Application Strategy of Big Data in the Development of Complex Industrial Products (CIPs)

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ABSTRACT
The product development is the key business of manufacturing and determines the competitive advantage of manufacturing enterprises, and has high difficulty in implementation. The product development of Complex Industrial Products (CIPs) is a great practical challenge for most enterprises. The demand for mass customization products makes enterprises to face more complicated product development situation. The deep integration of information technology and manufacturing technology makes big data an important value source for enterprises. Full application of big data to promote product development of CIPs has become a feasible approach for product development of enterprises. The value of big data needs to be applied through the knowledge-based application of data. The core work is to develop the functional data model. The application of big data in product development will eventually move towards knowledge-based intelligent. The case study provides the mechanism verification for the application strategy of big data in the development of CIPs.

CCS Concepts
• Information systems → Information systems applications • Information systems→Data management system→ Database design and models

Keywords
Big data; Complex Industrial Products (CIPs); Smart manufacturing; Data processing

1. INTRODUCTION
With the continuous penetration of information technology in the manufacturing industry, digitalization has become one of the most basic characteristics of advanced manufacturing. However, the digitalization will inevitably lead to big data and bring new opportunities and challenges to the manufacturing industry driven by the big data application [1-3]. Big data is also becoming the first driving force for future manufacturing [4-6]. It has only been a few decades from the emergence of big data to its great value being recognized by human beings. The systematic value mining of big data is no more than a dozen years. For the manufacturing industry, big data has become a "gold mine" containing enormous value and will certainly become the focus of future industrial competition [7-9].

Big data has a profound impact on all aspects of manufacturing. In the context of big data, the traditional R&D, design, manufacturing, logistics and services will face a deep transformation from the inside out [10-12]. However, the application of big data in manufacturing is still in the initial stage. Product development is the core link in the process from conception to value realization. Product development covers all aspects in the two stages of R&D and design, which is closely related to other product lifecycle links. Product development also directly determines the value level, technical content and cost of the product, thus determining the market competitiveness of products.

Complex Industrial Products (CIPs) are the concentrated reflection of the development level of manufacturing industry and the main carrier of various advanced technologies. The highly complex structural characteristics of CIPs have determined that its product development are characterized by high difficulty, time-consuming, large investment, insufficient collaborators and difficulty in risk control. The emergence of big data provides a new method to solve the main problems in the development of CIPs [13-15]. Therefore, complex industrial product manufacturers need big data and can exert the intrinsic value of big data. However, the application of big data in complex industrial product development still faces real challenges. The data involved in the development of CIPs are more complex and more difficult to process. The successful application of big data will certainly provide new development opportunities for CIPs manufacturers [16, 17].

This paper begins with the product development process and its requirements on the data application. Then the paper illustrates the internal logic between mass customization manufacturing and big data applications, analyzes the evolution trend of data processing technology, focuses on the thinking methods from big data to knowledge-based application, and provides the strategic reference for the application of big data in the complex industrial development.

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2. CIP DEVELOPMENT URGENTLY NEEDS BIG DATA APPLICATIONS

2.1 Traditional Model and Data Application Requirements for Product Development

Product development is a process from the identification of products that meet market needs to the completion of product design and process design. Product development can form enterprises competitive advantage, improve R&D capabilities, establish the enterprise image, make full use of enterprise resources, help talents cultivation and shape enterprise brand. The usual product development includes both the development of new products and the improvement and upgrading of existing products. Product development focuses on how to maximize the value of development resources, and devote limited human, material and financial resources for the highest value work [18]. Among them, the determination of product direction is the key of development efforts.

Product development should focus on product functions. Through market research to gain insight into customers' real demands and clearly figure out which functions of the product are still blank, which functions are insufficient and which functions are missing. According to its own R&D strength and production conditions, the enterprise develop product development plans that address the functional characteristics required for these products.

Having a lower cost while ensuring quality is an important competitive advantage for the product. The product cost includes both production costs and usage costs, and its level depends mainly on design development. Reducing the total product cost is one of the key objectives of the whole process of product development, including the adaptation of advanced technologies and process solutions that are suitable for the enterprise's own conditions, and to maximize the reliability of product in the service cycle.

Product development includes both the creation of new products and the improvement and upgrading of old products. But in either case, it needs to be based on creative thinking. In the process of product development, all kinds of effective creative methods should be used to explore the creative potential, and develop all-round and three-dimensional thinking to obtain product innovation. The content and process of product development are shown in Figure 1.

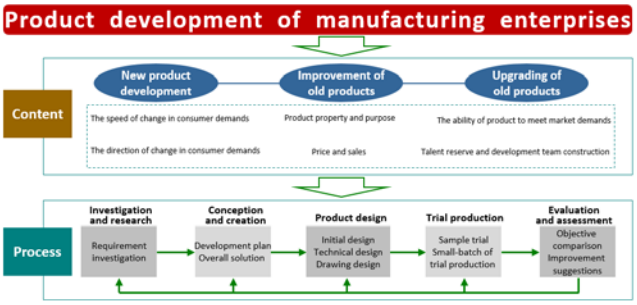

Figure 1. Main content and process of product development

For product development, enterprises need to conduct well-planned and rigorous market research to thoroughly understand market demand and make more market-oriented products. Secondly, product development requires the secure and reliable organizational guarantee to fully mobilize all available resources within the enterprise to jointly serve the product development. Whether conducting an external product market research or establishing an internal product development guarantee organization, its purpose is to completely penetrate the relevant information channels. Big data is the direct method to achieve this purpose.

2.2 Complex Industrial Product Development in the Context of Smart Manufacturing Requires Big Data Applications

2.2.1 Social demands stimulate smart manufacturing

To meet people's usage requirements is the essential attribute of commodity and the fundamental purpose of manufacturing. The traditional mass production method reduces the cost of a single product through mass and standardized production and basically meets the overall social demands. However, with the great enrichment of social material conditions and the improvement of people's living standards, standardized and homogeneous commodities are increasingly unable to meet the various personalized demands of people [19, 20]. The manufacturing method based on users' personalized demands, that is, C2B method is becoming the mainstream model in the future [21-23]. Consumers are more willing to break the original pricing rules for products, choose the products at will, and pay for their own recognized configurations.

Users also want to participate in the product definition, design, change, and even be willing to track their manufacturing and delivery. Correspondingly, the traditional massive and standardized production mode will develop into a massive customization mode. Enterprises should not only meet the customized demands of customers, but also have the advantages in cost and speed, the solution can only be smart manufacturing [24-26]. Compared with the traditional manufacturing model, the product development under the condition of smart manufacturing has undergone new change, from reference development to innovative development, from experience development to precise development, from reverse development to forward development. The changes in product development requirements resulting from mass customization are shown in Figure 2.

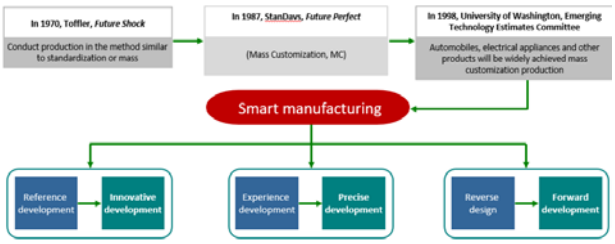

Figure 2. Mass customization production leads to new product development requirements

2.2.2 New manufacturing model urgently needs to apply big data

In addition to the transformation of development model, the product diversification brought by personalized customization makes the product development more onerous and complicated. Faced with the unprecedented onerous and complex product development tasks, enterprises need to break through key technologies on the one hand, and make efficient use of mature development experience to avoid the inefficient duplication of effort on the other hand. The best way for enterprises to get rid of this dilemma is to fulfil full talents potential and explore data

potential. Compared with the demands faced by enterprises, the status quo of talents and data in most manufacturers is not optimistic. In terms of talents, new design developers often lack experience and knowledge reserve, which makes it difficult to play a role quickly. At the same time, the retirement of experienced senior developers causes a significant loss of experience. In terms of data, firstly, the data storage mode gradually developed based on traditional conditions often results in the scattered storage and inconvenient management and utilization; secondly, the insufficient correlation degree affects the use of collaboration; thirdly, insufficient depth of data mining and low efficiency. In addition, the data environment of enterprise is too closed and the cross-industry and cross-domain data interface is insufficient. The demands of mass customization production for big data application are shown in Figure 3.

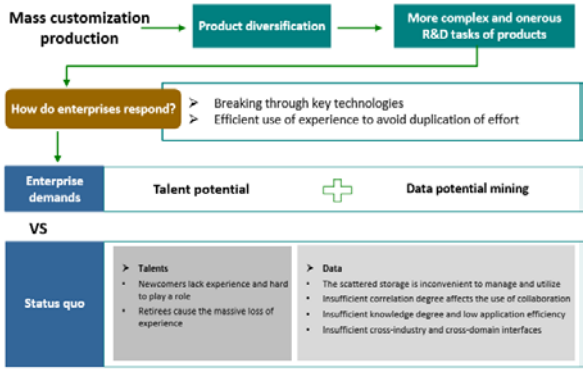

Figure 3. Mass customization production urgently needs big data application

In order to break through the talent and data dilemma generally faced by manufacturing enterprises and fully meet the requirements of mass customization product development, the knowledge-based application of big data under the conditions of smart manufacturing software and hardware will become the most direct and efficient choice.

3. BIG DATA RESOURCES IN THE DEVELOPMENT OF CIPS

The big data that is available in the development of CIPs, in terms of sources, there are Pan-Internet data from various social media, data from enterprise machine interconnection, and data from industry and other enterprises; In terms of content, there are both technical data, interview data and customer feedback data on the use of products. With the gradual promotion of 5G network, the channels and speed of data acquisition will show explosive growth, which not only provides more convenience for big data, but also puts forward higher requirements for data processing capabilities.

3.1 Complex Industrial Product Development Requires Strong Data Processing Capabilities

Product development big data is very large in quantity, and both structured data as well as a large amount of unstructured data in structure. With the continuous increase of the speed of data accumulation, the density of data value tends to decrease continuously. Before the product development, it is necessary to conduct a comprehensive and multi-level market investigation, and to make empirical demonstration or rigorous argumentation on the market demand, so that the product can enter the intended target market after being launched. This process is time-consuming and laborious, but achieved a non-significant result. In the era of big data, through Internet, IoT and various types of information media, multi-angle market data will be integrated in various data formats for the analysis and application of enterprises. Within the enterprise, sales personnel and technical service personnel have a deeper understanding of market demand due to long-term contact with customers, and can provide high-value market data. Professional researchers, with rich professional theory and technical knowledge, they can also provide enterprises with the initial creative data on product development. These data are important resources available for product development, but only if the enterprise must have strong big data processing and application capabilities. The development of CIPs has higher and more difficult requirements for processing big data than that of ordinary products.

3.2 Application Demands Drive Continuous Improvement in Data Processing Technology

Although product development big data has great application potential, it is still faced with the problem of storage of multiple types of data, rapid flow and acquisition of data, and the calculation of massive data and scale data due to the constraints of technical means [27, 28]. The original big data processing technology is obviously insufficient to deal with the rapidly changing big data generation situation and increasingly complex application requirements[29, 30]. There is still a lack of widely recognized mature model in the way of data value sharing. On the other hand, the difficulties in the application of big data also promote the rapid progress of data processing technology. The early relational database is gradually transformed to non-relational database, and to integrate the block chain technology into the application scope is expected. The non-relational database enables the data application system to manage and analyze massive data, enabling data-based giant Internet companies to operate successfully. The block chain technology guarantees the authenticity of data and business behavior due to its unique tamper-proof mechanism, enabling big data to have extremely high security and reliability. The progress trend of data processing technology is shown in Figure 4.

The progress of data processing technology provides the basic conditions for the knowledge-based application of data in product development, making big data facilitate the development of CIPs. However, how to effectively implement knowledge-based applications based on big data still requires more theoretical exploration and practical verification.

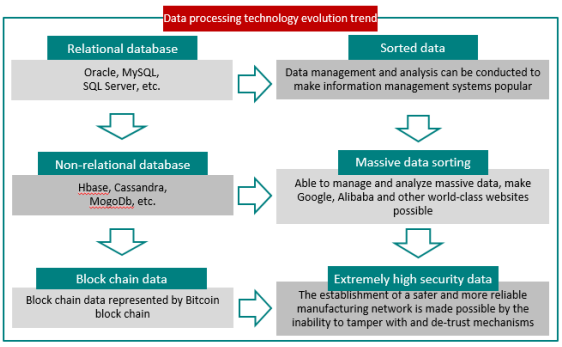

Figure 4. Data processing technology progress trend

4. PROMOTE THE CIPS DEVELOPMENT WITH KNOWLEDGE-BASED APPLICATION OF BIG DATA

4.1 Multi-layer Transformation from Data to Knowledge

The knowledge-based application of big data needs to transform data into knowledge and achieve the ordering of knowledge. The transformation process requires multiple levels of progressive evolution, along with the standardization, structuring and modeling of data. As the bottom starting point of data, data source mainly includes three types of data from design, usage and market. Among them, the design data contains a series of solutions from the known to the target, the monitoring data reflects the working status of products, and the market data records the customer information and market response. The above three types of data are integrated into the data aggregation layer through various channels, some of which are directly obtained by sensors, while some of them exist in highly structured databases and software. The data in the data aggregation layer, after being organized or structured, becomes a meaningful data array, and rise to the information layer. The data in the information layer can reflect the characteristics of things through the correlation based on various application requirements, and can be used for prediction, correlation analysis and support of decision-making. In this state, new knowledge is generated and the data application has reached the knowledge level. On the basis of knowledge layer, orderly knowledge network is formed through the ordering of knowledge, including value identification of knowledge, knowledge identification and establishment of knowledge relations. On the basis of ordered knowledge network, through more functional data models, knowledge from big data is used to generate new knowledge that can directly serve product development. The formation process from data acquisition to ordered knowledge network is shown in Figure 5.

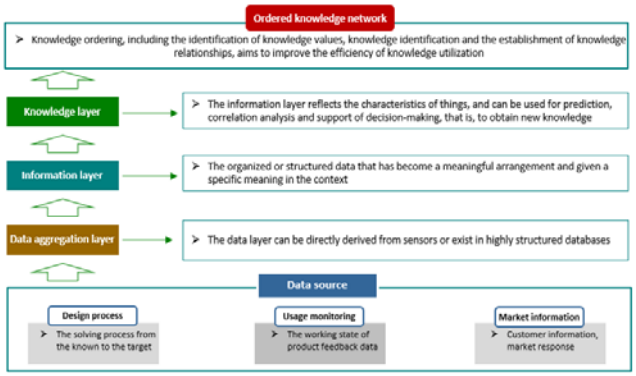

Figure 5. From data acquisition to knowledge network

4.2 Knowledge Application Eventually Moves toward Knowledge-based Intelligent

The product development is a high-intensity intellectual activity of human beings that requires strong logical thinking capabilities and knowledge application capabilities. Knowledge-based intelligent based on intelligent machines is a powerful weapon to help humans maximize these capabilities. Using big data to assist the development of CIPs, its application form will eventually move towards knowledge-based intelligent. The core of achieve knowledge-based intelligent is the knowledge model with various complex and powerful functions. Under the premise of specific knowledge expression and knowledge configuration, through the continuous processing of knowledge model, on the one hand, the complex relationship behind data can be achieved; on the other hand, it is more important to realize the evolution of knowledge. Only with the big data application system capable of deep knowledge mining and knowledge evolution can knowledge-based intelligent be applied in the product development process.

4.3 Knowledge-based Intelligent Maximizes Big Data Efficiency

Knowledge-based intelligent in the development of CIPs, especially good at knowledge screening and precise design. The huge data volume is the most basic feature of big data. While the knowledge required by product developers is widely accepted, this feature makes knowledge retrieval face more and more serious bottleneck, forming knowledge overload and knowledge disorientation. Knowledge-based intelligent could provide more efficient knowledge screening, solve knowledge overload and knowledge disorientation, and change passive knowledge utilization into active knowledge push, thus greatly improving development efficiency.

The accuracy level of undeveloped product can satisfy market's demand is the most immediate risk faced by product development. Under traditional manufacturing conditions, due to the limitations of information channels and technical means, it is difficult to rely on precise product requirements to develop products accurately. However, based on big data and knowledge-based intelligent, more dimensions of knowledge mining can be carried out, and knowledge can be evolved and derived, turning rough demands into fine demands, so as to achieve sufficient knowledge support for the accurate design. As an advanced form of big data application, knowledge-based intelligent is also the most efficient way to exert data value. The application process and role of knowledge-based intelligent in the development of CIPs are shown in Figure 6.

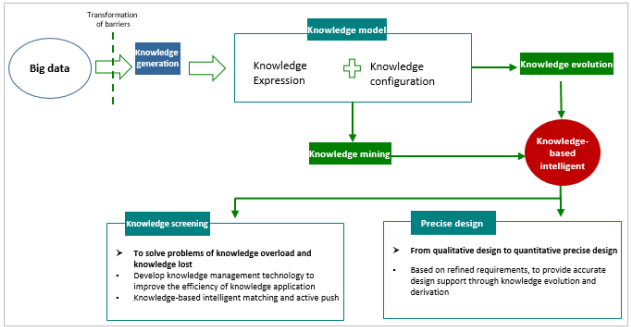

Figure 6. Knowledge-based Intelligent promotes product development

5. APPLICATION CASE: PRODUCT DEVELOPMENT OF SAIC MAXUS

Automobiles are typical CIPs. The application of big data in automobile development is also a typical case of big data in the complex industrial applications. Taking automobile and typical automobile enterprises as research objects, which can better illustrate the application of big data in the development of CIPs. SAIC MAXUS is the first large-scale enterprise in the automotive industry to try the customization mode, and its development path has strong representation. Since the invention of the automotive

assembly line, almost all advances in the automotive industry have focused on technology and scale, while business models have remained largely unchanged. Traditionally, OEMs have always been at the top of industrial chain to integrate supplier and dealer resources for product design, manufacturing and sales. OEM occupy a decisive position in the industrial chain, which has a great impact on the social division of labor and value division of the industry, and determines the profit distribution of suppliers and dealers. In the fierce homogenization market competition, SAIC MAXUS utilizes big data service platform to explore customer value, and organically integrates the serialization and modularization of products with the diversification and personalization of customer demands. SAIC MAXUS leads the market development with customization and takes the lead in the industry by allowing customers to participate in product lifecycle management such as product development and manufacturing services.

5.1 Determine User Demands by Knowledge-Based Big Data

The personalized and customized data entry of SAIC MAXUS is its self-built digital platform — "My Travel MAXUS". "My Travel MAXUS" is an open, multi-entry platform, including its official website, official WeChat with mall, forum, research and other functions, and can support millions of people online at the same time. Through the digital platform, SAIC MAXUS has nearly 4 million online fans, which is the source of its market data. As long as the user is willing to communicate with OEMs, the user's data and labels will be accumulated to express the user's preferences. Before that, MAXUS operated the small-batch and multi-variety business that relied on engineers and users to exchange information via telephone and email. MAXUS used to handle structured data only, and now it can process unstructured data, including voice and image and video. The application of VR (Virtual Reality) technology also provides customers with better product understanding and experience, enabling customers to more accurately express their feelings about the product. In addition to the online digital platform as the main data source, with MAXUS's smart vehicle gradually put on the market, the role of vehicle as a data source has been further amplified. Through intelligence vehicles, more data can be used to make the user's portrait clearer and more accurate.

Through the open digital platform and aided by the functions of software modules such as mall, forum and research, SAIC MAXUS transforms the structured and unstructured data from customers into enterprise knowledge, and applies it to the enterprise business data model, enabling users to participate in the process of "definition, development, certification, pricing, configuration and improvement" of vehicle. As the model of SAIC MAXUS is in its infancy, the data source is still limited, and there is a big gap between the data type and quantity and the idealized customization mode. However, its transformation mode from data to knowledge has been preliminarily mature.

5.2 Data Model Driven Knowledge Application

The data model determines the successful application of customization of each function. The core of SAIC MAXUS's intelligence customization is its intelligent adapter "Spider's Smart Mobility". After evolution and update, "Spider's Smart Mobility" has been able to provide 15 billion selections of vehicle models, its back is data processing and process reengineering. Both data processing and process reengineering require a series of powerful data models. With massive data from millions of users driving data models of various functions, SAIC MAXUS can redefine the automotive business based on knowledge. With knowledge-based data, SAIC MAXUS can redefine the service, marketing and service system according to the user's preferences and usage environment.

To achieve the cost pursuit through the data model. Cost is one of the most important concerns in the production of enterprises. The hundreds of millions of configurations that "Spider's Smart Mobility" can provide, each face the optimal cost considerations. Manufacturing costs and logistics costs are the most important cost components of products. The cost data model that developed according to the cost accounting rules of each link of product manufacturing is used to calculate the optimal cost at any time for the configuration and selection of "Spider's Smart Mobility".

The data models lead to more efficient departmental collaboration. The finalization of personalized and customized products requires efficient collaboration between different departments. It is dependent on the corresponding data model to decompose the businesses of different departments into a series of digital links and solve the problems such as the permission and time sequence in the operation process. However, for ordinary manufacturing enterprises, the development of data model required by departmental collaboration is very difficult, and not easy to achieve the desired effect. SAIC MAXUS directly used the mature commercial collaborative design package as the product development collaboration tool.

The data model guarantees the scheduling efficiency of supply network. Under the customization mode, SAIC MAXUS and users pay attention to users' demands at the same time, and the supplier supply and supply chain follows up, completely changing the original manufacturing mode. This mode is supported by the intelligent manufacturing system and logistics system, and its core is the intelligent production model and logistics model. This mode is not only supported by a platform, but also a set of internal system, and the core operation basis is the intelligent data model. When receiving orders, MAXUS synchronously transfers the order data to primary suppliers and some secondary suppliers in the supply chain. The data state of supply chain not only has logistics attributes as in the past, but also contains production attributes. In particular, distributed manufacturing under the guidance of data model enables the configuration of production resources in a fully optimized way, which makes manufacturing closer to customers and greatly speeds up the response speed and shortens the delivery time.

5.3 Preliminary Application of Knowledge-Based Intelligent

Knowledge-based intelligence is the advanced stage of big data knowledge-based application. SAIC MAXUS, which is still in the initial stage of customization mode, has not been deeply applied in this aspect, but it also has some basic prototypes.

Knowledge-based intelligent drives business iterations of users and enterprises. SAIC MAXUS enabling users to choose products freely through the customization mode. Once users adapt to the products and services of automobile enterprises, with the help of knowledge-based intelligent, users enabling automobile enterprises to keep iterating and provide more choices and services. SAIC MAXUS has the basic conditions for applying knowledge-based intelligent to serve its business iteration, but it

should be more proactive in promoting the application in the future.

Knowledge-based intelligent make product quality more reliable. Under the traditional automobile manufacturing mode, the user gives product feedback to the quality department through the after-sales department, and then the manufacturer determines whether it is a development defect or a manufacturing problem. The scope of knowledge about the quality problem is limited, and difficult to find the cause of problems. In the customization mode, NAXUS's all quality problems can be quickly stored in the public database. Relevant departments of each business can get relevant information at the same time and give reasons or solutions. Most importantly, under the condition of knowledge-based intelligent, with the accumulation of quality problems and solutions, the intelligent system will become increasingly powerful in quality diagnosis.

In the automotive industry, in addition to SAIC MAXUS's first attempt in custom development, there will be more enterprises join the industry. With the help of knowledge application, the product development and design process will be fully participated by users, and OEM and users will grow together. OEMs pay more attention to the precise grasp of customer demands and tend to outsource manufacturing business. In terms of components, users release requirements, manufacturers define boundaries, multiple suppliers participate, and users make decision of supplier's design. OEMs are more responsible for the certification of parts and components, but no longer need to occupy inventory funds. But the application of knowledge based on big data will become the basis for all business operations of enterprises.

6. CONCLUSION

With the continuous promotion of information technology, the digitization degree of manufacturing will continue to deepen, and smart manufacturing will become an inevitable trend of manufacturing. The upgrade of manufacturing to smart manufacturing must be driven by big data, and the "data blood" becomes the foundation of manufacturing. The personalized customization will replace the traditional mass standardized production mode and become the mainstream of future production mode. The personalized customization has brought severe product development challenges to manufacturing enterprises of traditional CIPs. Big data will become a powerful weapon for manufacturing enterprises to cope with personalized customization and provide new opportunities for the development of CIPs. Big data is providing tremendous pressure on traditional data processing technologies while rapidly creating new data processing methods. Emerging data processing methods provide support conditions for the application of big data in the complex industrial product development. Upgrading from big data application to knowledge-based application is the main way to promote product design and development with big data. Data modeling is the core of big data knowledge-based application, and manufacturing enterprises need to combine their own business demands to continuously improve data modeling level. Knowledge-based intelligent is the advanced implementation form of big data supporting the complex industrial product development, which will enable application enterprises to reach the highest data usage efficiency and provide maximum support for the development of CIPs.

7. ACKNOWLEDGEMENT

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