Fast Industrial Product Design Method and its Application Based on 3D CAD System

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Abstract. With the rapid development of science and technology and the emergence of new technologies, the speed of product upgrading has accelerated, and the life cycle has been significantly shortened, leading to increasingly fierce market competition. Through the analysis of the enterprise product development process, combined with CAD-based product rapid design technology and parametric design technology, this paper proposes a product configuration editor based on three-dimensional software with a visual interface, and combines it with the PDM system. A software system that can be applied to actual product development is formed. Finally, the feasibility of a vehicle steering gear product design process is proved in practice. The research of this article mainly has the following two aspects of academic significance: this article describes the process of product development and design by enterprises under the mass customization production mode. After analyzing the application of CAD technology in the product design process, we studied how to use advanced design knowledge to combine specific three-dimensional CAD software for rapid product design, which can guide manufacturing companies to better carry out product design work. It is proposed to improve and perfect the initial configuration results of products in a specific three-dimensional design environment, and it can communicate with data management systems such as PDM. The configuration results can be edited and modified in the 3D design environment, and when specific parts need to be modified and designed, the parametric module embedded in the 3D design software can be used to design directly, avoiding multiple heterogeneous systems switching back and forth between, shorten the development cycle. In addition, for enterprises, the research in this article is also of great application significance.

Keywords: Product design, Mass customization, Rapid product design
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1 INTRODUCTION

The manufacturing industry is produced and developed to meet people's needs for life, production, culture, technology, and war [1]. In human history, the manufacturing industry has experienced production methods such as single-piece production and mass production in hand workshops. In the 21st century, the market environment has undergone tremendous changes, and technological progress has also made significant improvements [2]. In terms of market environment, the total supply capacity of social production is far greater than the total social demand. Fundamental changes have taken place in the product market, and customer needs have begun to diversify and become individualized, transforming from the original seller's market to a buyer's market. In terms of science and technology, 3D commercial design software has developed vigorously. It has become more and more mature after physical design, parametric design and variable design. Enterprises have also popularized 3D design CAD on a large scale. Some other product design and manufacturing theories are becoming more and more mature. The tremendous progress made in science and technology has greatly promoted the improvement of product development quality, and the product development cycle has been greatly shortened. After the first industrial revolution, the product design-to-market cycle was 70 years; after the second industrial revolution, product development in European and American countries was mainly developed, from schematic design, detailed design, trial production, verification to small batch production, and commercial. It takes 40 years in total to put into production and put into the market; until now, the product development cycle is decreasing exponentially. It has changed from 5-10 years in the 1970s to 2-3 years in the 1980s and 1990s. The development of mechanical products even only takes a few months, stated by Zhang et al. [3].

The development of market and technical forces has made the competitive environment for enterprises more and more fierce. As a traditional business model, large-scale production of a single product has been unable to enable many enterprises to survive the competition. What customers need is cheaper, higher quality and fast delivery. In this context, if a machinery manufacturing company wants to quickly respond to customer needs and gain a good market share, in order to win in the turbulent and cruel market environment, it has to pay attention to products at the strategic level. The six elements "PTQCSE" specifically, the six elements refer to: innovative products, the shortest time to market, the best product quality, low product cost, after-sales service, environmental requirements, stated by Gardan et al. [4]. In the modern competitive environment, improving the six elements of products is the key to achieving the commanding heights of the market.

Mass customization production is just such a production method that meets the competitiveness of enterprises in the new era. Mass customization organically integrates two different production methods, namely mass production and custom production. It produces customized products with the benefits of mass production, that is: the cost of customized products should be as low as the cost of mass production, the delivery time of customized products should be as short as the delivery time of mass production, and the quality of customized products It should be as stable as mass production, but the products are customized according to the individual needs of customers [5].

This thesis aims at the requirements of manufacturing enterprises for the development of new products to quickly respond to customer needs and quickly produce high-quality products. Based on the analysis of many researches done in the field of rapid product design at home and abroad, the application of advanced theories and technologies is correct the company's new product development process has been optimized, said by Prakash et al. [6]. And on this basis, the relevant theories and method systems of rapid design are studied, and then the rapid design system of products based on 3D CAD is designed and developed. The main research contents are as follows: explained and analyzed the competitive environment faced by Chinese manufacturing enterprises. The current status and needs of new product development in contemporary

enterprises are expounded, the concept of rapid product design is explained, and the research status at home and abroad is analyzed. Finally, the source, purpose and significance of this research topic are pointed out. The main research content of this article is arranged. The new product development process of the manufacturing enterprise is described, and the business process of the new product design process is analyzed. Then it analyzes the application of CAD technology in product design. On this basis, a new product development business process based on the CAD system is proposed, and a business model of the product rapid design process is established. Finally, it points out the key technologies that need to be solved to realize the product rapid design system based on 3D CAD. In the context of current fierce competition, analyze the needs of enterprises for product design systems based on 3D CAD. After that, a solution to build a product rapid design system based on 3D CAD was proposed. At the same time, the performance requirements of the system, platform selection and other issues were briefly introduced. Finally, the function model and information model of the system were established using the IDEF method. The system architecture of the product rapid design system based on 3D CAD, and summarizes its workflow. From the perspective of the research and development of the product rapid design system based on 3D CAD, the key technologies involved in the system are discussed in detail, including: secondary development technology, XML data interface technology, and parameterized component design technology. Then the realization of the main functional modules of the product rapid design system based on 3D CAD is explained. Finally, an automobile steering gear product is taken as an example to demonstrate its design process in the rapid product design system based on 3D CAD. The results show that the system works well and can effectively support the rapid development and design process of the product.

2 RAPID INDUSTRIAL PRODUCT DESIGN

2.1 Overview of Product Rapid Design

Quick Design is proposed under the background that the product range is becoming more abundant, the customer demand is becoming more individualized, and the mass production method can no longer adapt to this environmental change. It can also be called Quick Response Design in academia, its theoretical basis is a variety of modern advanced design thought theories and methods; supporting technology is electronic computer technology, information, management and other advanced modern science and technology. The purpose is to quickly respond to customer needs, adapt to the transient market, shorten the product development cycle, and quickly obtain commercial products.

Some companies have used rapid design and manufacturing technology in the actual product development process and achieved significant results. For example, in the process of developing the new car Neno, the famous American automobile manufacturing company Chrysler, because of the application of rapid design technology, the number of optical technicians involved has been reduced by more than 60% compared with the traditional development method, and the development cycle has also been shortened to 80%. Take the Neno engine as an example, the amount of drawing revisions in the design process has been reduced by three quarters.

The successful cases of these famous enterprises have proved the research value and application significance of the related theories of rapid design. Combined with the rapid changes in customer demand in today's market, and the characteristics of individual requirements, rapid design has become the key technology of enterprise research, which in turn has led to the rapid development of rapid design technology theory.

2.2 Establishment of a Business Model for the Rapid Product Design Process Based on 3D CAD

Through the analysis of the traditional process of enterprise product design and development, combined with the actual needs of the enterprise during rapid product design, in order to quickly

respond to customer needs and shorten the product design and development cycle, this project will establish a rapid product design system. The company's traditional product development process is transformed. In this system, the business model of the product design process is shown in Figure 1.

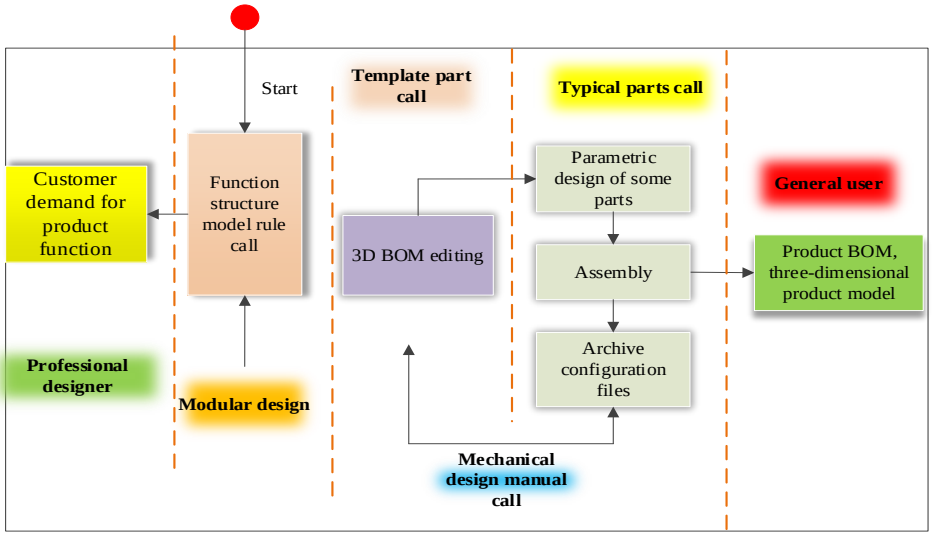

Figure 1: Product rapid design process business model.

2.2.1 3D BOM editor

After the configuration design is performed and the initial configuration result is obtained, it is often necessary to browse the 3D information of each configuration module. Even after the initial configuration is completed, the configuration result needs to be checked on the 3D interface. Especially when some parts need to be modified and redesigned, it is even more inseparable from 3D design software. The 3D BOM editor combines the BOM editing function and the 3D interface into one, which greatly facilitates the modification of the BOM in the design process.

2.2.2 Product management

In the process of mechanical product design, retrofit design occupies the majority, and their original shape often belongs to a certain product family. When a company has designed a lot of new products, it may form a new product family, and can know the subsequent product development, so that the product family will become more and more abundant. Therefore, it is necessary to establish a product library to strengthen the management of these products.

2.2.3 Management of parametric template parts

When performing part modification design, call typical part examples, modify the parameters on this basis, and re-drive the generation of the part's three-dimensional model to obtain new parts. The typical examples of these called parts are generally mature parts that already exist in the enterprise. When drawing them, the fully constrained parametric shape is used to obtain parametric template parts [7]. Due to the large number of parts of the type of parts such as enterprises, their types will become more abundant with the accumulation of time in the future, so it is necessary to establish a template parts library to manage them.

2.2.4 Calling of electronic mechanical design manual

When mechanical designers are designing products and parts, they always have a mechanical design manual on their desk as a design reference book. However, this traditional way of searching

is time-consuming, laborious and inefficient; there are currently electronic versions of mechanical design manuals, but they only exist independently in the form of files and cannot be integrated into the CAD system, causing some inconvenience. In order to solve this problem, the author Haleem et al [8] developed the "Quick Design System for Products Based on 3D CAD" (hereinafter referred to as the "QPD" system), and felt it necessary to integrate the electronic version of the mechanical design manual for designers to call at any time during mechanical design.

Based on the above points, this article has drawn up, and the establishment of a three-dimensional CAD-based product rapid design process business model is shown in Figure 1. It includes the editing of configuration information, parametric design of parts, and real-time calling of electronic mechanical design manuals.

2.3 Product Rapid Design System Structure based on 3D CAD

In recent years, the various products have been sold very well in the market. Coupled with the country's promotion of informatization and policy support for manufacturing enterprises, the informatization transformation has also developed rapidly. It has not only established a new product computer-aided design system through the application of 2D CAD/3D CAD technology, and has accelerated the development of new products. In addition, the company has also adopted a PDM system to manage product data, enabling preliminary configuration design. However, when carrying out detailed design, in the current product design process, the company is still in the empirical design stage, unable to summarize the design knowledge, and has done a lot of repetitive work during the design, and the design efficiency is not high; after completing the outline design, the initial design is obtained. After the product configuration information, detailed design is required. At present, they are not closely connected. The former is in the PDM system, and the latter needs to enter the three-dimensional drawing environment. A communication mechanism needs to be established in a heterogeneous environment; parts are being modified. When designing, there is no summary and filing of the existing design knowledge of typical parts, and there is no parametric part library. Every time a part is designed, it is basically a new one. These result in low design efficiency in the product development process, long product development cycle, and low competitiveness.

According to the business model of the general mechanical product development process and the actual business needs of CF, we have extracted the functions that a 3D CAD-based product rapid design system needs to provide as follows:

(1) Develop a data interface using XML documents as the medium to communicate between the CAD system and the PDM system, complete the preliminary configuration results and finally archive related documents for the configuration results to be transferred between these two heterogeneous systems;

(2) Establish a product structure tree editing module in the specific commercial CAD system to edit the BOM and other operations, so that it can modify, improve, or even redesign the product configuration results;

(3) It is planned to build a product database and a parametric part instance library to manage a large number of enterprises with existing products and parts, and provide instance models for parametric design parts to solve the problem of rapid part design;

(4) The parts in the parametric part instance library use parametric technology to establish a full-size constraint model, which makes it faster to perform part modification design.

(5) The mechanical design manual is a tool book that mechanical designers cannot do without product design. Because in order to further improve the development speed of parts and facilitate real-time access of design manuals by designers, the system provides an electronic version of the mechanical design manual [8].

In order to construct an integrated product rapid design system, on the basis of determining the enterprise demand analysis, combined with the determined solution, the author constructed the system structure of the product rapid design system based on 3D CAD, as shown in Figure 2.

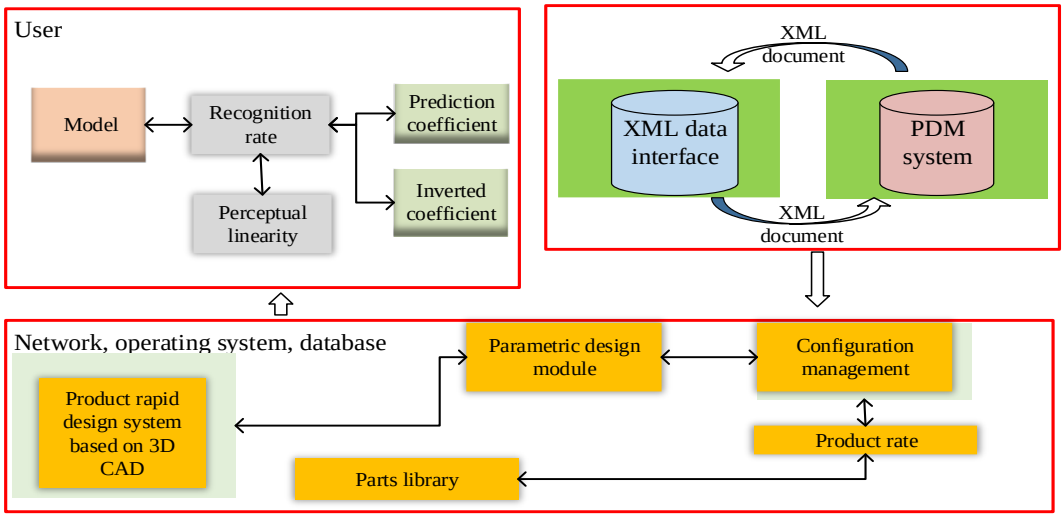

Figure 2: Architecture of product rapid design system.

3 APPLICATION IN RAPID PRODUCT DESIGN

3.1. Rapid Product Design Process

The steps of the existing product model generation are usually: function design-appearance design (existing shape change)-surface design-solidification-model completion. Using the method of previous analysis, the design process becomes:

(1). Product feature summarization, common component shape feature analysis, modeling a feature shape library (repeated use).

(2). Main shape modeling-feature shape import-curved surface integration-shape correction-solidification-Boolean operation-model completion.

Wherein, step (1) and step (2) can be performed by multiple people at the same time.

Figure 3 shows the improved product design process described above. In the whole design process, the features formed by loading the feature shape library can be fully parameterized. For example, the size, rotation angle, and digging depth in the outline drawing can be modified, and the final shape will also vary. Sun et al. [9] said these methods combine the characteristics of the existing 3D CAD technology and feature modeling, and can form a design knowledge base for the parts that are not easy to parameterize, such as product appearance and shape, and can be quickly applied to innovative product design, thereby greatly improving product design efficiency, shorten the design cycle.

3.2 Application of QPD System Mechanical Products

According to the design process of general mechanical product development, and at the same time, according to some actual needs of the enterprise, we have drawn up the workflow of a product rapid design system based on 3D CAD as follows.

3.2.1 New product scheme design

In the development and design of new products, according to market research needs and customer order information, the new product scheme design is conceived, according to customer needs-

product technical index matching rules, and product family information is initially determined in the PDM system.

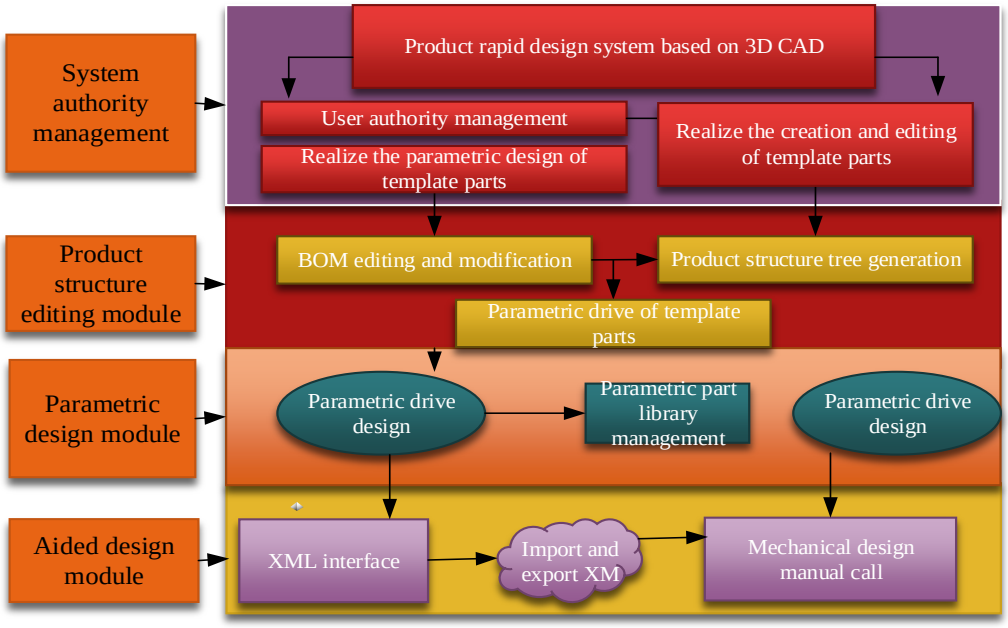

Figure 3: Rapid product design process.

When constructing the solution space, the approximate solution accuracy obtained by the hybrid algorithm needs to be considered. That is, compared with the calculation of normal finite element calculation results, it is ensured that the approximate solution error obtained by the hybrid algorithm within the range of design variables can be controlled within a certain range. The evaluation method for the accuracy of a certain solution space is to traverse the variation range of all design variables and find the maximum error value between the approximate solution and the finite element solution as the accuracy value of the solution space, according to Gardan et al. [10].

As mentioned above, the structural response matrix can be obtained by traversing the range of design variables, and the solution space under specific working conditions can be obtained after decomposition by SVD singular value decomposition method. When using this method to construct the solution space, different singular value truncation errors will result in different solution spaces. This paper divides the truncation error into several levels, and the number of column vectors in the solution space corresponding to each level is not equal. Taking the number of solution space column vectors of different levels as the abscissa and the solution space accuracy value under the corresponding level conditions as the ordinate, the solution space accuracy map under certain sample conditions can be obtained. Aiming at the car body design problem, Figures 4 to 5 reflect the spatial accuracy of the two statics working conditions and the first-order modal frequency of the car body under different sample numbers.

In Figures 4 and 5, the solid line represents the variation of the solution space accuracy with the number of columns, the other line represents the variation of the three-dimensional solution space accuracy with the number of columns, and another line represents the solution space accuracy of the rapid product design. For multiple abscissas, from top to bottom, the number of column vectors corresponding to the solid line in sequence.

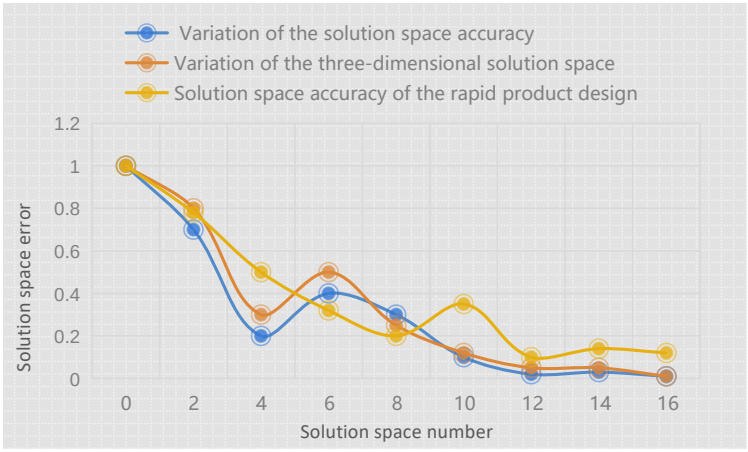

Figure 4: Corresponding statics and modal errors under 16 samples.

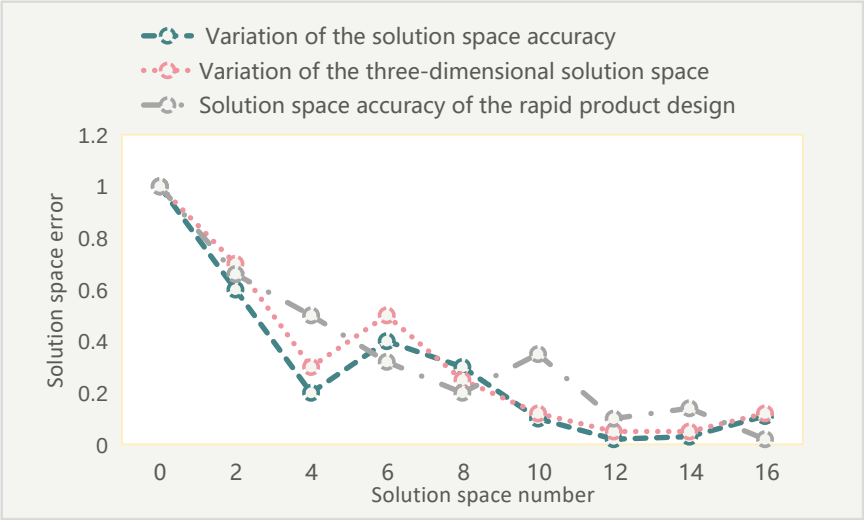

Figure 5: Corresponding statics and modal errors under 72 samples.

3.2.2 XML technology

Using XML technology and using XML documents as the medium to import the configuration results initially determined in the PDM system into the 3D CAD system. In the CAD system, the secondary developed BOM editing and modification function modules are used to parse the XML documents and generate the configuration interface.

The comparison of time-consuming XML technology and time-consuming hybrid algorithm is shown in Figure 6.The advantages of XML are very significant, mainly in the following aspects: XML can realize data conversion between heterogeneous data; because XML is a meta-markup language, it can be applied to any platform, so it has the same Like Java and other cross-platform features, this feature of XML provides a data exchange standard for the interaction of heterogeneous data. It is a public interactive platform. As long as a data source can convert its data into XML format, it can be effectively identified by another data source.

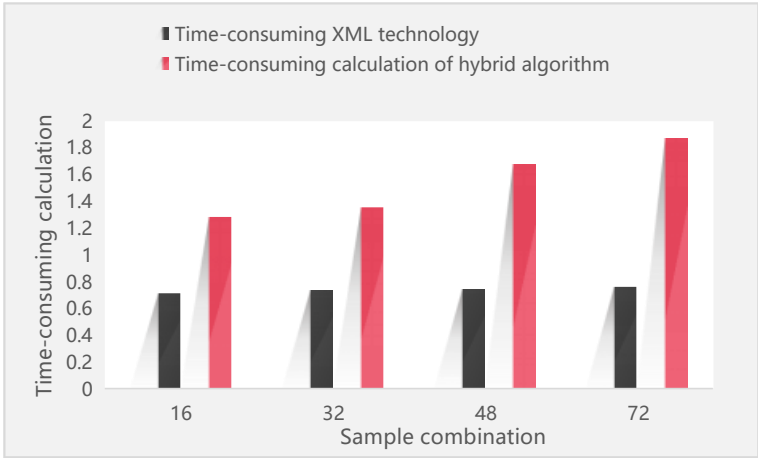

Figure 6: Comparison of time-consuming XML technology and time-consuming hybrid algorithm.

This provides a good tool for data migration and integration. The content of the data is separated from its form; in the XML document, the display style of the data has been separated from the document and put into the relevant style sheet file. In this way, if you want to change the presentation form of the data, you don't need to change the data itself, but you only need to change the style sheet file that controls the data display. Looking back on the development in recent years, a variety of digital devices have appeared in people's lives, such as mobile phones, handheld computers, and digital TVs. Each device has its own different display specifications. It is the advantage of XML to ensure that the same data is successfully displayed on different devices, which makes it easier to implement mobile office.

3.2.3 Parametric design

After parsing the configuration information, query the part name number of each node in the parts library. When the query is found, directly read it, and when it is not found, enter the 3D design module to perform a new design of the parts, or, modified design. The error graph of feature shape replacement method and parametric design is shown in Figure 7.

The feature shape replacement method also has some shortcomings: in the case of large changes in the contour shape, the change of the contour shape will inevitably cause various problems in the reconstruction process of subsequent features based on the shape, such as the disappearance of edges leading to rounding. The feature cannot be applied, the original drilling position disappears due to the shape change, etc. These problems need to be manually modified one by one in the subsequent feature steps, and resolved by re-designating the reference elements of the feature and canceling unnecessary feature steps. The similarities and differences between the feature shape replacement method and the parameterized design are shown in Figure 7.

a. Avoid overly complex editing on feature steps with large shape changes. For complex shapes, it can be broken down into multiple simple steps to achieve, and each step only processes 1 to 2 shape features.

b. Clearly specify the reference point, direction and other parameters of each element in the design.

When designing parts, if it is a retrofit design, you can directly call the parts in the parameterized template library to perform parametric drive, directly and quickly generate new parts, and you can also call the mechanical design manual for auxiliary design during design. After all the parts are designed, the assembly rules can be queried, and the imported and newly designed parts can be assembled. In the 3D software system, the configuration results can be

verified by auxiliary means such as interference check. After passing, regenerate the configuration result, and import it and the 3D model into the PDM system for archiving.

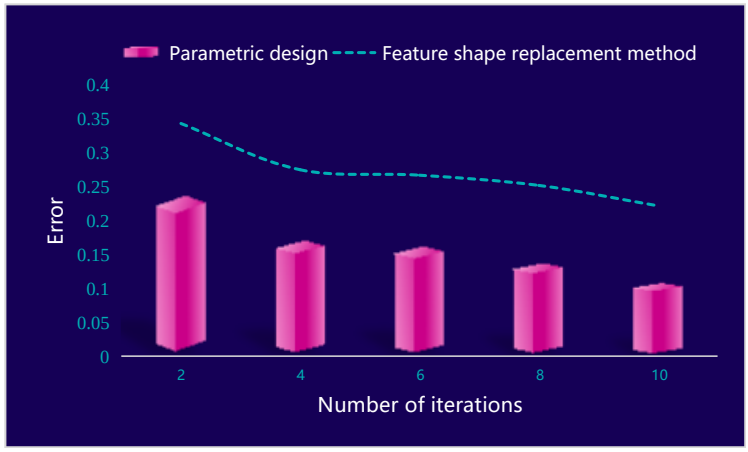

Figure 7: Error graph of feature shape replacement method and parametric design.

4 CONCLUSION

This paper studies the technology of rapid product design and analyzes the business needs of manufacturing enterprises in the process of product development and design. Aiming at the new product development and design process of manufacturing enterprises, a new product design process business model combined with CAD design technology is proposed. And on this basis, using commercial software as a platform, a rapid product design system based on 3D CAD has been developed. Research shows that by constructing a reasonable solution space, the hybrid algorithm can greatly reduce the calculation time while ensuring the necessary accuracy. Although this article has conducted certain research and discussion on the relevant key technologies of system development and implementation, and has also built a rapid product design system based on 3D CAD, and has been applied to a certain extent, due to my limited time and knowledge, There are still some unsolved problems in the research and development of the system: It is necessary to further study the theory of rapid product design, and to study its related implementation technologies, to integrate more advanced technical ideas into the system, and to improve the system; configuration editing is required modules are further improved, more functions are added, and the degree of automation of the system is improved. The automatic assembly technology in specific 3D CAD software is researched, so that when the 3D model is generated, it can be intelligent; the enterprise needs to be in the process of informatization. Under the overall planning of enterprise informatization, according to the characteristics of the enterprise's own products and the advantages of the enterprise, the enterprise's various information systems and this system are integrated to realize the information between each other's systems Integration and sharing.

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