Association Rule-Based Knowledge Management in Aviation Manufacturing: Postprint

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Abstract

[Purpose/Significance] Addressing the two major safeguard measures for strengthening China's industrial foundational capabilities proposed in "Made in China 2025"—"strengthening the construction of standard systems in fundamental domains" and "vigorously developing information technology services oriented toward manufacturing"—and based on the practical requirements for product research and development in China's aviation manufacturing industry under the new situation of the industrial revolution, this paper explores how to provide high-quality and efficient knowledge management information services for China's aviation manufacturing industry. [Method/Process] Starting from existing national and industry standard documents in China's current aviation manufacturing domain, this paper analyzes the association rules of knowledge elements in standard documents within the aviation manufacturing industry from both explicit and implicit association perspectives, and establishes a knowledge association network description model for aviation technical standards based on knowledge elements. [Result/Conclusion] This provides sound technical support for developing information services in the aviation manufacturing industry, establishing knowledge-level knowledge management systems, and further advancing the intellectualization process of design, production, and manufacturing in the aviation manufacturing industry.

Full Text

Preamble

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Research on Knowledge Management of Aviation Manufacturing Based on Association Rules

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Abstract

[**Purpose/Significance**] In response to the two major measures proposed in "Made in China 2025"—"strengthening the construction of basic domain standards systems" and "vigorously developing manufacturing-oriented information technology services"—and based on the actual needs of China's aviation manufacturing industry to complete product R&D under the new circumstances of the industrial revolution, this study explores how to provide high-quality and efficient knowledge management information services for China's aviation manufacturing industry. [**Method/Process**] Starting from existing national and industry standard documents in China's aviation manufacturing field, this paper analyzes the association rules of knowledge elements in aviation manufacturing standards from both explicit and implicit association perspectives, and establishes a knowledge association network description model for aviation technical standards based on knowledge elements. [**Result/Conclusion**] This work provides robust technical support for developing aviation manufacturing information services, establishing knowledge-level knowledge management systems, and further advancing the knowledge-based processes of aviation manufacturing design, production, and manufacturing.

Keywords: association rules; aviation technical standards; aviation manufacturing; knowledge management

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Knowledge is an intellectual resource and the capital for enterprise independent innovation. In the era of the knowledge economy, informatization and intelligence have become essential characteristics. "Drowning in data while starving for knowledge" represents a primary challenge people face. Knowledge-based work is not merely a feature of emerging information technology companies but characterizes organizations across virtually all domains. Knowledge association forms the foundation for conducting knowledge activities and implementing knowledge management. Aviation technical standards have become two important development trends and characteristics of modern manufacturing technology. Knowledge management of aviation technical standards is key to developing advanced aviation manufacturing technology, making research on knowledge management methods for aviation industry informatized manufacturing significant both theoretically and practically.

The aviation industry reflects a nation's comprehensive national strength, and

knowledge management of aviation manufacturing is critical for developing advanced aviation manufacturing technology. As carriers of aviation industry technology, aviation technical standards contain substantial technical knowledge information and serve as important vessels recording knowledge generated during aviation industrial design, production, and manufacturing processes. The aviation industry is a typical knowledge-intensive, technology-intensive, multidisciplinary integrated high-tech industry featuring long industrial chains, high industrial correlation, and global integrated development. Due to the complex structure of aviation industrial products, numerous component varieties, complex manufacturing processes, and diverse materials, the knowledge utilized and generated in aviation industrial design, manufacturing, and production involves numerous fields and is dispersed across various storage media. This complexity makes knowledge management in the aviation industry extremely challenging.

The knowledge management model for aviation manufacturing based on knowledge element association rules provides a theoretical and methodological foundation for constructing aviation technology dynamic management systems oriented toward aviation industrial informatized design, production, and manufacturing from the domain knowledge level. By establishing a knowledge association network description model for aviation technical standards based on knowledge elements, this approach enables effective knowledge management, sharing, and reuse, thereby facilitating efficient management of aviation technical knowledge. This not only allows users to quickly and conveniently access knowledge resources contained in aviation technical standards but also provides new ideas and directions for the digital construction of related technical resources in the aviation field.

With industrial development, users in digital and informatized environments no longer merely seek individual knowledge content but increasingly demand technical solutions and integrated analytical knowledge. Knowledge management systems are no longer simple literature collection, storage, and transmission systems but are based on knowledge organization and application. Therefore, understanding aviation technical standards should not remain at the surface level but should delve deeper to discover knowledge associations and unearth hidden knowledge. To deeply develop aviation technical standards and fully utilize their value, we must first classify and excavate knowledge associations within them based on standard literature knowledge units.

1 Analysis of Aviation Technical Standards Association Model

In research on knowledge association of aviation technical standards, delving deeper into the knowledge element level enables the formation of a systematic knowledge association network among knowledge elements, discovering their potential logical relationships. This facilitates enhanced utilization of aviation technical standards and allows users to quickly and accurately acquire technical knowledge within them. This has practical significance for developing aviation

manufacturing knowledge management and information value-added services, achieving knowledge discovery and innovation in standard literature, and particularly plays an important role in industrial manufacturing production processes and decision-making.

1.1 Explicit Association

As carriers of technical knowledge in industrial production activities, technical documents of aviation manufacturing enterprises possess feasibility, openness, and dynamism. Explicit associations among standard literature consist of mutual adoption, substitution, revision, reference relationships, and knowledge associations with technical regulations and patents. The mutual adoption, reference relationships among standard literature, and associations with technical regulations and patents can be represented by a citation chronological network as shown in [Figure 1: see original paper]. Explicit associations among standard literature can also be represented using co-citation relationships—when two unrelated standard documents jointly cite (or adopt) the same technical standard or technical regulation/patent, this co-citation relationship forms a co-citation network that reflects the explicit content associations among standard literature.

1.2 Implicit Association

Beyond explicit associations such as mutual reference and adoption, standard literature in aviation manufacturing can also be connected through logical relationships describing technical problems, forming undiscovered implicit associations. Analyzing and discovering implicit associations among standard literature can yield substantial potentially hidden knowledge, creating greater value from standard literature. Implicit associations represent the logical relationships hidden among standard literature, primarily comprising technology-dimension knowledge associations including clustering associations, reasoning associations, and technical knowledge associations.

1.2.1 Clustering Association Knowledge clustering association refers to analyzing and integrating knowledge objects according to their attributes. Knowledge clustering has an inverse relationship with knowledge classification—unlike classification, the clustering process generates new knowledge. Literature has categorized knowledge clustering into six types: discipline-based, concept-based, event-based, application-based, person-based, and spatiotemporal-based clustering. Standard literature knowledge clustering primarily employs discipline-based, concept-based, and application-based clustering to form knowledge groups around specific knowledge elements from different dimensions.

First, aviation technical standard texts undergo preprocessing, including word segmentation for pure text to extract knowledge element information, construct

term matrices, and establish index labels. This study employs the Lingo clustering algorithm for clustering association of aviation technical standards. Let K be the set of knowledge elements in the knowledge base, which can be divided into x classes. Since the Lingo algorithm is a label-based clustering method, we first select corresponding centers as X. The membership degree of each knowledge element j to a certain class is uij. Based on semantic labels of knowledge element attributes, similarity calculations are performed for various elements in space, thus defining the objective function:

$$\sum$$

with constraint conditions:

$$1, 2,$$

where constraint condition uij is between (0,1), Xi represents a certain clustering center. Treating clustering center Xi and a knowledge element as two points in vector space, their distance in vector space is d =‖ki − xj‖2. Therefore, the distance between knowledge elements in knowledge element set K in vector space can be expressed as:

Introducing weighted coefficient T= (t1,t2,…,tn) , the constraint conditions and weighted coefficient T are introduced into the objective function to construct a new objective function:

According to semantic labels of knowledge element attributes, the semantic distance between extended classes and central classes in the constructed aviation domain knowledge semantic space model is calculated, considering clustering model construction from different dimensions, node depths, and node densities. The clustering association relevance expression is:

Thus, clustering of knowledge elements in set K can proceed according to the following steps: (1) Define knowledge element classification and determine the number of classes x; (2) Initialize the membership matrix U of knowledge elements between (0,1) to satisfy the constraint conditions; (3) Calculate clustering centers of knowledge elements based on constraint conditions; (4) Define a threshold and calculate the objective function. If it is smaller than a certain threshold, the algorithm stops, and knowledge elements smaller than the threshold form spatial clustering relationships around clustering center Xij, ultimately forming associations based on the knowledge element set constituted by clustering center Xij; (5) If the result calculated in step (3) exceeds the determined threshold, return to step (2) for iterative calculation.

1.2.2 Technical Knowledge Association In the knowledge economy era, users are no longer satisfied with obtaining content from standard literature or individual technical standards but increasingly demand integrated knowledge

and solutions. Knowledge association should be problem-centered, extending solution association patterns from problems. To solve a problem, knowledge is reasoned layer by layer according to logical relationships to constitute solutions, with each solution associating new knowledge.

Aviation technical standards are built upon aviation industrial technology and can themselves be considered part of technology, reflecting technical levels and summarizing technical knowledge applied in industrial production activities. Industrial production activities constitute a systematic, massive industrial system, making aviation technical standards involve extremely extensive and diverse technical knowledge. As the main body of knowledge evolution, technology possesses implicitness, complexity, and cumulativeness. Technology application is a dynamic development process—any technology not only forms technical units through its internal elements but also forms a three-dimensional network-structured technical system with other technical units.

Aviation industrial production activities are structurally an interconnected and interactive system. Relationships such as technical complementarity, compatibility between new and old technologies, and progressive layering among technologies constitute the technical knowledge associations of standard literature. These associations can form a three-dimensional network-structured technical system through a series of chain effects from quantitative or qualitative changes in technical units or technical systems, promoting innovation and development of the entire standard literature system.

Aviation industrial product development and design have sequential order, and the required knowledge also has stages. The association and combination of knowledge needed at each stage constitute the development network of knowledge required for product development. Therefore, it is essential to clarify what knowledge needs to be acquired and what knowledge learning should be conducted. The knowledge required for product development and design includes basic knowledge, design R&D knowledge, and process assembly knowledge. Taking aviation wheel brake system design as an example, the required knowledge includes: (1) Basic knowledge, including aircraft wheel performance requirement indicators and technical condition indicators; (2) Design R&D knowledge, including design specifications, design methods, and accessory selection; (3) Process assembly knowledge, including material selection, material testing standards, scheme selection, and 3D simulation assembly. These involve not only knowledge selection but also knowledge application. By associating and summarizing the knowledge and capabilities required for aviation wheel brake system design to constitute a knowledge development network, designers can conduct targeted learning, improve design capabilities, and obtain complete technical knowledge structures.

2 Description of Aviation Technical Standards Knowledge Association Network

Knowledge association of aviation technical standards is divided into explicit and implicit associations. Explicit associations exist directly and can be expressed through text, images, etc., making them easily discovered, expressed, and systematically organized with intuitiveness. Implicit associations primarily represent the logical relationships of technical knowledge hidden in standard literature, requiring analysis and induction of large amounts of standard literature to extract these hidden, abstract, and indirect associations.

The primary task is to analyze and summarize the knowledge contained in technical standard literature in aviation manufacturing, identify their association relationships, and intuitively express the association network to better share and utilize knowledge, achieving knowledge innovation and technological development. This paper proposes a descriptive logic model for aviation technical standards knowledge association, as shown in [Figure 3: see original paper].

For describing association relationships of aviation technical standards, description logic can be used to achieve formal expression of object-oriented knowledge elements and hierarchical knowledge structures, thereby enabling knowledge reasoning. The most fundamental elements are knowledge elements (concepts) and association relationships, where knowledge elements represent subsets of knowledge in a certain field, and association relationships represent relationships between knowledge elements. A description logic system can be represented by a six-tuple:

$$M =< C, R, EC, RC, Ke, A >$$

where C represents the classification of aviation technical standards (knowledge unit classification); R represents the attributes of aviation technical standards; EC represents the explicit association set; RC represents the implicit association set; Ke represents knowledge elements, i.e., the smallest elements constituting knowledge structures, the most basic atomic concepts; and A represents the knowledge association 集合 where A (E/R)Ki×(E/R)Kj.

The knowledge association network of aviation technical standards is a complex system model containing both explicit and implicit associations that interconnect to form an aviation technical standards association network. The association network is primarily constructed based on the classification of standard literature. Several underlying explicit associations can infer higher-level explicit or implicit associations, where new knowledge units generated by knowledge associations interconnect with each other or combine with other knowledge associations to generate even higher-level associations. The network structure knowledge association composed of several linear results or tree structures reflects the logical relationships of aviation technical standards knowledge structure.

3.1 Data Acquisition

Given the vast quantity, rich content, and numerous technical knowledge areas covered by standard literature in aviation manufacturing, the first step involves text conversion, information optimization, and knowledge unit processing of structured knowledge (text, data) and unstructured knowledge (multimedia materials) in existing aviation technical standards to make them computer-readable information sources.

3.2 Data Optimization

Concepts and terms are extracted from collected information sources, corresponding association relationships are established among concepts, and ambiguous concepts and their relationships are manually intervened through annotation. This enables concept relationship sets to fuse and form knowledge element sets.

3.3 Construction of Aviation Domain Knowledge Element Association Network

Due to the density of aviation domain knowledge and the complexity of relationships among aviation technical standards, the association network includes classes, concept attributes, condition constraints, description information, relationship sets, and instance information of knowledge elements parsed from standards. Through induction of knowledge elements, the association network is constructed according to relevant logical relationships. [Figure 4: see original paper] shows an example of an association network constructed with classes as the center after logically decomposing and parsing some aviation technical standards in the aviation manufacturing domain.

The knowledge association network of aviation technical standards is not merely a network 集合 formed by mutual reasoning between explicit and implicit associations but also includes new knowledge structures composed of associations among knowledge sets with different characteristics. These involve both quantitative changes in knowledge units and qualitative changes in knowledge structures, with both changes promoting each other to form richer knowledge association structures. Due to the dynamic development of technology, this process is also a dynamic spiral ascent—knowledge continuously increases and changes with technological reform and development, and knowledge association structures continuously extend and transform.

After knowledge modeling, constructing a knowledge base provides technical support for achieving knowledge sharing and reuse. Research on aviation technical standards knowledge association plays a crucial role in analyzing knowledge content generated by aviation manufacturing design and production activities and excavating knowledge value. Mining potential knowledge associations in technical standard documents can not only form good information resources at the knowledge level of technical standards and achieve the transformation of

aviation resources from data text to knowledge, providing basic guarantees for developing information technology services oriented toward aviation industrial activities, but also promote knowledge sharing, innovation, and application. It provides good technical support for developing aviation manufacturing knowledge management services, further improves current aviation technical standards from the information level, and promotes the development of industrial production activities toward informatization, intelligence, and service-oriented manufacturing. This plays a vital role in conducting rapid and efficient design, manufacturing, and production activities and offers guiding significance for promoting knowledge management in aviation manufacturing enterprises.

4 Conclusion

Knowledge association network is a fundamental problem to be solved in establishing knowledge models. This paper proposes a method based on association rules and constructs a simple aviation technical standards knowledge association network model with instance verification, providing a unified system for knowledge modeling and knowledge interaction in the aviation technical standards domain, thereby guaranteeing intelligent retrieval and knowledge reuse.

References

[1] ARSENIJEVIC O, TRIVAN D, PODBREGAR I, et al. Strategic aspect of knowledge management[J]. Organizacija, 2017, 50(2): 163-176.
[2] ZHOU J H, ZENG Q L, XIONG G L, et al. Research on design and selection of knowledge management models for equipment manufacturing industry clusters[J]. Manufacturing Automation, 2013(16): [page numbers].
[3] GRAY P H. A problem-solving perspective on knowledge management practices[J]. Decision Support Systems, 2001, 31(1): 87-102.
[4] ZHANG J C, XIAO G C, ZHUANG S P, et al. Analysis on development status and trends of knowledge management in aerospace enterprises[J]. Aerospace Industry Management, 2018(4): 130-133.
[5] WEN T X, LIU X Y. Research on the theoretical basis of knowledge association[J]. Library, 2010(4): 9-11.
[6] CHEN H W, GAO Q, WANG C Y. Research on product knowledge clustering integration model based on knowledge association[J]. Manufacturing Automation, 2016(9): 122-125.
[7] ZHOU H Y, WANG H W, JIA L. Research on knowledge association system oriented to knowledge innovation[J]. Information Studies: Theory & Application, 2013(10): 66-68.
[8] SUN Y, LIU J Q, NIU S D, et al. Research on management method of structured knowledge units for aerospace product enterprise standards[J]. Aerospace Industry Management, 2018(4): [page numbers].
[9] GAN K Q, JI X F. Standard big data practice (3)—knowledge association organization[J]. Standard Science, 2016(3): 15-18.
[10] GUO D H. Research on knowledge linking service mode of standard litera-

ture[J]. Library and Information Service, 2011, 55(9): 76-79.
[11] HAN X Y, LI Y, LIU Y, et al. Knowledge organization method for aerospace domain based on ontology[J]. Aerospace Industry Management, 2018(4): 66-69.
[12] WEN Y K, CHENG P. Knowledge discovery based on implicit association between knowledge units[J]. Journal of the China Society for Scientific and Technical Information, 2007(5): 653-658.
[13] JIANG Y F. On knowledge clustering[J]. Library and Information Service, 2000, 44(12): [page numbers].
[14] WEN X M, LIU Z, YUAN X J. Regional technological innovation system construction based on technology groups and industrial groups[J]. Scientific Management Research, 2002(3): 1-4.

Author Contributions

Du Jiang: Proposed theoretical methods and wrote the main content;
Liu Hang: Constructed the aviation technical standards knowledge association network description model and aviation domain knowledge element association network;
Bai Yu: Provided guidance for paper writing and proposed revision suggestions.

Note: Figure translations are in progress. See original paper for figures.