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Research on Key Technology of Aero-engine Operation and Maintenance Based on Intelligent Knowledge Network

Zhexuan Huang, Yunbin Yan, Wenwen Yu*, Kai Han

Shijiazhuang Campus, Army Engineering University, Shijiazhuang 050003, Hebei, China.

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***Corresponding author:** Wenwen Yu, Shijiazhuang Campus, Army Engineering University, Shijiazhuang 050003, Hebei, China.

Abstract

Knowledge graphs are known for their powerful knowledge representation capabilities, knowledge reasoning capabilities, and support for semantic retrieval. The aero-engine disassembly process knowledge map can clearly present the many elements in the process and the complex relationship between them. At the same time, the disassembly process knowledge map can assist craftsmen in managing unexpected situations during disassembly. It enables the rapid construction of a new disassembly process for parts or equipment that are challenging to disassemble in reverse order, in accordance with the assembly process. This advancement promotes the development of engine disassembly technology, enhances the operability of intelligent engine maintenance, and significantly improves the safety and reliability of equipment operation. In the automatic construction of a complex equipment disassembly process knowledge graph, extracting textual data into a fragmented knowledge graph is of great theoretical significance for expanding the scale of the knowledge graph and improving the practical application of equipment disassembly process knowledge graph. In the application of the knowledge graph, using the disassembly process knowledge graph improved in this paper, the study of disassembly and assembly sequence planning technology is also an important direction for the engineering of the method proposed in this paper.

Keywords

Intelligent knowledge network; aero-engine; intelligent maintenance; reliability

1. Research background

The aero-engines have been in a complex, variable, and even harsh operating environment for a long time, and the deterioration of parts has been intensified, leading to a significant increase in the number of repairs, maintenance complexity, and maintenance costs of aero-engines during their entire life cycle. The complexity of an aero-engine encompasses various aspects, including system structure, functional requirements, technical challenges, manufacturing processes, maintenance difficulties, and management intricacies. These factors contribute to a high level of technical content, knowledge density, and systematic integration throughout the manufacturing, operation, maintenance, and management phases of the equipment. Compared with ordinary equipment, the maintenance and disassembly of an aero-engine is more complex, more dependent on professional knowledge and skills, and requires more stringent requirements of the disassembly process and a higher disassembly safety factor. (1) Specifically, aero-engine system integration is high and usually consists of multiple systems and subsystems, which are interdependent, interactive, and tightly integrated. Therefore, it is more necessary to understand the interrelationships between the systems during maintenance and disassembly to avoid unintentional disassembly damage; (2) Aero-engine applies a variety of advanced technologies, such as advanced materials, complex structures, high-performance sensors, and control systems. These technologies require maintenance personnel to have higher skill levels and professional knowledge to ensure proper maintenance and disassembly; (3) Due to the complexity of aero-engines, maintenance, and disassembly are more difficult, requiring the selection of more specialized tools and equipment, more decision-making knowledge and higher decision-making efficiency; (4) The parts and components used in aviation engines are more precise, and the dismantling costs and consequences of improper dismantling are more serious, even threatening life safety. In summary, compared with ordinary equipment, aero-engine maintenance and disassembly require a more accurate disassembly process to guide the disassembly process, so intelligent support tools for aero-engine disassembly process decision-making are urgently needed.

The dismantling of complex equipment relies heavily on the technology and dismantling experience of experts. Improper dismantling will not only prolong the dismantling cycle and increase dismantling costs but may also cause secondary damage to parts and components and even lead to safety accidents. Due to the high uncertainty and experience dependence of the disassembly process, there is an urgent need for a decision-making tool supported by sufficient knowledge and experience to ensure that the disassembly process is carried out correctly and safely. A process knowledge base for guiding technicians to disassemble equipment scientifically and professionally and for supporting technicians in constructing disassembly process solutions quickly is the actual need for complex equipment disassembly. The automated construction and intelligent application of the complex equipment disassembly process knowledge graph is of great significance for improving equipment disassembly efficiency, reducing complex equipment maintenance costs, and avoiding disassembly accidents. In this paper, for the key technologies involved in this field, we have studied the semantic quantitative expression method of complex equipment disassembly process knowledge, the entity category prediction method of complex equipment disassembly process knowledge graph, the similarity metric and fusion modeling method of fragmented knowledge graph of the equipment disassembly process, and the fine-grained collective entity linking method of complex equipment disassembly process knowledge graph, and the results of which have certain theoretical significance for improving the disassembly and assembly of complex equipment. The results have certain theoretical significance for improving the intelligent level of complex equipment disassembly and assembly, and at the same time, they have practical value for improving the level of equipment disassembly and disassembly process construction of complex equipment manufacturers.

2. Current status of knowledge graph application in aero-engine manufacturing and operation and maintenance field

Currently, most of the data and knowledge in the field of aero-engine manufacturing and operation and maintenance are stored in the form of traditional relational databases, with high redundancy, dispersed distribution, weak correlation, and relatively small storage capacity [1]. Therefore, in order to extract useful information from redundant data and knowledge texts, effectively express the intrinsic associations between data and knowledge to achieve efficient information retrieval and information reasoning, and improve the reusability of knowledge in the field of aero-engine, intelligent knowledge network has been gradually applied to various stages of aero-engine manufacturing and operation and maintenance. In general, the construction and use of knowledge graphs in the field of aero-engine manufacturing and operation and maintenance is still in the initial development stage, especially in the field of the aero-engine disassembly process. Specifically, aero-engine manufacturing and operation and maintenance domain knowledge map construction technology are slow and poorly scalable, and although there are research results, they are poorly disseminated and lack influence. The main reason lies in the lack of domain knowledge learning and the lack of automatic construction method of domain knowledge map; although the data is abundant, the lack of unified management leads to the difficulty of data collection and aggregation, which cannot form the iterative updating and enrichment of the knowledge map; limited by the quality of professionals themselves, resulting in the low degree of engineering of the knowledge map. The current research results mainly focus on the interconnection of equipment maintenance data [2, 3], the complex material query [4, 5], equipment failure knowledge quiz [6, 7], equipment fault diagnosis [8, 9], and so on.

In the manufacturing and operation of complex equipment, Germany's research is currently at an advanced level. Siemens in Germany has established an equipment maintenance knowledge graph, which links different aspects of enterprise data such as production equipment, production materials, personnel, and production processes, providing users with more direct and effective digital solutions; In order to support engineers in developing and introducing new materials for production, Bosch Germany has constructed a large-scale knowledge graph of chassis system control related data to meet the query requirements of engineers for complex material properties [11].

With the promotion of knowledge graphs, Chinese researchers have achieved a series of achievements in the fields of aviation engine manufacturing and operation and maintenance. In the field of aviation engine manufacturing, Zhao et al. constructed an industrial knowledge graph using an open platform and proposed a hierarchical matching strategy to support semantic matching of equipment manufacturing services. These matches mainly include feature similarity matching, numerical matching, and functional matching [12]. In response to the current problems in the construction of knowledge graphs in the field of equipment manufacturing, Yuan Fangyi established a knowledge graph construction and representation model for the field of equipment manufacturing, studied technologies such as named entity extraction and knowledge graph completion, and improved the construction method of manufacturing knowledge graphs, providing a reference for the construction of manufacturing knowledge graphs [13]. He et al. constructed a manufacturing knowledge graph based on ontology technology to acquire and integrate multi-layer manufacturing knowledge; And a graph-oriented meta-knowledge model was established to represent semantic information between knowledge entities, and semantic-based knowledge calculation methods were used to calculate the inherent term similarity and relational term similarity between two knowledge entities [14]. Lu et al. established the definition of fault knowledge graph, studied knowledge acquisition and fusion techniques in the field of engineering machinery and equipment faults based on multiple data sources, proposed a data-driven iterative automatic construction method for knowledge graphs, and explored digital applications such as template-based fault knowledge Q&A and knowledge graph reasoning for fault elimination [15].

3. Introduction to the operation and maintenance method of the aero engine based on an intelligent knowledge network

3.1 Semantic vectorization expression method of complex equipment dismantling process knowledge

A translation model is established to achieve an accurate semantic vectorized representation of process knowledge. The current knowledge semantic vectorization expression methods are oriented to the general domain, and it is difficult for the traditional model to extract the semantic features of process entities and multiple relationships at the same time because there are no multiple complex relationships that define the knowledge graph of the complex equipment disassembly process. In order to solve this problem, this paper analyzes the complex relationship types of the process knowledge graph of complex equipment disassembly, establishes a dual-projection hyperplane model that can effectively extract the semantic features of complex relationships, and obtains semantic vectors that can accurately represent the process entities and relationships.

3.2 Entity category prediction method of complex equipment dismantling process knowledge graph

At present, there are a large number of entities in the fragmentation knowledge graph of the disassembly process, but because the entity category information does not affect the implementation of the process scheme, there is the problem of missing the entity category, and it will cost a huge amount to manually label the entity category for each entity. In order to realize the automatic completion of category information, a machine learning model can be established to predict the unknown entity category by using the semantic vectors of process knowledge that have been obtained.

3.3 Similarity measurement and fusion modeling method of fragmented knowledge graph of the equipment disassembly process

In the process of modeling the knowledge graph of complex equipment disassembly, the existing disassembly process scheme is fully considered, and the method of automatic modeling of the knowledge graph is studied by fusing the fragment process scheme, focusing on solving the problem of similar knowledge graph measurement and fusion. In this paper, we propose to establish an enhanced maximally connected co-homology structure similarity model based on graph structure similarity, path similarity, and entity importance, and measure the similarity of fragmented knowledge graphs from the aspects of graph structure and path similarity. At the same time, a similar knowledge graph fusion method based on entity fusion, path fusion, and branch fusion is proposed to support the automatic construction of a knowledge graph of complete and complex equipment disassembly processes.

3.4 A fine-grained collective entity linking method for the knowledge graph of complex equipment dismantling process

In order to realize the efficient fuzzy semantic retrieval of complex equipment disassembly process knowledge, an entity linking method based on an equipment disassembly process knowledge graph was studied. This paper proposes a fine-grained collective entity linking method based on strong correlation sequences, which considers the logical features of the language, treats the entities in a retrieved text as a whole, introduces the knowledge semantic vector representation, and finally establishes a strong correlation sequence similarity model to measure the overall relevance of the candidate entity groups. This method can effectively improve the accuracy of entity linking and realize the fuzzy semantic retrieval of process knowledge.

4. Discussion and suggestions

The automated construction and intelligent application of the aero-engine disassembly process knowledge graph is of great significance for improving equipment disassembly efficiency, reducing aero-engine maintenance cost, and avoiding disassembly accidents. This paper explores the essential technologies in this field and investigates several methods related to the aero-engine disassembly process. These include the semantic vector expression method for disassembly process knowledge, the entity category prediction method for the aero-engine disassembly knowledge graph, the similarity metric and fusion modelling method for the fragmented knowledge graph of the equipment disassembly process, and the fine-grained collective entity linking method for the aero-engine disassembly knowledge graph. The findings hold significant theoretical implications for enhancing the intelligence of aero-engine disassembly and assembly processes. The results have certain theoretical significance for improving the intelligent level of aero-engine disassembly and assembly, and at the same time have practical value for improving the level of equipment disassembly and disassembly process construction of aero-engine manufacturers.

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