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Personalized Product Design Based on Digital Twin

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Abstract: With the advent of the German Industry 4.0 era, a new generation of information technology is widely used in the manufacturing industry. And, under the individualized designing demands, manufacturers need an advanced production method that can realize mass customization. The connotation and research status of digital twin are introduced. For big data, the Internet of Things researched the key technologies of digital twin. The personalized product design process was proposed. we present a review of semantic recognition model. It provides a theoretical basis for realizing digital twin - driven personalized product design.
Keywords: digital twin; big data; product design; mass individualization; OWL.

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1. INTRODUCTION

With the progress of society and the improvement of people's living standards, people's personalized demand for products has become higher and higher, and personalized product design has received widespread attention from manufacturing companies. A new generation of information technology, such as cloud computing, big data, 3D printing, and artificial intelligence, is applied to the manufacturing industry. The traditional product design customization method first constructs the configuration space on the modularization, and then combines the inference and optimization technologies to meet the user's individualized requirements. This is a static design, with a long design cycle and low efficiency. Dynamic design is through a large number of sensors and online measurement equipment, collecting large amounts of data, design optimization algorithms, rapid calculations, online simulation of the production process, in order to reduce product design and production time, improve product quality. Obviously, the dynamic design of products is our pursuit. The key to dynamic design is to shift the focus of product design to virtual models, creating a virtual environment with high fidelity and one-to-one mapping to the physical world. The digital twin paves a way to cyber-physical integration. Digital twin is to create the virtual models for physical objects in the digital way to simulate their behaviors [1]. It uses data to simulate the behavior of a physical entity in a real-world environment and adds or expands new capabilities for physical entities through virtual and real interaction feedback, data fusion analysis, and decision iteration optimization. At present, digital deafness has achieved initial application in many aspects such as product design, workshop

design, equipment failure prediction and maintenance.2016 Hannover Messe in Germany, Siemens CEO gave Obama a golf club. This club is entirely simulated and tested by the “digital twin” in a virtual environment, according to Obama’s weight, swing posture and with tailored strength and other related factors, the "digital twins club" has shortened the production cycle compared with the ordinary clubs, and the products are more suitable for users, but the cost is no different or even lower. It can be seen that applying digital twin to product design is bound to bring huge benefits to the company. Recently, although excellent scholars at home and abroad have conducted research on digital twin, there are still many problems that need to be solved to achieve the digital twin application.

This paper first introduces the background and development status of digital twin, analyzes the problems existing in the current digital twin application, and studies the key technologies of digital twin for big data and Internet of Things, and adopts OWL language to achieve semantic-based The product model expresses, through analyzing the individualized design flow, provides the product personalized design flow driven by the digital twin, provides the theoretical foundation for the realization of the digital twin driven personalized product design.

2. DIGITAL TWIN

The concept of digital twin was firstly presented by Grieves at one of his presentation about PLM in 2003 at University of Michigan [2]PLM is the activity that enables a company to grow revenues by improving innovation, reducing time-to-market for new products, and providing superb support and new services for existing products, as well as enables better support of customers’ use of products [3].At that time, it was called virtual digital expression equivalent to physical products and was defined as a three-dimensional model including entities. Products, virtual models, and connections between them. However, this concept of futurization was not taken into account when it was put forward in 2003. It was mainly due to the limitations of the development of information technology at the time and it was difficult to realize real- time data acquisition and real-time processing. Computer technology was relatively backward, virtual space and physics. Space information data transmission is even more difficult to achieve. Until 2011, the digital twins were proposed and further developed by the U.S. Air Force Research Laboratory to solve future aircraft maintenance problems and life prediction problems in a complex service environment.

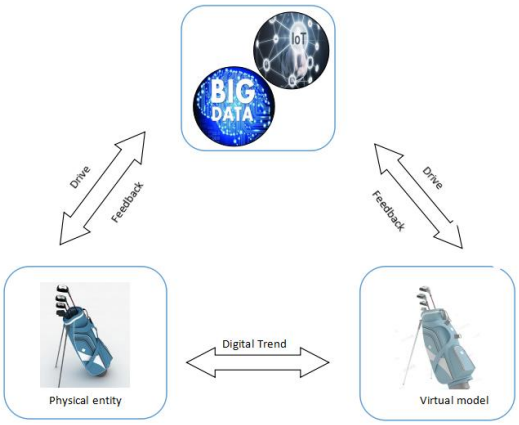

Fig.1. digital twin conceptual model

In 2012, NASA collaborated with the U.S. Air Force Research Laboratory to propose a digital twin targeting an aircraft and defined the digital twin as an integrated Multiphysics, multiscale,

probabilistic simulation model for aircraft or systems. The current best available physical model, updated sensor data, historical data, etc. reflect the state of the flying entity corresponding to the model. It was only after the figures were born that they entered the public's field of vision and received extensive attention from scholars at home and abroad. The BUAA team led by Tao Fei [4] has done a lot of research on digital twin and its key technologies, proposed six application guidelines for digital deafness driving, and explored the key issues that need to be overcome in the 14-category application assumptions and implementation process of digital dehydration drivers. They put forward the concept of digital twin shop-floor (DTS) and discussed the basic theory and key technologies of information physical fusion in the digital twin shop-floor. Zhuang Cun bo[5] systematically expounded the concept and connotation of the product digital twin system, established the system structure of the product digital twin system, and provided the implementation path for each stage. Carlos Eduardo Pereira [6] present a review of how the involved concepts, which have a strong computational background, relate to industrial applications and how they can expand the possibility of services and business models. With the advances of the Internet, Internet of Things (IoT), big data, cloud computing, artificial intelligence (AI) and other new generation information technologies (New IT) [7], the digital twin technology has also received great attention and extensive attention from well-known companies such as Siemens. Dassault established a 3D experience platform based on digital twin, using the information of user interaction feedback, continuously improving the product design model in the information world, and feedback to physical product improvement. In order to improve the production efficiency of F-35, American Loma Airlines has built a “smart space” platform. This platform has established a digital real-time mirroring of the actual production environment, making the production process visible and realizing the virtual model and physical entities in real time.

Digital twin is a simulation process that uses real-time interactive control of the virtual environment and the physical world using technologies such as Internet of Things, big data, and wireless sensing. Digital twin creates a one-to-one mapping virtual model for physical entities in a digital manner, simulating the behavior of physical objects in a real-world environment. By building a digital twin production system that reflects the actual production environment, the entire process of product design, production planning, production and execution and service can be digitized, and can be real-time and dynamic. Adjust the entire process of product design and product life cycle. The digital twins came into being as well as digital twins and digital lines. Digital twins are virtual models that correspond and correspond exactly to the physical entities in the real world. They can simulate their own behaviors and performance in the real-time environment, and they also become digital twinning models. The digital mainline is a data flow and information flow that is built using modeling and simulation tools and runs through the entire product life cycle, from materials, design, technology, manufacturing, to maintenance, and is driven by a unified model. The above analysis shows that the research and application of digital twin are still in the preliminary exploration stage, and the large-scale application of digital twin technology is realized. There are still many key technical issues that need to be resolved.

3. DIGITAL TWIN DRIVEN PRODUCT DESIGN

Product design is a process of transforming the needs of users through analysis and research into a specific physical form. The traditional product design relies on empirical analysis to propose a design proposal, use physical entities to perform product performance testing, feedback optimization information, and further change design proposals to meet user requirements and best design solutions. The modern product design process is more and more inclined to customer-centered and improve the user's participation. In addition, with the application of a new generation of information technology, the product design process is increasingly virtualized, networked, and visualized. The product design based on digital twin refers to the synergies between the existing physical products and virtual products in the design driven by the digital data of the products. It constantly taps into new, unique and valuable product concepts and turns into detailed products. The design plan continuously reduces the inconsistency between the actual behavior of the product and the expected behavior of the design. The digital twin-driven product design builds a virtual model based on physical products and relies on information physics fusion technology to achieve iterative interactive optimization between the two. Personalized product design is the process of analyzing and researching the best product design solutions based on meeting the individual needs of users. The traditional personalized product design is based on the personal needs of the user's initiative to analyze, is a passive design. Based on digital twin, personalized product design is based on product sales data, user survey data, market demand analysis, and other factors that affect product design. Data analysis is performed to integrate the user, production, and product design features and requirements. Active design is more consistent with the user. Requirements, more marketable products. Traditional product design methods rely on experience design. Although most product designs have replaced two-dimensional engineering drawings with three-dimensional digital modeling, information interaction between virtual models and physical products cannot be achieved. Through the digital twinning technology, a twinkling virtual world is built, and the twin data are analyzed and processed using big data, cloud computing and other information technologies. The optimized twin data is transferred to the physical space, and the physical objects are fed back to the virtual model to realize the physical space. Interactive control with virtual environment to improve product design efficiency and quality. For the product verification method, the product design of the digital twin drive has also made great progress compared with the traditional product design. The traditional verification method is based on physical prototype experimental verification. This verification method will inevitably increase product design costs and cause waste of resources. Digital-based product design can be verified on-line in real time. The virtual model can be simulated and tested online. The design can be modified based on the simulation results. Iterative optimization can be achieved until the optimal design is achieved.

That is, when we design and manufacture the product, we do not need to manufacture it in advance. A small batch of products can evaluate the quality and manufacturability of the design plan and test the design directly in the virtual environment. Before the product is manufactured, the quality of the finished product manufactured by the design plan and the existing defects can be predicted. Figure 2 shows the digital product- driven personalized product design flow.

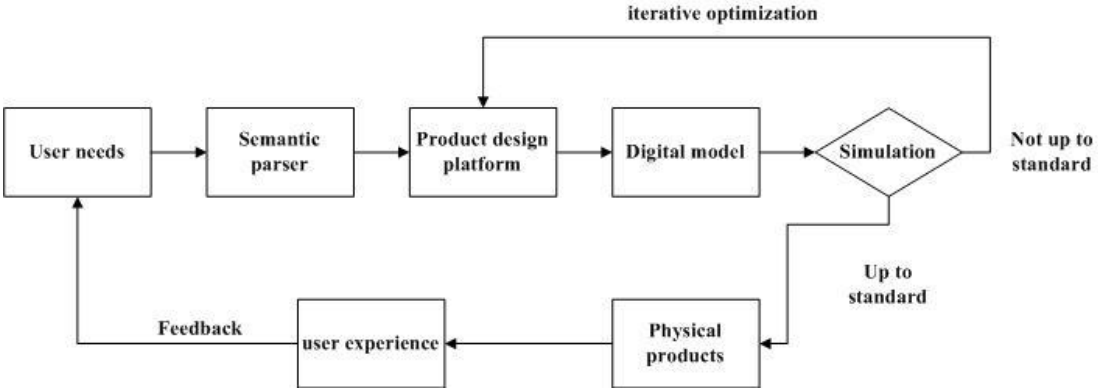

Fig.2 digital product- driven personalized product design flow

Personalized product design is based on Internet technology and can be designed to interact with users. The so-called interaction design refers to the design should pay attention to the interaction between people and products, to consider the user's background, experience and experience in the operation process, in order to design products that meet the end user. Using virtual reality technology and internet of things technology, a real-time interactive web platform can be set up to communicate with users in real-time and effectively, so that users can participate in product design. Through the user's self-selection, the platform can quickly generate satisfaction. The product model personalized by the user. The digital twin technology can realize the interaction between the user and the product, and can transmit data in real time, so that the communication between the user and the product and the designer is more transparent and faster.

4. KEY TECHNOLOGIES

Digital twin is an integrated multi-physics, multi-scale, multi-discipline attribute, with real-time synchronization, faithful mapping, and high-fidelity features that enable the physical world to interact and fuse with the information world. Digital twin integrates a variety of information technologies, including Internet of Things, big data analysis and calculation, and Multiphysics modeling. The most basic and critical technology is how to establish the association between the physical world and the virtual environment and realize physical entities and virtual One-to-one mapping of models. The Internet of Things (IOT) is a Network for radio frequency identification (RFID), cloud computing, etc., according to the agreed protocol, to connect any item to the Internet, to exchange information and communicate, to realize intelligent identification, positioning, tracking, monitoring and management. The Internet of Things technology can connect physical entities, virtual models, and users through the Internet. It is a link that enables real-time interaction between users and product designs.

In order to realize the dynamic design of the product, the system expresses the product knowledge, and meets the control requirements in the digital twin product design process, a semantic-based product model needs to be established. This product model can establish correlations with related R&D data, include product design-related configuration data, and achieve dynamic response of product design control processes, providing the basis for product design and manufacturing efficient collaboration. The traditional expression of product knowledge is focused on the static structure, focusing on the inclusion relationship between the various components of the product. The product

design process changes dynamically with time. Therefore, based on the static structure expression, we must also add product dynamic behavior expression. The behavioral model is associated with the structural model to form a complete shared information model. OWL language is a kind of web ontology language developed by W3C. It is used to semantically describe ontology. for specific areas and applications, using OWL language, we can define owl classes and owl properties.

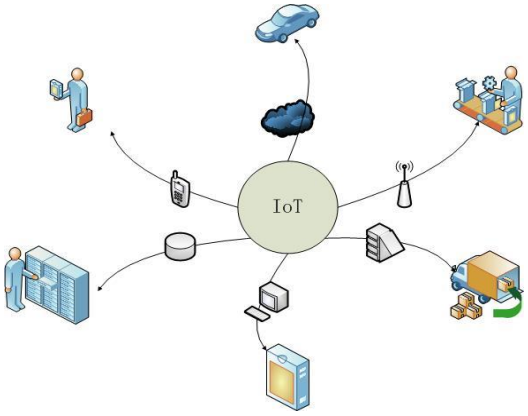

Fig.3 IoT model

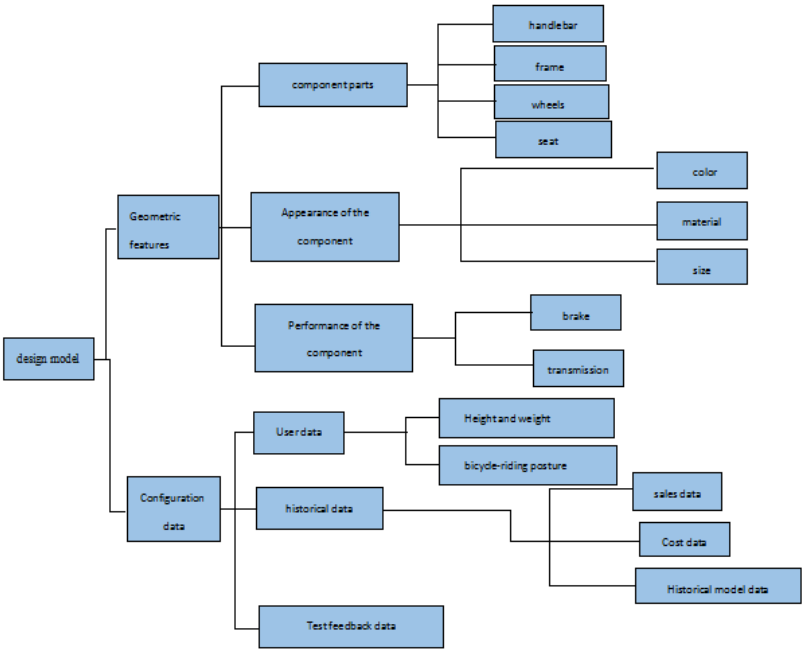

Fig.4. the expression of the bicycle digital twin mode ontology

The ontology is a formal expression that describes the objective objects of the real world. Applying OWL language can realize the static structure expression of products. OWL-S, Semantic Web Service Markup Language, is widely used in service composition. Using OWL-S language, the product behavior is abstracted as a service and describes the dynamic behavior expression of the product. The dynamic behavior information of a product is a combination of multiple processes. The use of control flow can describe the behavior process. OWL-S includes eight control flows[8]Through the eight kinds of control flow, will be linked to each subsystem in the static structure, subsystem of A output interface that is associated with the input interface subsystem B, but when the state variable changes, the subsystem priority connection relationship between A and B will be broken, and connect with

other subsystems, the formation of A variety of combinations, realize the value of product model reuse.

By constructing a shared semantic model, the reuse of the model is realized, and the owl-s service-oriented dynamic product model description is used to enable the designer to call the services he needs. The digital twinning model can carry out conceptual design, scheme design, further detailed design according to different requirements analysis results, and finally complete online virtual verification to optimize the design.

5. CONCLUSION

The digital twin driven product design process is characterized by visibility, interoperability, and predictability. It promotes efficient collaboration between design and manufacturing, improves the quality and efficiency of product design, and allows users to participate in the design to satisfy the user's personalization. demand. In this paper, the digital twin technology is applied to product design to meet the requirements of product personalized design. The key of digital twin product design is how to build a semantic-based product model and describes the static structure and dynamic behavior of products using OWL ontology language. expression. The dynamic behavioral expression laid the foundation for the dynamic interaction and iterative optimization design of the digital twin product design. Taking the personalized bicycle design as an example, the knowledge representation of the product model was given. It is worth pointing out that modeling is only the most basic step in the digital twin design process. In addition, iterative optimization theory of data mining, storage, analysis and calculation, information physics fusion technology, static design and dynamic execution. Waiting for further study.

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