Exploration and Application of Information Technology in Quality Control over the Development of Spacecraft

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Abstract. Starting from quality data of spacecraft development, the present study revolves around quality data collection, quality control over the production process, and quality data exploration in the production process to explore how data lake technology, digital twin technology, big data, and artificial intelligence can be applied in the development and quality control of spacecraft. This way, it contributes to the deep exploration and effective use of quality data produced in the spacecraft production process.

Keywords: spacecraft development, quality data, quality control

1 Introduction

As the informationalization in production increases, enterprises pay more attention to data collection and application. The development of cloud computing and artificial intelligence provide strong technical support for storing, processing, and analyzing quality data. Meanwhile, we are keenly aware that most manufacturing enterprises are still struggling with unsystematic quality data and isolated information. Instead of utilizing data, many enterprises still make management decisions on quality control and improvement based mainly on the human experience. They find themselves in a predicament where they do not know how to use the existing data. In the big data era, an integrated guiding ideology and action framework is urgently needed, with which problems in production, operation, and management can be solved with an overarching, dynamic and developmental perspective. The value of data will be explored and changed into knowledge that can be used repetitively and inherited. Also, enterprises will rely not on the human experience but on evidence produced by data analysis to carry out management and make big data intelligent decisions.

Data generated during the development and production of aerospace products include product information such as design, techniques, production, tests, trials, technical conditions, quality problems, and product acceptance. The data regulates the development of aerospace products, as its correctness, effectiveness, and consistency truly reflect the quality control of products. As industrial processes go automated, intelligent, and internet-based, production processes become increasingly complicated. Spacecraft development becomes digitalized, internet-based, and intelligent, and

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quality control enters a stage of innovative development and effective improvement. However, with existing digital tools, it is hard to establish a quality control system for the new era satisfying the requirements of development. Adopting data thinking, the current study explores the new generation IT application in the quality control over spacecraft development.

2 Exploration and Application of Information Technology

2.1 Use Data Lake to Support Quality Data Collection

A data lake is a repository or system of data stored in its raw format [1]. It stores data as it is without structuring it in advance. A data lake can include structured data (such as tables in relational databases), semi-structured data (such as CSV, logs, XML, and JSON), unstructured data (such as emails, documents, and PDF), and binary data (such as pictures, audios, and videos), Core Functions of Data Lake is shown in Figure1.

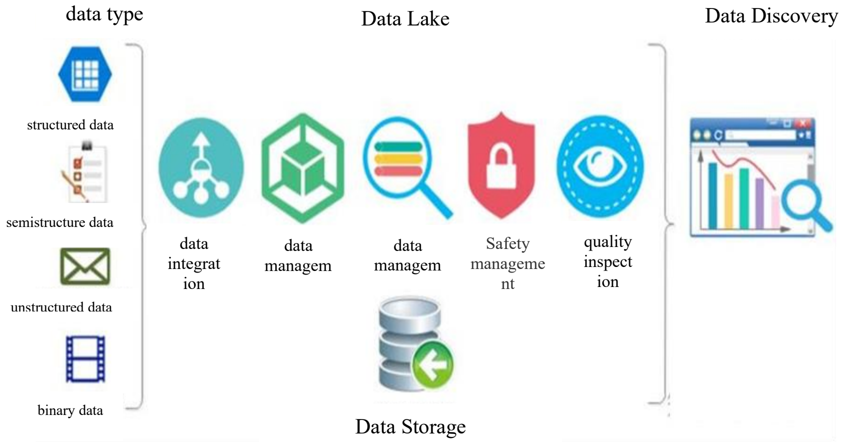

Fig. 1. Core Functions of Data Lake

Quality is important in every stage and step of spacecraft's development and production. Different departments and specialties have all established systems of process control and management. However, data is stored in various forms, including structured data, unstructured data, and image data, which makes it difficult to provide effective real-time quality data analysis for the whole process of development. A data lake can technically solve these problems in the following four ways:

1) It can provide diverse data acquisition interfaces for quality data in different forms, thereby acquiring raw quality data in production through reliable and real-time means.

2) It offers a unified data storage platform for spacecraft's quality data, making centralized data storage in various forms possible at all levels, stages, and processes. By processing data, it can also form quality data assets.

3) It analyzes data and explores platforms. It predicts and analyzes risks in spacecraft production through analyzing and digging quality data and lowers developmental risks by assisting the establishment and improvement of a quality data system.

4) It offers data quality services to guarantee risk control, the sharing of data quality, and self-service analytics based on BI.

The application of a data lake can provide effective support for the collection and accumulation of quality data, thus further improving the developmental quality of spacecraft and increasing the value of quality data.

2.2 Use Digital Twin Technology to Support Quality Control in Production

A digital twin is a digital replica of an existing or non-existing physical entity [2]. With digital twin technology, the physical entity's state is sensed, diagnosed, and predicted using actual measurement, stimulation, and data analysis, and its behaviors are regulated through optimizations and instructions. Besides, a digital twin realizes self-evolution with the help of mutual learning between related data models and improves stakeholders' decisions within the life cycle of the physical entity. A digital twin aims to establish a cyberspace model reflecting the physical reality accurately. Based on data collection, simulation, and computing, it reflects the production processes and states in a real-time way and, in light of this, provides feedback and control for the physical production environment and processes. Reference Architecture for Digital Twin Manufacturing Systems is shown in Figure 2.

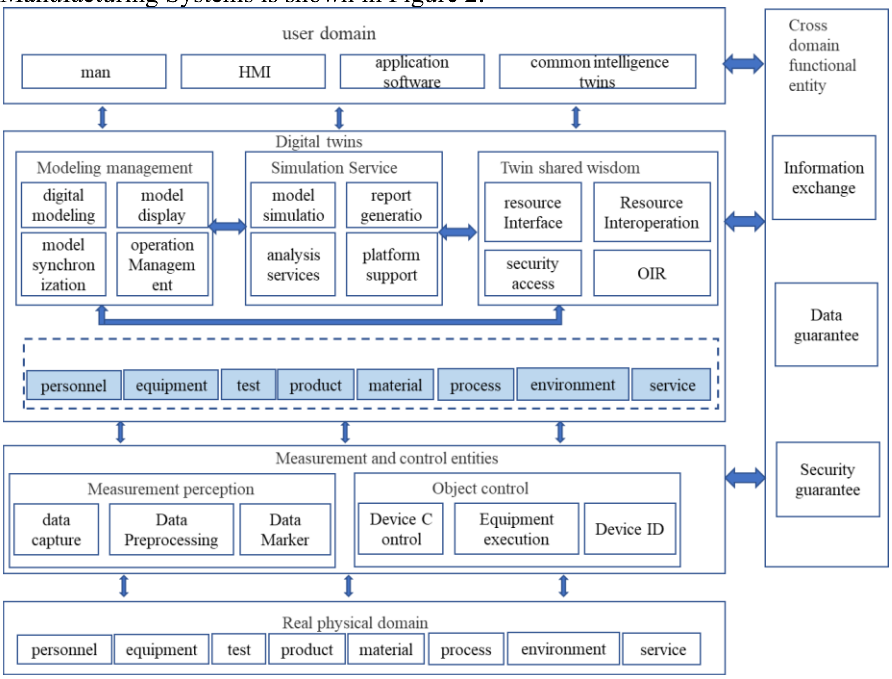

Fig. 2. Reference Architecture for Digital Twin Manufacturing Systems

Digital twin technology has already been used in the aerospace industry abroad. American General Corporation, for instance, combined digital twins with traditional fault analysis methods to study faults of spacecraft, including fatigue cracks, and made more accurate predictions [3]. In the manufacturing assembly industry, Lockheed Martin utilized digital twins with digital threads to make full use of data and models in the whole production process of F-35, thus significantly improving F-35's productivity [4]. Northrop Grumman applied digital twins in quality control over the production of F-35 to effectively improve technological processes and shorten decision-making time. Airbus adopted digital twins in the assembly line of A350XWB and achieved digital monitoring and automatic control in the assembly process.

Building a digital twin system in spacecraft development and production will make quality control possible in the following three aspects:

1) In the design stage, it can complete the multidisciplinary stimulation analysis and the co-simulation analysis from a single machine to the sub-system and system level to further improve the design of products.

2) In the manufacturing stage, based on the perception of the production environment, real-time monitoring of the health status of test equipment, mechanism-based stimulation, and big data analysis, it can predict risks in the production in real-time, reflect and control equipment, and improve the developmental quality of spacecraft.

3) In the in-orbit operating stage, it will collect the spacecraft's in-orbit states in real time and provide guidance for in-orbit maintenance, repair, and fault analysis in accordance with virtual simulation, analysis, and predictions, thereby increasing the spacecraft's lifespan.

2.3 Use Big Data and Artificial Intelligence to Support the Exploration of Quality Data

Artificial Intelligence is applied in every step of the industrial field, such as design, production, management, and service. It serves as a technique, method, production, and application system simulating or surpassing human abilities, including sensing, analysis, and decision-making [5]. AI, in its nature, is combining AI technology with industrial scenes, mechanisms, and knowledge to produce innovative applications such as design mode innovation, intelligent decision-making in production, and optimum resource distribution. Therefore, it needs to be equipped with the ability of self-sensing, self-learning, self-executing, self-decision-making, and self-adapting to adjust to the fast-changing industrial environment and complete various industrial tasks. Its ultimate target is to improve entrepreneurial insight and increase productivity or the performance of equipment and products. At present, the application of AI in production monitoring and diagnosis is still a hot research topic, as AI presents unique advantages when used in complicated industrial processes.

In the process of spacecraft product development and test, based on artificial intelligence technology, the following exploration and application are made:

1) User management: collect information, enter classified information for personnel in different posts and subsystems, establish big data model, and conduct intelligent authority division, task allocation and personnel deployment through expert system.

2) Test equipment management: Genetic algorithm penetrates the test equipment management, tracks the specific situation of each equipment in the large equipment database, and uses neural network technology to achieve virtual equipment management during the test process, unifies the type of equipment instructions, and realizes intelligent monitoring, intelligent management, and intelligent coordination.

3) Test process management: in view of the complex test process, diversified test schemes and other problems, through the data collection of previous test information, combined with expert systems and neural networks, continuous iterative optimization is carried out to ensure the successful completion of aerospace product test tasks.

4) Test data management: satellite ground test generates a large amount of data, which is the key information for quality problem tracing. The integration of big data based on genetic algorithm, neural network and expert system can achieve intelligent interpretation and analysis of test data to a large extent, and improve intelligence while ensuring reliability.

5) Fault diagnosis: through neural network calculation and discrimination, expert system processing and evaluation and other intelligent technologies, automatic diagnosis and reasoning of test data can be realized, and fault diagnosis instructions and solutions can be given accurately and timely.

Industrial big data refers to the total of industrial data. It is divided into three categories: enterprise information-based data, data of the industrial IoT, and external cross-border data [6]. Of all, the large amount of time series generated by machines in enterprise information and IoT is the main source of the expanded industrial data. The causes of quality problems can be traced, and quality assurance ability in production can be constantly strengthened if a product lifecycle data governance system is established, consisting of product definition data, technical data, industrial process data, online monitoring data, and using process data. What is more, the fundamental causes of complicated quality problems can be found by analyzing data from multiple sources both inside and outside enterprises. Technology Architecture of Industrial Big Data is shown in Figure 3.

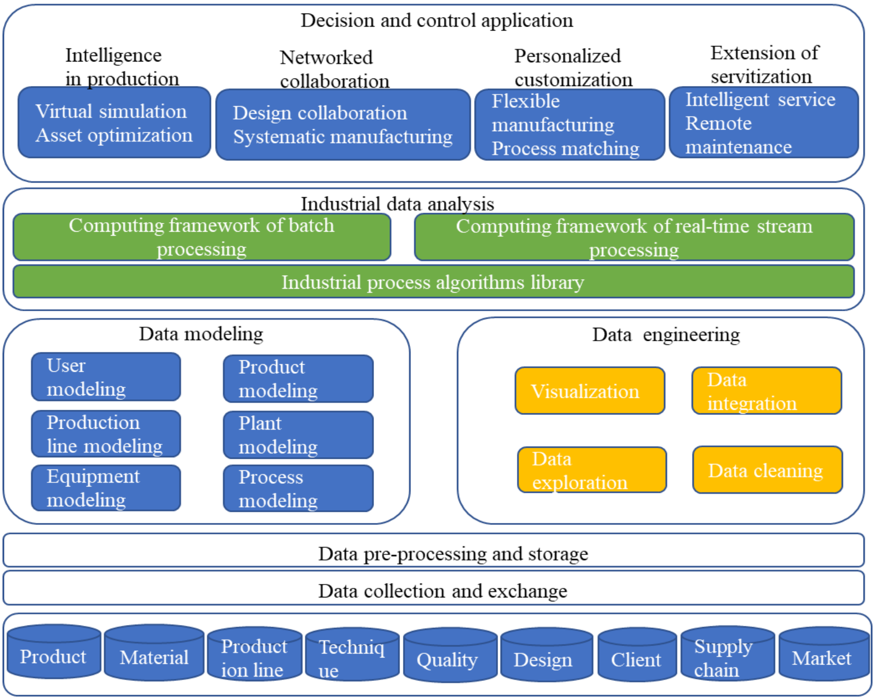

Fig. 3. Technology Architecture of Industrial Big Data

Pursuant to the requirements of all departments and specialties throughout the whole process of spacecraft development, industrial big data can help connect equipment and data and manage the development process from production plan, design, production process, quality, and security to supply chain. Thus, it can act as effective technical support to trace the causes of quality problems.

3 Conclusion

To sum up, the current study starts from quality data of the development stage of spacecraft and explores effective tools that can improve product quality and reliability. These tools include data lake technology supporting quality data collection and accumulation, digital twin technology providing quality control for production processes, and AI technology responsible for quality data exploration and analysis.

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