Customization-Oriented Product Flexible Manufacturing Experience System Design Based on VR

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Abstract. It has gradually become the trend of the world to integrate the individualized and diversified needs of customers into products, which has brought new pressure to enterprises, and the diversification of users' needs has led to the diversification of the market. Manufacturing industry must adjust the existing production mode to adapt to these changes. This paper puts forward the research and development of product flexible customization experience system based on VR considering users' customization requirement. Through the research of data modularization modelling and dynamic product family model and configuration for product flexible customization, the functions and operation processes of typical industries are analysed. By using modularization idea, the general rules are found out from customer requirements, and the multi-layer module division and model from production system planning to equipment design are studied. Group coupling technology, explore customer modular customization methods and technologies for equipment manufacturing industry. Combining with a case of customization of logistics equipment system, this paper explores how to combine VR technology application with production system simulation technology, build a digital personalized flexible configuration experience system, provide an immersive visual environment of interactive design for customers, and improve the market competitiveness of enterprises.

1. Introduction

In the industrial 4.0, with the rapid development of information technology and manufacturing technology and the transformation of the world market from relatively closed to increasingly open, the competitive environment of modern manufacturing enterprises has undergone tremendous changes, which are mainly manifested in the progress of modern science and technology and the endless pursuit of products by users, resulting in endless emergence of new products and greatly shortening the market life of products [1]. Customers are no longer satisfied with choosing repetitive standard products provided by enterprises, they want to get diversified products to meet their individual needs. It has gradually become the trend of the world to integrate customers ‘individualized and diversified demands into products, which has brought new pressure to enterprises. At the same time, the diversification of users' demands has led to the diversification of the market. Manufacturing industry must adjust the existing production mode to adapt to these changes [2]. Enterprises place more efforts on customer requests to obtain competitive advantage in global competition. Mass customization (MC) is aimed to give customers exactly what they want with low-cost, high-quality in ever changing environments.

Due to the influence of the above factors, the survival environment and competitive environment of enterprises have changed fundamentally, and the traditional production mode, management mode and technical means have been difficult to adapt to these changes. In this case, manufacturing enterprises show a series of problems in participating in market competition. The investigation of enterprises shows that under the information environment, manufacturing industry is facing the increasing
proportion of multi-varieties and small batches in production due to the shortening of product life cycle and the increasing demand of customers’ individuation and diversification [3]. Traditional product design technology expresses the final result of product production activities, and there is no large amount of design knowledge and enterprise resources hidden in these results. Full description and mining. In the process of transformation from small variety and mass production mode to multi-variety and small and medium batch production mode, manufacturing enterprises are facing increasingly international market competition and diversified customer demands because of the inherent characteristics of products and the limitations of management and production modes formed by manufacturing enterprises for a long time, the poor flexibility of manufacturing systems and the increasing backlog of inventory funds. Enterprises are unable to provide high-quality, low-cost and customer-satisfied personalized products to the market in time, resulting in the lack of competitiveness and flexibility in the fierce market competition and poor market adaptability. Customer co-design and customer specified manufacturing are often performed in MC systems and make-to-order (MTO) or build-to order (BTO) processes are often utilized [4-6]. In view of the significant changes in the external environment of the above manufacturing enterprises, this paper develops a VR-based flexible customization experience system aiming at mass customization of products.

2. Related works
A flexible manufacturing system (FMS) is a computer controlled manufacturing system which consists of a limited set of resources and is capable to process multi-types of parts. Typical applications in real-life include eyeglass productions, industrial stamping systems, and semiconductor manufacturing industries [7]. A flexible manufacturing system (FMS) is an integrated, computer-controlled complex of automated material handling devices and numerically controlled machine tools that can simultaneously process medium-sized volumes of a variety of part types [8]. FMSs can produce product components within its wide envelope of variety and can be used to automate MC.

With the development and progress of market economy, customers demand for products is more colourful and varied. In the production process, how to deal with product customization diversification and customer demand agile response is a major challenge of traditional production mode [9]. Enterprises need to reform the original rigid production process and establish appropriate flexible production system. Enterprises have changed from large-scale batch production mode to flexible production mode with multi-varieties and small batches, which has promoted the transformation of the whole production mode of manufacturing enterprises. Theorists have done a lot of theoretical analysis and research in order to cope with the change of demand flexibly, and enterprises have carried out many production practices to meet the fluctuating demand.

Flexible customization is a product of the combination of modern information technology development and product design. It is a product production mode that meets the individual needs of customers with the cost of traditional mass production. It can realize the maximum diversity of products with the minimum diversity of products inside, and then meet the diversified needs of customers [10]. It can shorten the production cycle of products. The decrease of cost, the increase of added value and the increase of market share. However, with the intensification of market competition and the continuous improvement of product design requirements of modern production, especially the rapid development of information technology and network technology, mass customization production has a broader development space, and gradually develops towards the direction of intelligence, digitalization, integration and networking.

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Mass flexible customization of products responding to customer needs can be divided into two aspects: new product development and rapid deformation design. The development of new products requires detailed analysis of the needs of existing customer groups and prediction of potential needs. On the basis of these forecasting and analysis, the product family structure is established, the future requirements and equipment are met in advance, and a perfect flexible mechanism is formed to provide a good basis for rapid response to the diverse needs of customers. When customers have needs, the flexible configuration type developed at the same time in the development stage is used to
select and match products to meet customers’ needs. If the products cannot meet customers’ needs, the customization design needs to be redesigned. The organic combination of this new product development model and rapid deformation design model has improved the ability of enterprises to adapt to the changing market demand.

3. Proposed Method

Through the construction of basic digital three-dimensional object sets such as human, machine, environment and material, the modular platform of data configuration oriented to product production is built, and the unified representation of three-dimensional data is realized; the knowledge object set of digital factory behaviours is constructed; and the universality of human being is realized. Cognition is representation-oriented, and a fusion mapping set based on modular monomer (human, machine, environment, material) is constructed, which is called ‘3D entity object-behaviour object-data object’. From the point of view of system dynamics, the mathematical model and simulation model of equipment manufacturing process system are constructed to realize self-organization and self-balance of flexible product configuration. A digital factory system design verification system combining geometric modelling technology, simulation analysis and virtual reality (VR) technology is constructed to provide an immersive visual environment for user interaction, as shown in Figure 1.

3.1. Data Modular Modeling for Product Flexible Customization

With the passage of time, technological progress and the growth of customer demand, new types of manufacturing equipment will be constantly derived. Even for a specific model, because different customers have different requirements for the choice of various equipment, as well as the
accumulation of experience in the use and maintenance of equipment and the continuous improvement of equipment design, product configuration will change. Configuration is a specific modular product. Different configurations reflect different users' demand states for products or different periods of the same user's demand states. Based on extension theory, this platform studies data modular configuration standards of different products, establishes product model base, realizes unified expression of quantification and formalization of equipment modules, and provides data basis for personalized customization technology. The main problems need to be solved include product data module size, module boundaries, basic modules and so on.

3.2. Dynamic Product Family Model and Configuration for Flexible Customization

The important feature of product design for flexible customization is to separate the product development process into two stages: new product development and variant design. In the new product development stage, the product family is not designed for a single product, but for a product family. According to the common needs of customer groups, a dynamic product family model supporting variant design covering the functional requirements of the entire product family is established. Through effective product modularization, production efficiency can be improved, cost can be reduced, and diversified products can be manufactured, so as to achieve the goal of rapid personalized customization design and manufacturing for single machine. Aiming at the specific needs of customers, with the support of information technology, through the different combinations of product structure modules, the configuration technology of relevant functions, structures or parameters is studied. In a short time, with the lowest cost, personalized products with satisfactory quality are provided to users, so as to meet the needs of modern enterprises in the fierce market competition. The project will focus on enterprise practice from modular methodology to product modular design.

3.3. Research and Development of VR Interactive System for Flexible Customization Experience

Aiming at the feasibility evaluation and user experience of digital system solutions in the design stage of enterprises, the key problem of personalized customization is to construct a database of general product configuration module, form corresponding physical model and mathematical model, and realize the data fusion of the two, and develop VR-based products. The research and development of flexible customization experience system can improve the technical service capability of enterprises in the design stage, shorten the design cycle of the system and reduce the risk of project implementation. Based on the data scenario model of production system, a three-dimensional virtual display system is constructed on the basis of software platform. The immersive experience of system scheme design and evaluation is realized to meet the extensive business needs of equipment virtual maintenance and training for equipment manufacturing industry.

4. Case study

Customization-oriented product flexible manufacturing experience system design based on VR combines UE4 software with HTC vive virtual reality device to display the three-dimensional entity in the way of virtual reality. The operating system services of independent devices are all completed in the virtual reality. The interaction in virtual environment has changed from the traditional two-dimensional interface to the virtual three-dimensional space. The user's operation mode and the feedback mode of the system have changed. The interactive mode based on three-dimensional virtual reality technology in space has become the focus of this summary. In the process of displaying the operation behaviour and action of the system equipment and products, the interactive logic and feedback mode of the related individual equipment are fully represented. Based on the UE4 blueprint programming technology, the input of operation information is completed by the touch of the controller using the three-dimensional model of the device and the feature elements of the interface. The blueprint programming technology can code the individual or part of the device features in the virtual reality. The independent feature part edited can complete the operation in the virtual reality. This paper takes one sorting system as case study shown in Figure 2.
Customization-oriented product flexible manufacturing experience system design based on VR consists of four parts from bottom to top, namely hardware infrastructure layer, basic software service layer, business support layer and business application layer. Each layer at the bottom provides support for each layer on it. The system strictly follows the relevant standards and specifications in design and implementation, and realizes the interaction and seamless link between the interfaces of each layer, modules and components in the general development environment. In addition, the system management platform and the system test platform run through the whole level of the system, providing necessary management and testing for the various devices, components, modules involved in each layer.

(1) Hardware Infrastructure Layer

The hardware infrastructure layer is the bottom layer of the flexible customization experience system based on VR, which is the basic guarantee for the normal operation of the whole system. This layer mainly includes physical infrastructure, communication infrastructure and network infrastructure. Among them, physical infrastructure mainly refers to the storage space of servers, PCs and hardware devices; communication infrastructure mainly refers to the wiring required for network communication; network infrastructure mainly refers to network devices such as switches, routers, firewalls and so on.

(2) Basic Software Service Layer

The basic software service layer is the second layer of the product flexible customization experience system based on VR, which provides the necessary basic software support for the upper application services. This layer mainly includes Windows operating system, IE browser, Web service middleware and related functional plug-ins.

(3) Business Support Layer

Business support layer is the third layer of product flexible customization experience system based on VR, which is the key support module of the upper practical application function module, and also the focus and difficulty of this paper. The main key modules of this layer are: data acquisition module, software and hardware interaction module, real-time collision detection module and roaming module.

(4) Business Application Layer

Business application layer is the top layer of product flexible customization experience system based on VR. It is a functional module that users can operate and use directly. This layer mainly includes the functions of simulation of each process in the process of product manufacturing.

5. Conclusion

With the rapid development of modern information technology, the distance between enterprises and enterprises, enterprises and individuals is becoming smaller and smaller, showing the trend of global market. The market began to shift from product-centric to customer-centric. Customers have become
the main body of modern market. The products that satisfy customers’ individualized needs emerge in the modern market in endlessly, which makes the life cycle of products shorter and shorter.

In this paper, the development of customization-oriented product flexible customization experience system based on VR is studied. Through VR technology and on the basis of large data application, the application platform of product data modular configuration is established to meet the production requirements of highly personalized, shortening product innovation cycle and accelerating production rhythm, so as to realize highly flexible allocation of production factors and mass customization production, and overcome the shortcomings. Rapidly changing demand for product and service, shortening response time, improving service quality, reducing service cost and improving service pressure, can make rapid response to the changing market, and continuously develop products and services to meet customer's personalized and customized needs to occupy the market to win competition. It ensures the flexibility of equipment manufacturing service flow, responds to the changes of environment quickly, and provides personalized process services for customers.

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