Design and Implementation of Cloud Platform Knowledge Service Mode for High-end Equipment Manufacturing

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Abstract—With the advancement of intelligent high-end equipment manufacturing, knowledge in the field of high-end equipment manufacturing provides decision support and knowledge innovation services for all aspects of the product life cycle, and plays an increasingly important role in design and production. However, the multi-source, heterogeneous and fragmented nature of domain knowledge brings difficulties to the organization and management of knowledge. To solve this problem, this paper proposes a cloud platform knowledge service mode for high-end equipment manufacturing throughout the product life cycle, including three-dimensional knowledge classification standard, ontology-based knowledge representation and integration, knowledge sharing through knowledge navigation, knowledge retrieval and knowledge reasoning. The application of aerospace manufacturing related fields shows that this mode can provide effective knowledge support for the product life cycle, strengthen the production collaboration between upstream and downstream enterprises in high-end equipment manufacturing, and provide a comprehensive guarantee for the aeroengine manufacturing industry chain.

1. INTRODUCTION

High-end equipment manufacturing is led by high technology. It is at the high end of the value chain and the core of the industrial chain. It is a strategic emerging industry that determines the Comprehensive Competitiveness of the whole industry chain. It is the backbone of modern industrial system and the engine to promote industrial transformation and upgrading[1]. One of the most important characteristics of high-end equipment manufacturing is high technology content and intensive knowledge and technology. With the advancement of the service-oriented process of high-end equipment manufacturing, knowledge has become an important manufacturing resource. Knowledge management activities have penetrated into all links of the product life cycle. Knowledge sharing and integration service mode has become an important guarantee for promoting the optimized operation of high-end equipment manufacturing intelligent factory.

Knowledge service is based on the search, organization, analysis, and reorganization of knowledge, centered on user demand, and provides knowledge content or solutions. Jain et al. designed a system framework for knowledge services[2]. Seong et al. shortened the work cycle through knowledge reuse[3]. Lee et al. proposed a knowledge-centric innovative service design model based on case-based
knowledge reasoning[4]. Wu et al. designed an ontology-based knowledge service integration framework for product development[5]. At present, the application of knowledge services in manufacturing is scarce, and there are fewer attempts in high-end equipment manufacturing field. This paper proposes a cloud platform knowledge service mode for high-end equipment manufacturing, which runs through the whole product life cycle, including knowledge classification, knowledge representation and integration, knowledge management and knowledge sharing. The mode can provide decision support and innovation activities based on knowledge for the optimal operation of high-end equipment manufacturing intelligent factory.

2. **CLOUD PLATFORM KNOWLEDGE SERVICE MODE AND ARCHITECTURE**

2.1. **Characteristics of High-end Equipment Manufacturing Knowledge**

Knowledge in the field of high-end equipment manufacturing is diverse, with rich sources and complex structure, which brings difficulties to the organization and management of knowledge. Without a unified and effective knowledge service platform, it is impossible to unify the manufacturing and process standards of parts and components provided by different suppliers, and the overall performance of the equipment cannot be guaranteed. The main characteristics of knowledge in the field of high-end equipment manufacturing are manifested in the following aspects:

2.1.1. **Multi source of knowledge**: There are many knowledge sources of high-end equipment manufacturing. For example, expert experience knowledge such as fault diagnosis, mathematical models such as product design models, production knowledge such as production schedule.

2.1.2. **Heterogeneity of knowledge**: The production process of high-end equipment manufacturing is complex and has many links. Knowledge comes from different workshops, departments and systems. Moreover, the knowledge forms are complex and diverse, and the storage format is not unified.

2.1.3. **Fragmentation of knowledge**: With the development of information technology, intelligent sensor equipment brings more knowledge output. The industrial Internet and Internet of things make the knowledge source no longer limited to production workshop and supply chain.

2.2. **Cloud Platform Knowledge Service Mode**

According to the characteristics of knowledge discovery and knowledge management in high-end equipment manufacturing intelligent factory, research the knowledge service mode for high-end equipment manufacturing. Taking cloud computing as the platform architecture, this paper studies the knowledge cloud service architecture of high-end equipment manufacturing intelligent factory, proposes knowledge sharing and integration mode, and forms a service system. As shown in figure 1.

![Figure 1. Knowledge service mode based on cloud platform](image)
The cloud platform knowledge service mode is divided into three parts from top to bottom: cloud storage system, cloud service system, and cloud computing platform. The service objects include cloud platform users and system administrators.

The cloud storage system includes user database and information database. The user database stores the user information, including the user’s personal information, required information storage space, frequently searched items and information resources. The information database is used to store all the resources obtained from experts, production workshops and users, and is the basis of the entire knowledge service system. The cloud storage system is distributed in the data server, and users retrieve and utilize the resources through the network cloud.

Cloud service system provides specific knowledge services for users, including knowledge management, knowledge navigation, knowledge retrieval and knowledge reasoning. Knowledge management module provides users with knowledge deletion, update, query and retrieval services; Knowledge navigation module manages the classified knowledge modularized. Users can directly obtain the knowledge in the module through the link; Knowledge retrieval module matches knowledge from the knowledge base according to user demands, and pushes the matching results to user, thereby realizing knowledge sharing between knowledge providers and knowledge demanders; Knowledge reasoning is based on the knowledge reasoning conditions input by the user, providing user with reasoning results that meet the requirements, and providing basis and support for the process parameter setting of the production and design process.

The cloud computing platform includes infrastructure and network terminals. Infrastructure provides a unified platform for cloud storage and cloud services, is the structural foundation of the knowledge service system, and plays an important supporting role for the system. The infrastructure is usually managed and maintained by the equipment supplier, and the end users obtain the right of use by leasing. Network terminal refers to the software and hardware equipment used by users and administrators to log in to the system. Users put forward service requirements on the network terminal, and data and knowledge are transmitted through the network cloud, thereby realizing the connection between the infrastructure and the network terminal.

2.3. Knowledge Service Architecture
This article designs a knowledge service mode for the product life cycle of high-end equipment manufacturing. The product life cycle includes the formulation of production plan, the design of shape and structure parameters, the research and development of personalized innovative products, product manufacturing, parts assembly and finished product test in flexible production workshop, product marketing, operation and maintenance after delivery. The knowledge services provided include knowledge organization and management, knowledge navigation, knowledge retrieval and knowledge reasoning. Based on the technical support of knowledge identification and classification, ontology construction, concept mapping, semantic extension, knowledge reasoning, etc., this knowledge service system is implemented on the cloud platform to realize the collaborative management of enterprise knowledge and reduce the cost of enterprise production management. As shown in figure 2.

2.3.1. Knowledge classification. According to the characteristics of high-end equipment domain knowledge, this paper proposes a three-dimensional knowledge classification standard. Knowledge type dimension: OECD divides knowledge into four categories[6]: Know-what, know-why, know-how, know-who. Product life cycle dimension: The product life cycle is divided into product design, manufacturing, parts assembly, testing, operation and maintenance. Object oriented dimension: the object-oriented of knowledge service system includes engineers, decision-makers and administrators.

2.3.2. Knowledge integration. Ontology can effectively eliminate the heterogeneity of knowledge. In order to realize the collaborative management, it is necessary to integrate the local ontology from various departments to form a new global ontology. Ontology similarity includes attribute similarity and concept similarity. If the similarity of attributes is greater than 0.5, the similar attributes are
integrated to form new attributes in the new global ontology. If the attribute similarity is greater than 0.8, the similar concepts and the attributes under the concepts are integrated to form new concepts and attributes in the new global ontology. Update the global ontology and delete duplicate knowledge to get the global ontology in the field of high-end equipment manufacturing.

2.3.3. Knowledge reasoning. Bayesian network is a directed acyclic graph representing the probability dependence between nodes. Bayesian network can combine with ontology to solve the uncertainty problem in high-end equipment manufacturing process[7]. This paper constructs Bayesian network based on ontology model. Knowledge reasoning is the process of probability reasoning in Bayesian networks. This system uses three kinds of reasoning models: predictive reasoning, diagnostic reasoning, interpretative reasoning.

Figure 2. Knowledge service architecture for high-end equipment manufacturing

Figure 3. Implementation of knowledge service system for aeroengine

3. SYSTEM IMPLEMENTATION BASED ON CLOUD PLATFORM
Civil aviation is an important development direction of high-end equipment manufacturing industry. With the development of intelligent manufacturing of high-end equipment, the knowledge contained in aeroengine production process is increasing. It is urgent to create a unified knowledge service mode for knowledge organization and management.
3.1. Cloud Platform Deployment

The cloud platform system is divided into infrastructure layer (IaaS), platform layer (PaaS), and software layer (SaaS) from the bottom up. The infrastructure layer is responsible for the management, operation, maintenance and virtualization of distributed physical resources. This layer consists of physical resources and virtual resources. Physical resources are composed of servers, memorizers and network devices scattered in different regions. Virtual resources virtualize physical resources, eliminate the heterogeneity among distributed resources, and provide unified computing resources, storage resources and network resources, including assembly data, technical documents, fault data, operation monitoring, computing resources, expert experience, etc. The platform provides standard interfaces for all cloud computing resources through XML service mechanism; The platform layer provides knowledge resources such as expert experience, calculation models, specifications and standards. At the same time, it uses the basic development and operation environment provided by this layer to develop and deploy application systems, and provides service components for the software layer; The software layer provides users with knowledge service functions for the high-end equipment manufacturing field, including knowledge navigation, knowledge retrieval and knowledge recommendation.

3.2. Realization of Aeroengine Knowledge Service System

Figure 3 shows the knowledge service system for aeroengine. Analyze and extract knowledge features through clustering analysis, text recognition and knowledge experts, so as to realize the classification and recognition of knowledge, and provide the definition of attributes and related relationships of aeroengine knowledge. The open source ontology editing platform protégé can be used to construct knowledge representation ontology. Users access the system through the knowledge service interface of the client, and obtain knowledge and corresponding services according to their requirements.

3.2.1. System management: Mainly to ensure the operation of knowledge service system. Users can manage the basic information and set the operation authority of the role.

3.2.2. Knowledge management: This module is to update and manage the knowledge base. Users can import knowledge into the system. the system can classify and recognize automatically.

3.2.3. Knowledge navigation: Users can directly acquire the classified knowledge, which is modularized managed according to the three-dimensional classification standard.

3.2.4. Knowledge retrieval: The system obtains the user’s retrieval requirements from the knowledge service interface and forms the core concept set, and obtains the extended concept set through semantic extension[8]. Semantically match the extended concepts with the knowledge item in the knowledge base to obtain the knowledge item set. In this way, all knowledge retrieved is obtained. Knowledge items can be displayed in the order of similarity.

3.2.5. Knowledge reasoning: In the process of aeroengine design, production, assembly and test, numerous technological parameters are set, many of which affect each other. Knowledge reasoning can infer the probability of unknown variables according to the information of known variables, provide decision-making basis for parameter setting, and greatly improve the product design and production process.

4. Conclusion and Prospect

This paper proposes a cloud platform knowledge service mode for the product life cycle of high-end equipment manufacturing. According to the characteristics of high-end equipment manufacturing domain knowledge, this paper proposes a knowledge type-product life cycle process-oriented object three-dimensional knowledge classification standard. Domain knowledge is represented by ontology,
and product collaborative management is realized based on ontology integration. Knowledge services include knowledge management, semantic-based knowledge retrieval and Bayesian network-based knowledge reasoning, so as to realize knowledge innovation and knowledge sharing. With the background of aeroengine parts manufacturing and assembly, the knowledge service is deployed on cloud platform, which provides knowledge-based decision support and innovation activities for the optimization operation of aeroengine manufacturing, shortens the product cycle to a certain extent, speeds up the production efficiency and reduces the enterprise cost.

In the future, with the development of new information technology, cloud computing, artificial intelligence, machine learning and other technologies, the knowledge service system can further apply these new information technologies. In the current complex production environment, the data from people including suppliers, product users and experts is becoming more and more important. We can further consider how to construct a knowledge service system based on artificial intelligence knowledge graph that integrates human-cyber-physical ternary data.

ACKNOWLEDGMENT
This research was funded by a major project of National Natural Science Foundation of China, "Operation Optimization of Intelligent Factories for High-end Equipment Manufacturing under the Internet and Big Data Environment" (Project No. 71690230/71690234).

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