization customization platform of construction machinery products based on parametric

design, including the parametric design function equation and the description of the visualization of construction machinery products and virtual reality feature parameterization, as well as the parametric design of construction machinery The development tools of the product virtual reality visualization customization platform and the deployment process of product configuration, and the process framework of the virtual reality visualization customization platform for construction machinery products based on parametric design is emphatically designed. The parametric design is used to test the mechanical products in four highway engineering projects, which proves the practical value of the virtual reality visualization customization platform for construction machinery products based on the parametric design.

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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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