



Research on enterprise knowledge service based on semantic reasoning and data fusion

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Abstract

In the era of big data, the field of enterprise risk is facing considerable challenges brought by massive multisource heterogeneous information sources. In view of the proliferation of multisource and heterogeneous enterprise risk information, insufficient knowledge fusion capabilities, and the low level of intelligence in risk management, this article explores the application process of enterprise knowledge service models for rapid responses to risk incidents from the perspective of semantic reasoning and data fusion and clarifies the elements of the knowledge service model in the field of risk management. Based on risk data, risk decision making as the standard, risk events as the driving force, and knowledge graph analysis methods as the power, the risk domain knowledge service process is decomposed into three stages: prewarning, in-event response, and postevent summary. These stages are combined with the empirical knowledge of risk event handling to construct a three-level knowledge service model of risk domain knowledge acquisition-organization-application. This model introduces the semantic reasoning and data fusion method to express, organize, and integrate the knowledge needs of different stages of risk events; provide enterprise managers with risk management knowledge service solutions; and provide new growth points for the innovation of interdisciplinary knowledge service theory.

Keywords Semantic reasoning · Knowledge fusion · Enterprise knowledge service · Risk management

1 Introduction

In recent years, with the intensification of world trade frictions and the global new coronavirus epidemic, enterprises have been in a critical period of innovation and development and economic transformation and upgrading [1]. Due to the complex and changeable internal and external environment of enterprises, various risk factors are highly concentrated, leading to frequent corporate risk events. Some companies in related industries are restricted by their ability to respond to sudden risk early warning and

insufficient disposal capabilities and are facing the risk of bankruptcy [2]. The big data environment provides massive amounts of data for risk management decision making, but these risk data present a fragmented and isolated organizational status, which makes it impossible for corporate risk control agencies to grasp the knowledge requirements of each stage of risk events from the perspective of knowledge services and quickly identify risk events and conduct early warning and handling. The development of the semantic web and the maturity of knowledge graph technology provide an opportunity to solve the above problems. The proposal and application of knowledge elements, ontology, knowledge fusion, knowledge mining, and reasoning enable us to build a multilevel and multi-angle knowledge organization method for risk big data, break the phenomenon of data islands in the risk field, and determine the interaction between various elements of risk events. The associated knowledge service network monitors and processes the occurrence and evolution of enterprise risk events in real-time. Therefore, building a risk management-oriented enterprise knowledge service model

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based on big data in the field of risk and knowledge graphs can quickly handle risk events with complex, diverse, dynamic, and unexpected characteristics and effectively improve enterprise risk identification, prediction, and coping abilities.

An enterprise knowledge service is an information service process that extracts knowledge content from explicit and tacit knowledge resources in accordance with enterprise needs, builds a knowledge network, and provides knowledge content or solutions to enterprise management problems [3]. It transforms enterprise data and information into knowledge and provides personalized knowledge services for enterprises according to their specific needs. At present, the domestic and foreign research on corporate knowledge services has not attracted sufficient attention. Through a search of English and Chinese academic journal databases, this article found that there are few results of real research on corporate knowledge services, and these studies mainly address the following aspects. The first is the research on the enterprise knowledge service model. Cheng Gang and others have constructed a knowledge service model for enterprise knowledge innovation and proposed countermeasures for the realization of the knowledge service model of small- and medium-sized technology enterprises [4]. The second is the construction of enterprise knowledge service platforms, such as Wang Fei et al. who use Service characteristics and web service technology to build a knowledge service platform for enterprises to manage and share of enterprise knowledge resources [5]. In essence, the above research has not divorced itself from the traditional knowledge service function. That is, the research provides information services of various knowledge resources for enterprises from a macro perspective and has not provided a knowledge service model for corresponding solutions to specific enterprise problems.

In the application of risk management knowledge service, knowledge service is provided by the internal and external knowledge service organizations of the enterprise, but the risk incident and its handling process should be integrated into the entire knowledge acquisition, organization, and service process. The characteristics, evolutionary law, and processing process of risk events determine the direction of enterprise knowledge service, which directly affects the quality of the knowledge service [6]. Therefore, it is necessary to incorporate risk events into the enterprise knowledge service process. Based on this, this article builds an enterprise knowledge service model based on big data in the risk domain using a knowledge graph as its power, risk events as the driving force, and risk decision making as the target and analyses and explains the application cases of knowledge service in the risk domain.

2 Related research

2.1 Research on enterprise risk management

Enterprise risk management is a process in which enterprises use various scientific methods to identify, warn, and handle various possible risks in production and operations. In recent years, scholars have conducted relevant research on enterprise risk management issues, mainly focusing on the sources of risks, influencing factors, and risk management processes. Li Supeng proposed the internal and external risk control system framework for enterprises. The framework divided the internal and external risk sources faced by enterprises into macro policy risk sources, natural environment risk sources, market risk sources, operational risk sources and financial risk sources and established risk identification and assessment, early warning and response mechanisms [7]. Kathryn et al. divided enterprise risk sources into root risk sources, status risk sources, and unidentified risk sources and analyzed the relationship between risk sources, risk events, and risk management [8]. Based on the characteristics of corporate risks, Yang Jun-ping classified corporate risks into static risks and dynamic risks. Among the risks, static risk involves fixed risk factors, so it is easier to identify, and it is easier to compensate for the harm and loss caused by smaller risk factors [9]. However, dynamic risks involve many factors and are complex and changeable, which makes them difficult to determine. Once they occur, an enterprise experiences huge losses. Ning Fangwei and others classified risk levels according to a multilevel fuzzy comprehensive evaluation method, quantified the impact of various risks, and proposed a risk precontrol plan [10].

At present, domestic and foreign scholars have proposed many dynamic risk event, occurrence probability, and dynamic risk management measures in enterprise dynamic risk research [11], but these risk data are scattered, and there is no unified and reusable risk knowledge. This leads to inefficient enterprise risk management. Therefore, how to effectively store, organize, and manage large-scale risk knowledge and how to effectively use existing knowledge for reasoning are important research issues in the field of knowledge management.

2.2 Research on enterprise risk management knowledge service

Enterprise risk management knowledge service is a service that combines risk knowledge and enterprise risk management to meet the specific needs of enterprises [12]. Yusoff et al. believe that the choice of enterprise risk management strategy requires a large amount of

knowledge to assist risk decision making [13]. Zhang et al. stated that risk management information services play an important role in the production and operations of enterprises. With the development of the economy and society, the demand for risk management information services is increasing [14]. Zhang et al. elaborated on the enterprise risk management information service; analyzed the functional mechanism, operating mechanism, and operating process of the risk management information service in the process of enterprise growth; and constructed the development power model of the risk management information service. In recent years, with the development of big data and artificial intelligence-related technologies, people have presented higher requirements for enterprise risk management information services. Systematic research on intelligent risk management knowledge services oriented by enterprise risk management issues is still being explored. The emergence of big data, cloud computing, and related technologies has laid the foundation for the rapid development of artificial intelligence. On this basis, the application of related technologies such as artificial immunity, case-based reasoning, and knowledge graphs in the field of risk management makes risk management knowledge services more professional and intelligent [15]. Kumar et al. found through a literature research that recent research has focused on how to discover knowledge from massive multisource heterogeneous data and provide users risk management knowledge services [16]. Kumar et al. found that knowledge mining from massive text data can provide more efficient and accurate knowledge services. They also found that risk management knowledge can allow for more efficient risk identification, early warning, and processing and provide professional risk decision-making knowledge services for corporate managers.

Domestic and foreign scholars have continuously explored the personalized and intelligent risk management knowledge service system oriented by the growth risk management of new ventures and found that multisource heterogeneous risk data can provide more efficient growth risk management for new knowledge service ventures [17]. These studies focus more on cutting in from the level of technical methods, innovating the content of risk management knowledge services for new ventures, and expanding the data dimension of risk analysis, but they lack systematic and visualized research on the characteristics of risk management knowledge services from the macro level. In addition, these studies have focused more on the level of risk management information services. Compared with knowledge services, information services lack the need for enterprise risk management. They integrate services such as risk identification, risk early warning, and risk processing into the enterprise and run through enterprise risk decision making. This encompasses the

process to provide enterprises with intelligent risk management knowledge services [18].

In view of the shortcomings of the current enterprise knowledge service model, this research proposes a risk event-driven knowledge service model. The model is mainly based on the characteristics of the risk event itself, uses the knowledge acquisition and organizational technology of the knowledge service characteristics in the growth and risk evolution of the new venture as a means to integrate all aspects of risk management into an enterprise's comprehensive knowledge service process, and finally provides managers with the best risk decision plan. In addition, compared with the traditional knowledge service model, this model has a certain degree of innovation, mainly in the following two aspects. One aspect is to closely link risk events, the knowledge organization environment, risk management requirements, and knowledge services through a driving mechanism. The driving mechanism shows that the knowledge service process changes as risk events evolve, and the power of the change comes from the adaptation of the context of risk events and the orientation of risk management requirements. Second, based on the characteristics of the risk event itself, the various elements of a risk event are integrated with the knowledge organization environment as the driving element of the enterprise knowledge service model. The risk event drive is a dual drive focused on the risk management knowledge service environment, and risk management needs and emphasizes the comprehensiveness of enterprise risk knowledge services and the cyclicity and feedback of each link in the risk management process.

3 Risk event-driven knowledge service-related concepts and their relationships

3.1 Related concepts

3.1.1 (1) Definition of corporate risk events

Enterprise risk refers to the potential for enterprise loss or failure due to economic turbulence, major mistakes and other risk events in the course of business operations [19]. From a management perspective, corporate risk refers to the sum of the various probabilities of a certain adverse event or loss in an enterprise. Risk is a potential source of risk, and the occurrence of risk events turns the potential source of risk into actual losses for an enterprise. Enterprise risk management is the process in which enterprises use various scientific methods to investigate and identify sources of states of risk, evaluate and provide early warnings for unidentified risk sources, and handle risk events in the process of achieving business objectives. The

relationship between risk sources, risk events, and risk management is shown in Fig. 1.

3.1.2 (2) Defining knowledge to support risk management

According to the DIKW (Data, Information, Knowledge, Wisdom) hierarchical model, the most basic model in the knowledge management discipline, data are descriptions of events, objects or concepts in the real world. Information is structured data associated with the context. Knowledge is information that is further processed, handled, and organized and can guide managers' decision making. Wisdom is the application and innovation of knowledge. "Data, information, knowledge, wisdom" is the data transformation and improvement process and corresponds to the process of analyzing and solving problems in the real world [20]. Therefore, the knowledge formation process in the risk management domain is essentially the knowledge acquisition, organization, and application process, as shown in Fig. 2. The knowledge that supports risk management is a forward-looking judgment obtained through a comprehensive analysis of corporate risk events. Its core idea is to process massive contradictions and incomplete corporate risk event data and then provide valuable judgments on risk events. This eliminates the uncertainty of risk management issues, discovers the need for knowledge in the risk domain, and uses existing risk management knowledge to prevent future risk events.

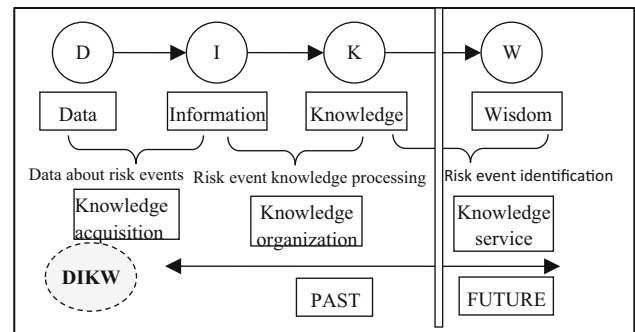


Fig. 2 The process of forming knowledge in the risk management domain

3.2 Conceptual relevance

3.2.1 (1) The relationship between knowledge services and risk management

First, serving risk management is the core function of knowledge. The goal of enterprise knowledge service is to provide accurate, reliable, and valuable knowledge for enterprise strategic decision making. Li Pin et al. believed that having timely and accurate risk knowledge helps to achieve long-term corporate goals, and knowledge can provide wisdom and inspiration for risk managers [21]. This article believes that the prerequisite for wisdom of the risk field is to accurately analyse and judge the risk environment, rely on the knowledge service path that meets the

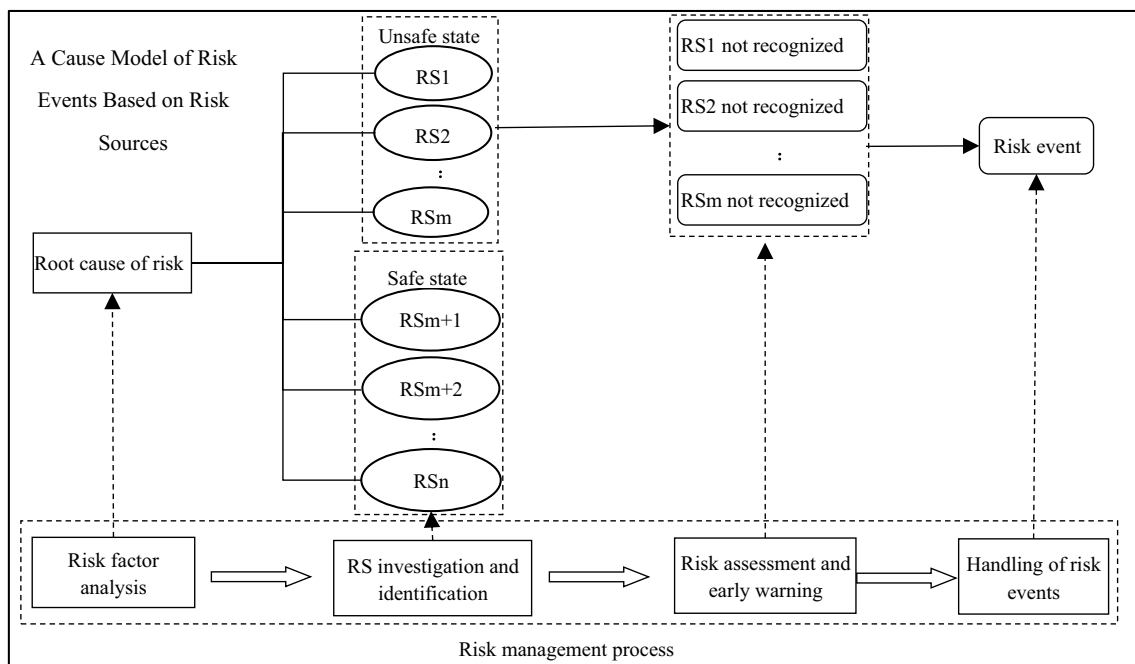


Fig. 1 The relationship between risk sources, risk events and risk management

needs of risk management, and provide the optimal risk control plan to managers (as shown in Fig. 3).

Second, knowledge is an integral part of the risk management process. Davenport and others believed that in the era of big data, data are an indispensable and important factor in the management decision-making process [22]. In all aspects of management decision making, decision-making data need to be considered. These data make the risk management quantitative system completer and more reliable. Chen Guoqing and others believed that through the construction of knowledge service capabilities, it is possible to more efficiently and accurately evaluate, monitor and provide real-time early warnings of risks in different fields [23]. This article believes that the risk management process includes three key elements: the knowledge organization environment, knowledge, and risk management. The role of knowledge in risk management is to transform the knowledge organization environment into knowledge that can solve risk management problems, to form a knowledge service product based on judgments of unknown risk events, and then to influence the judgments of managers on the basis of meeting the needs of risk management, as shown in Fig. 4.

3.2.2 (2) The relationship between risk events, drivers, and knowledge services

Knowledge-supported risk management should focus on the precontrol solutions provided to solve risk management problems, not just the risk knowledge itself [24]. Knowledge services essentially need to undergo two transformations. The first is to transform risk events into risk management knowledge requirements, and the second is to transform risk management knowledge requirements into knowledge service problems, as shown in Fig. 5. The drive is the source of the power to break through the two transformations.

Therefore, in general, “drive” emphasizes the integration of risk events and knowledge services, highlighting the synergy between risk events and knowledge services, especially the seamless connection of knowledge services and risk management processes. As a result, knowledge services start from risk events, are faithful to the

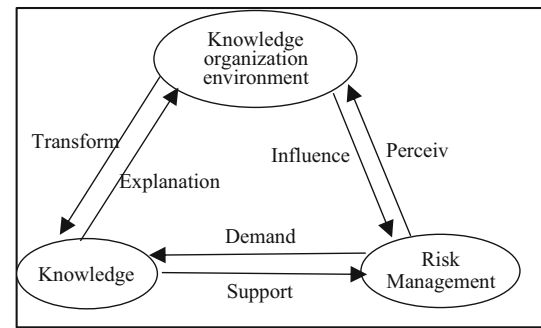


Fig. 4 The relationship model between knowledge and risk management

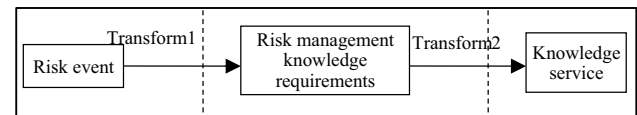


Fig. 5 Risk event-knowledge requirement-knowledge service model

requirements of risk management, and cycle in the application of the risk precontrol plan and its continuous optimization.

4 The construction of a knowledge service model driven by risk events

In view of the limitations of existing knowledge service models, based on the analysis of the relationships between risk management and knowledge services, risk events, and knowledge services, this paper proposes a risk event-driven knowledge service model. Driven by risk management issues at different stages such as risk event prevention, risk event emergency plans, and risk event handling, the model divides the risk management knowledge service process into a knowledge acquisition layer, a knowledge organization layer, and a knowledge service layer, as shown in Fig. 6. The knowledge acquisition layer obtains multi-source heterogeneous enterprise risk data from the Internet and transforms it into structured data, providing data support for the knowledge organization layer. The knowledge organization layer conducts a unified conceptual modeling of the data of the knowledge acquisition layer to form a risk

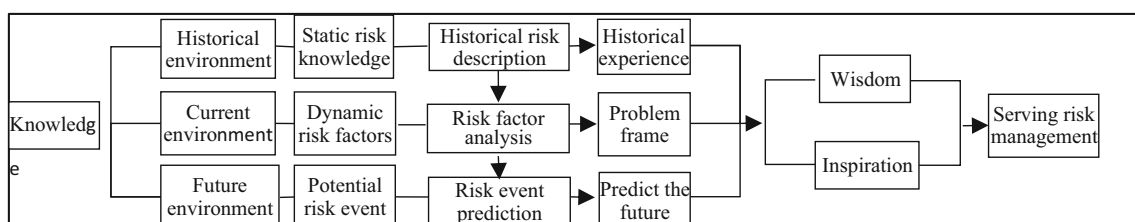


Fig. 3 The role of knowledge in risk management

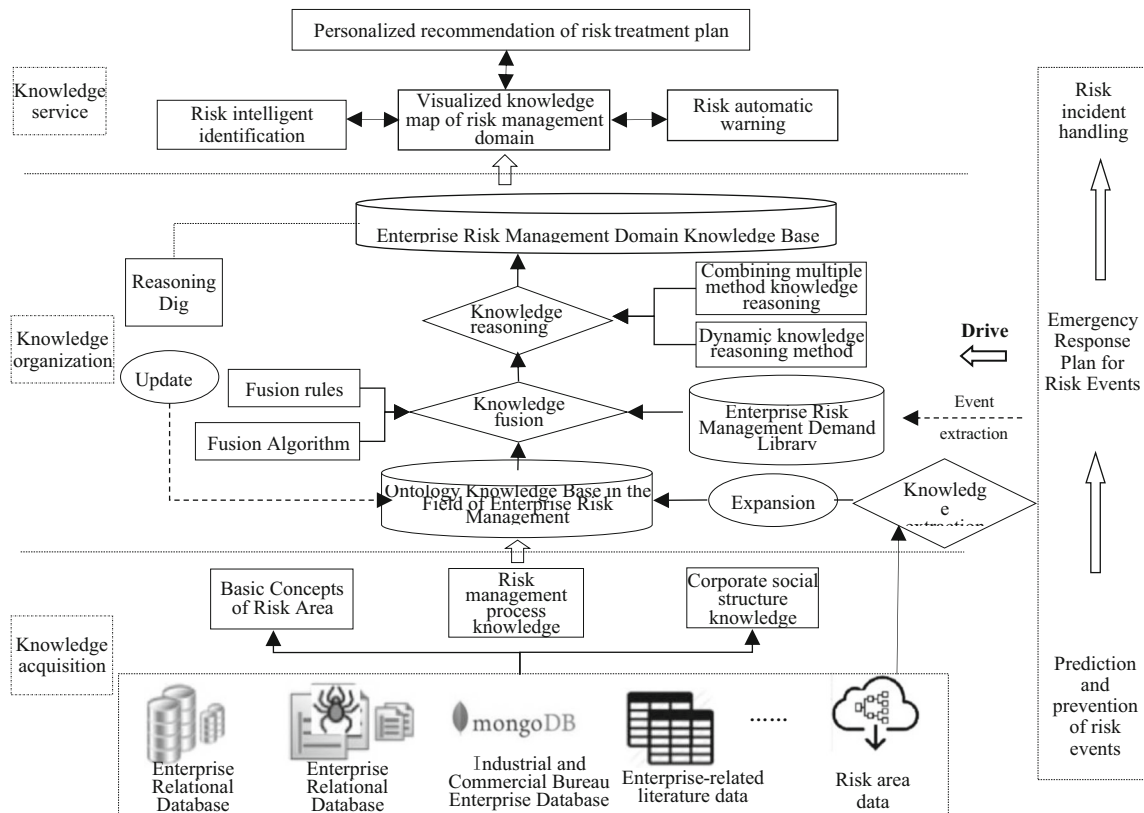


Fig. 6 Risky event-driven knowledge service model

domain ontological knowledge base, merges with the enterprise risk management requirement library, and forms a risk management domain knowledge base to solve enterprise risk management problems through knowledge reasoning. The knowledge service layer provides enterprises with various knowledge services such as risk identification, risk early warning, and risk processing through the visualized knowledge map of the risk management domain.

4.1 Knowledge acquisition in risk domain

Knowledge acquisition is the basis of knowledge services. The availability of rich and effective enterprise risk data directly affects the quality of risk management knowledge services. Knowledge acquisition for knowledge-oriented services not only needs to obtain the existing risk data of the enterprise but also needs to obtain the enterprise risk management demand data and the situational data of the occurrence of risk events. That is, knowledge acquisition is based on the enterprise risk management demand. The objects of knowledge acquisition mainly include two categories, namely, various enterprise risk data resources and enterprise risk management demand data. Various risk data resources of enterprises include basic concepts in the field

of risk, knowledge of risk management processes, and knowledge of corporate social structures. Enterprise risk management demand data include risk events and their evolutionary laws, risk event solutions, and specific preventive measures.

The data in the field of enterprise risk management are fragmented and present the characteristic of multisource heterogeneity. Most of these data are unstructured data such as texts, web pages, and charts. After analysis and processing, the knowledge required for enterprise risk management can be obtained [25]. Therefore, the main task of knowledge acquisition is to collect the required data from various data resources according to the requirements of enterprise risk management and then use granular principles and knowledge modeling methods to process enterprise risk data to form an ontological knowledge base in the field of risk management. This base will facilitate knowledge organization and application.

4.2 Risk domain knowledge organization

A knowledge graph can describe concepts and their relationships in the physical world in a structured form, express knowledge in a form closer to human cognition, and has the ability to organize and manage massive amounts of

knowledge. The knowledge organization layer uses knowledge graph technology to perform unified knowledge modeling on the data of the knowledge acquisition layer to build an ontological knowledge base in the field of risk management, integrate it with the enterprise risk management requirement database, and generate domain knowledge graphs to solve enterprise risk management problems. The construction of an enterprise risk management requirement database and ontological knowledge base in the field of enterprise risk management and the knowledge fusion and reasoning between multiple databases are the key issues of knowledge organization [26]. Risk management-oriented knowledge services excavate enterprise risk management needs through potential risk sources in enterprise production and operations and integrate the risk management domain ontological knowledge base with the enterprise risk management demand database based on relevant fusion rules and algorithms. Then, the services conduct knowledge reasoning with the main goal of solving enterprise risk management problems and provide the knowledge after reasoning to enterprise risk decision makers. Figure 7 shows the process of enterprise risk management requirement database discovery, knowledge fusion and knowledge reasoning in the knowledge organization process.

4.2.1 The composition of the ontological knowledge base in the enterprise risk domain

A reasonable knowledge structure is the prerequisite for knowledge preservation and accumulation and the basis for the formation of a knowledge map in the field of enterprise risk. Ontology is a normative description that describes the concepts of a certain subject domain knowledge graph and the relationship between concepts at the semantic level.

The ontological knowledge representation method provides rich structured semantic information for the knowledge service model [27]. The enterprise risk domain ontological knowledge base is a summary and formal description of various concepts and related patterns in the enterprise risk domain on the conceptual level and mainly realizes modeling based on ontological knowledge of the risk domain [28]. The enterprise risk domain ontological knowledge base can standardize the unified concepts and terminology of the risk domain, promote the integration and sharing of risk domain knowledge, eliminate any confusion in semantic understanding caused by contextual differences, and lay the foundation for the integration and reasoning of risk domain knowledge.

At present, ontology construction is mainly divided into manual and automatic methods. The artificial ontology method can ensure the reliability and practicability of domain ontology, but the ontology construction process takes a long time and is inefficient [29]. The automatic ontology construction method automatically constructs and expands the ontology by using technologies such as text extraction and machine learning. The risk domain ontology mainly describes the evolution of the risk knowledge network in the enterprise risk management process. This part of the knowledge mainly describes the knowledge of each stage of risk event prediction and prevention, risk event emergency plans, and risk event handling and has obvious contextual relevance. The risk domain ontology mainly describes the dynamics of enterprise risk, including the risk state transition and risk management process. In the enterprise risk management process, risks are usually driven by certain specific risk events and have corresponding social or economic impacts on a company. These impacts are spread through corporate social relationships. There are various sources of enterprise risk events, including the

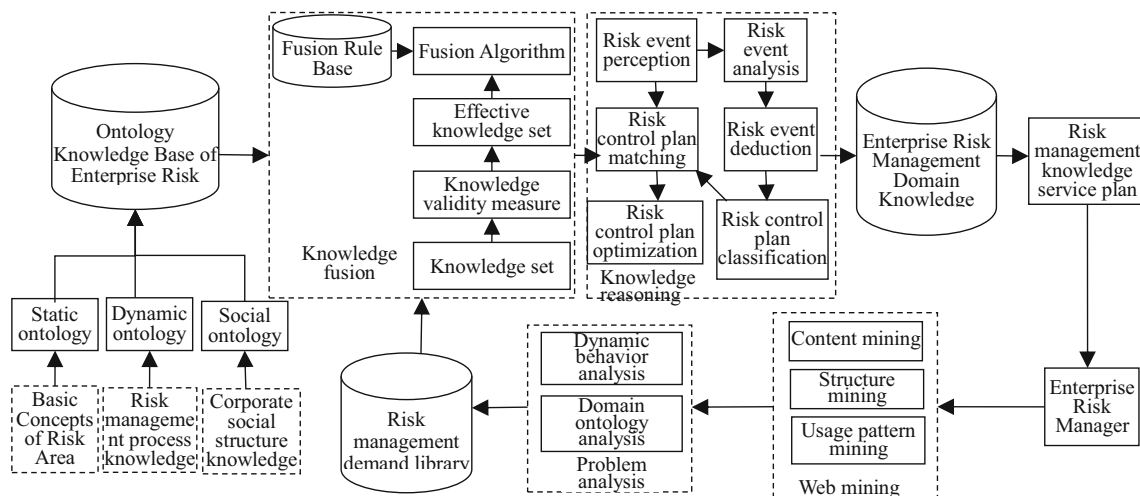


Fig. 7 Knowledge fusion and reasoning process at the knowledge organization layer

impact of the external environment of the enterprise, the accumulation of internal risks of the enterprise, the loss of control of enterprise risk management, and the defects of the enterprise culture or system. In order to improve the operability of semantic text, the IEEE Standard Upper Ontology (SUO) research group designed the SUMO ontological library that integrates government, economics, finance, and engineering. SUMO extracts and covers all entities in the objective world. The entities in SUMO include two major categories, namely, physical entities and abstract entities. Material entities are used to describe all things that exist in the objective world. Abstract entities are used to describe concepts or entities that do not exist in the objective world but can be abstracted through thinking. Drawing lessons from SUMO's description of domain entities, the top-level concepts of the risk management domain ontology include risk events, risk propagation, risk types, time dimensions, spatial dimensions, and risk prevention, as shown in Fig. 8. Risk events are the products of enterprise losses or failures caused by the accumulation of various risk sources in the production and operations of enterprises. Risk spread mainly describes the target of the risk spread of the enterprise, the attacked target, the path through which risk spreads, and the opportunities and challenges that the risk brings to the enterprise. The time dimension describes the start and end times of a risk event, the key nodes of the evolution of the risk, and the judgment

of the time of each stage of risk management. The spatial dimension mainly describes the spatial correlation, spatial agglomeration, and spatial heterogeneity manifested in the risk communication process. Among these components, the spatial correlation means that the relevant groups of the enterprise are affected by the risk event and show a certain correlation in space. If the directions are the same, the time is positively correlated; and if the directions are not the same, the time is negatively correlated. Spatial agglomeration represents the spatial agglomeration of corporate groups affected by risk events. Spatial heterogeneity means that the spatial volatility of the risk propagation process causes an uneven degree of impact on the relevant groups of enterprises. Risk prevention is the result of predicting and handling enterprise risk events after analyzing, summarizing, and mining the historical risk case database. Risk prevention mainly includes risk assessment, emergency resources, occurrence conditions, auxiliary measures, and prevention and control plans. The risk domain ontological knowledge base can discover the relationships between the ontological concepts of the risk domain so as to determine the rules of the occurrence, evolution, and propagation of enterprise risk events.

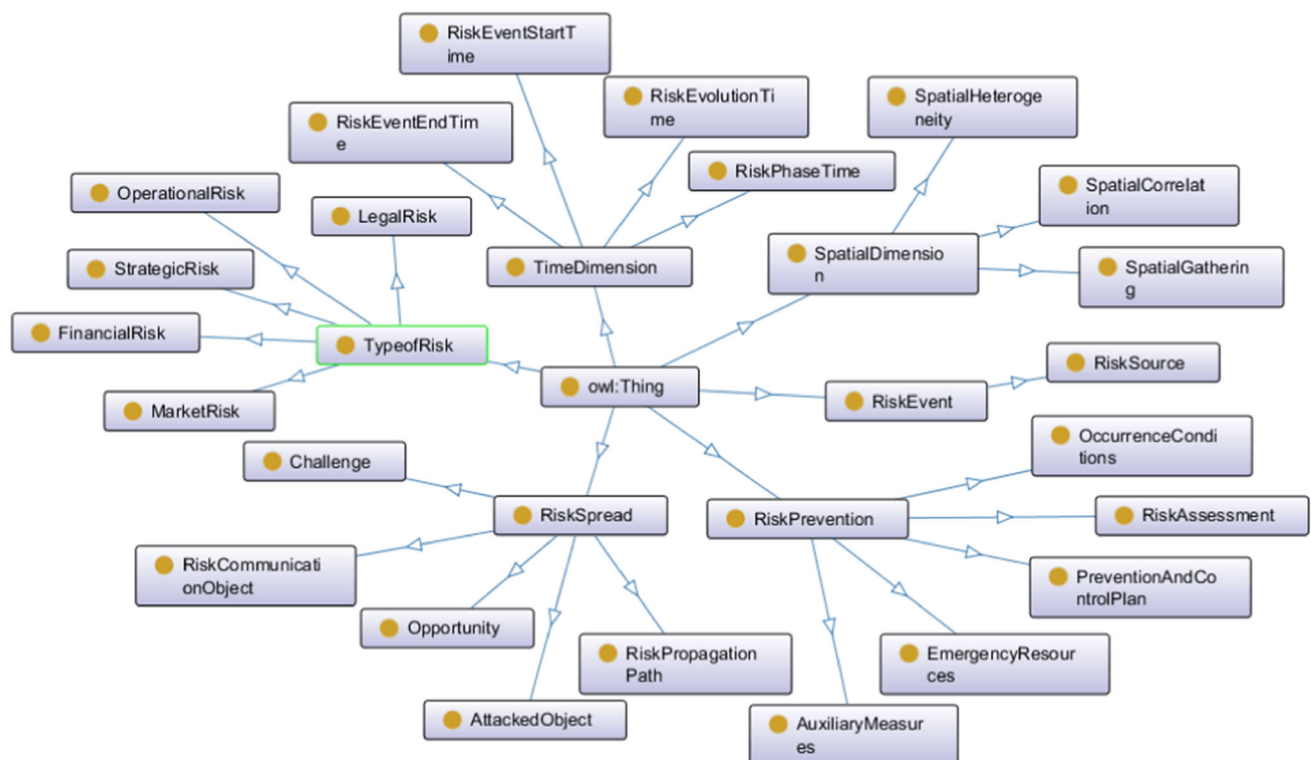


Fig. 8 Ontology knowledge base of enterprise risk domain

4.2.2 Knowledge integration in the field of corporate risk

Knowledge fusion in the field of risk management includes three parts: unified knowledge model construction, fusion processing, and derivative knowledge processing. The construction of a unified knowledge model is the cornerstone of knowledge fusion, and the selection of fusion algorithms is the key to knowledge fusion. The use of artificial intelligence and deep learning methods to process derived knowledge is an important means to improve the performance of knowledge fusion models [30].

In the big data environment, knowledge in the field of enterprise risk management presents a large amount of multisource heterogeneous characteristics, and building a unified knowledge model framework based on effective metaknowledge sets is the key to achieving knowledge fusion [31]. The knowledge graph is composed of concepts, entities, relationships, and attributes. Ontology provides a knowledge representation method for the knowledge graph of the risk management domain and is suitable for describing the potential relationships of knowledge in the risk management domain. Metaknowledge is knowledge about knowledge, which is used to describe the characteristics of knowledge elements in a knowledge graph and their characteristic values [32]. For example, in the knowledge map of the risk management domain, the metaknowledge set of the i th risk event is defined as: $KS_i = \{(C_1^i, E_1^i), (C_2^i, E_2^i), \dots, (C_n^i, E_n^i)\}$, where C_n^i is the n th characteristic attribute of the risk event knowledge, and E_n^i is the n th characteristic of the risk event knowledge. The attribute value of (C_n^i, E_n^i) is the metaknowledge of the i th risk event. In the knowledge fusion process of the risk domain ontological knowledge base and risk management requirement base, the method of combining ontology and knowledge elements is used to construct an initial metaknowledge set with a standard form, and the effectiveness of the initial metaknowledge set is measured with the help of semantic entropy. Then, an effective metaknowledge collection is formed. Fusion processing takes the effective metaknowledge set as the object, combines the fusion rules, and processes the effective metaknowledge set through fusion algorithms such as the ant colony algorithm, immune genetic algorithm, and neural network to form new knowledge. Derivative knowledge processing uses artificial intelligence and deep learning methods to perform derivative knowledge processing on the conditional constraint knowledge set and solution space knowledge set in the risk management demand database, thereby generating new knowledge and fusion rules, writing them into the knowledge base and rule database, and forming the dynamic knowledge fusion system with feedback function

that lays the foundation for further knowledge fusion and reasoning.

4.2.3 Knowledge reasoning in the enterprise risk domain

After the standardized representation and integration of knowledge, the system still cannot solve the actual risk management problems for the enterprise. The system requires reasoning operations such as knowledge classification, deduction and association mining to form a knowledge map in the field of enterprise risk management and provide strong support for an enterprise to provide efficient risk management knowledge services [33]. Knowledge reasoning in the field of enterprise risk management is essentially the knowledge query and knowledge discovery process based on a risk management knowledge graph, including the quantitative processing of graph knowledge, the semantic matching of graph knowledge, and the reasoning of graph knowledge. The quantitative processing of risk knowledge is based on the comprehensive consideration of the knowledge map structure of the risk management domain and the semantic information of the risk domain; and the entities, relationships and attributes in the map are mapped into easy-to-operate mathematical expressions. The semantic matching of risk knowledge quantifies the risk domain knowledge and adds the index of the nodes and edges in the graph to the existing semantic matching algorithm to realize the rapid matching of the risk management domain knowledge [34]. Graph knowledge reasoning includes two aspects. One aspect is based on knowledge acquisition and knowledge fusion. It fuses enterprise risk management needs and corresponding situations and discovers novel and unknown knowledge by studying the correlation between graph data in the knowledge base of risk management. Tacit knowledge, such as the evolutionary relationship between risk events, can solve risk management problems. The second aspect combines risk event analysis and risk event deduction to form the characteristics of risk management problems, obtain corresponding solutions from the enterprise risk management field case database, study the correlation clustering between the solutions and the risk management problems, match the model, and finally match the optimal risk control plan.

4.3 Enterprise risk domain knowledge service

The knowledge service layer is a risk management service module directly facing enterprise managers. The knowledge service layer uses information retrieval and knowledge reasoning techniques to perform knowledge calculations on the risk domain knowledge base in response to risk event prevention, risk event emergency

plans, and risk event handling at different stages of risk management needs and problems so as to provide enterprises with risk domains. Knowledge services occur in the form of knowledge graphs, intelligent analysis and the retrieval of risk knowledge, and the recommendation of risk solutions.

4.3.1 Knowledge navigation and knowledge graph service in the enterprise risk domain

The enterprise risk domain knowledge navigation service displays the domain knowledge elements related to the risk management domain knowledge elements in the risk management domain knowledge map in a navigable form so that the enterprise managers can quickly and conveniently obtain the risk management domain knowledge. Knowledge navigation services cannot only provide enterprises with outlined static navigation services in the conceptual hierarchical structure of the risk management field but also provide targeted guided dynamic navigation services based on specific risk management issues. This can effectively address the various types of enterprise risk management knowledge and the intricate and complex relationships between risk event knowledge and other characteristics to solve the lack of knowledge problem for enterprise managers.

The enterprise risk domain knowledge map service displays enterprise risk domain knowledge in an interactive and visual way by analyzing the evolutionary law and correlation characteristics of risk events [35]. The enterprise risk domain knowledge map service can describe the hierarchical structure of the risk domain knowledge and the semantic connections between the risk event knowledge and intuitively display the organizational structure and relevance of the risk domain knowledge so that the enterprise risk manager can quickly obtain the required risk domain knowledge, thereby promoting the association and sharing of knowledge in the field of enterprise risk.

4.3.2 Intelligent analysis and retrieval service of enterprise risk knowledge

The main function of enterprise risk knowledge intelligent analysis and knowledge retrieval service is to conduct semantic analysis of enterprise risk events and provide intelligent knowledge retrieval services based on the risk domain knowledge map. Enterprise risk knowledge intelligent analysis and knowledge retrieval services first perform semantic analysis on enterprise risk management issues, then perform knowledge graph queries on the resolved risk management issues, and feedback the query results to enterprise risk decision makers. Traditional information retrieval mainly uses keyword matching

methods to realize knowledge queries at the grammatical level and lacks the semantic understanding of enterprise risk domain knowledge. Knowledge retrieval requires the use of knowledge content in the enterprise risk domain and related paths between knowledge for retrieval. That is, on the basis of enterprise risk knowledge analysis, knowledge retrieval uses intelligent knowledge mining and semantic search technologies to provide enterprises with accurate retrieval results and realize the intelligent retrieval service of enterprise risk domain knowledge to meet an enterprise's demand for the retrieval of risk management knowledge.

4.3.3 Personalized recommendation of enterprise risk prevention and control plans

At present, most enterprise risk control network platforms lack personalized knowledge services for specific risk event handling solutions, and enterprise managers need to spend considerable time and costs to obtain knowledge of risk control solutions or they will suffer huge economic losses due to risk decision-making mistakes. The personalized recommendation service of enterprise risk prevention and control solutions mainly uses the advantages of knowledge graphs in semantic expression and knowledge reasoning; combines knowledge graphs with artificial intelligence, deep learning and other algorithms; and analyses the risks of enterprise risk events from the known risk event case database. The characteristics and evolutionary laws provide decision support for enterprise risk events in similar situations, thereby satisfying the knowledge needs of individualized plans for handling different risk events.

5 Application of an enterprise knowledge service model driven by risk events

5.1 Construction of a knowledge graph in the field of enterprise risk

The data sources of this article mainly come from data resources in the field of corporate risk collected by project partners; and through technologies such as web crawlers and information extraction, the risk data publicly disclosed by more than 3,800 listed companies in nearly 100 industries across the country are comprehensively integrated. The data include the risk disclosures information, risk cases, risk reports, and major event information such as litigation, financial restatements, and business plans of listed companies; various public information resources of enterprises, including business registration information, administrative penalties, corporate relationship

genealogical information, and government departments and other authorities, released by institutions, etc.; and data related to market sentiment, including the current mainstream risk control websites released news and public opinion, market trends, macro environment, policies and regulations and other data.

In the risk domain knowledge organization process, data cleaning and semantic disambiguation are conducted for more structured data, and the D2RQEngine semantic mapping method is used to convert relational data into Neo4J graph data format. Knowledge extraction technology is used for semistructured and unstructured data; the known enterprise risk domain ontological knowledge base is used as annotated data to complete the extraction of attributes, entities, and relationships (as shown in Fig. 9); and knowledge elements, neural networks, and other methods are combined to integrate effective knowledge elements. On this basis, this paper discovers new knowledge in the field of risk management through knowledge classification, deduction and association mining and other reasoning operations and stores the risk field knowledge in the Neo4J graph database to form a knowledge map of the enterprise risk management field (as shown in Fig. 10).

5.2 Intelligent analysis of enterprise risk events

Analyzing and summarizing the causes, evolutionary laws and prevention and control strategies of risk events are the effective way to improve the level of enterprise risk management. This paper uses the method of combining natural language processing and deep learning to analyse the descriptive information of enterprise risk events and extract

key risk knowledge elements such as risk elements, risk sources, risk stages, and countermeasures so as to form the knowledge source of the knowledge map of enterprise risk management. A knowledge map in the field of enterprise risk management not only provides comprehensive and powerful data support for the intelligent analysis of risk events but also provides a visual interpretation path for the analysis of the correlation between the various knowledge elements of risk events. Enterprise risk event intelligent analysis mainly includes the risk event profile, risk event intelligent search, and risk event correlation path analysis.

A user portrait is a modeling tool to describe the features of real users. It can use a series of data to describe behaviors such as user characteristics and preferences [36]. The risk event profile is centered on corporate risk events, characterizes the key knowledge elements of risk events by class entity attributes and their associated nodes, and comprehensively describes the characteristics of risk events. In the risk management knowledge map, the risk event profile can describe the risk source, risk event description, time of risk occurrence, risk reason, risk element, risk response measures, risk type, company and related information of the risk event, etc., as shown in Fig. 11.

The intelligent search for risk events first performs semantic analysis on the content to be searched, then uses the entity annotation model to map it to the entities and attributes of the enterprise risk domain knowledge graph, then uses the knowledge matching method to search in the graph semantic network, and finally returns the structured risk management knowledge required by the enterprise. For example, a user searches for the content “risks brought by

Enterprise Risk Event Knowledge Extraction

The outbreak of new coronavirus pneumonia in 2020, domestic provinces and cities have successively initiated major public health emergencies. The company attaches great importance to the epidemic prevention and control work, and resolutely implements and cooperates with the implementation of various government decisions and deployments. It is in Guangzhou After the epidemic prevention and control headquarters of various districts of the city announced that catering service units would suspend dine-in services and prohibit all gathering dining activities, dine-in services were temporarily suspended, and food sales and takeaway methods were retained to provide catering services. The company's catering business will be greatly affected during the duration of the epidemic. After the epidemic is over, it will take a certain period of time for market consumption willingness and intensity to be restored. The continued impact of the epidemic has not been determined, and the company will face the risk of annual operating performance and related businesses that will be affected by the epidemic.

Extract »

Knowledge Extraction Results

Risk Event: The risk of market consumption fluctuations caused by the nc

Risk Type: Operational Risk

Risk Source: Novel Coronavirus Pneumonia Outbreak

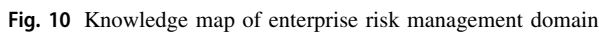
Risk Consequence: The company's operating performance and related business

Risk Measures: The company actively adjusted its operation methods; promoted takeaway and e-commerce sales; accelerated product innovation and launched differentiated products such as bon choi and quick-frozen dishes; actively controlled costs.

Begin Time: 2020

Submit

Fig. 9 Knowledge extraction of corporate risk events



domain, the entity relationship visualization knowledge network diagram of the search content is returned, and the entity-related information is displayed in the form of cards, as shown in Fig. 12.

An association path is in a complex network, and any two nodes can establish an association relationship through multiple intermediate nodes to form a path between nodes [37]. Risk event association path analysis analyses the association relationship between risk event entities from the enterprise risk domain knowledge map, discovers the developmental and evolutionary rules of risk events, and analyses the characteristics of the intermediate associated entities so as to explore the possible risk management



Fig. 11 Portrait of corporate risk events

problems of the enterprise. According to the length of the corporate risk event correlation path and the intermediate associated entity objects, the risk event correlation path can

be constructed arbitrarily. If the associated path length of the enterprise risk event is 2, the number of intermediate entities is 1, and the type of intermediate entity is an enterprise, then the graph database query statement “MATCH t = (a1: riskEvent)-[r1]-(a2:company)-[r2]-(a2: riskEvent) RETURN t”, the query result is shown in Fig. 13 (green represents the enterprise, red represents the risk event). It can be seen from the figure that as the number of risk events associated with an enterprise increases, the greater the number of associated risk events, and the greater the number of enterprise risk issues; therefore, the enterprise should strengthen risk management.

5.3 Intelligent decision support for enterprise risk management

Enterprise risk management intelligent decision support is the key to accurate risk control. It is essentially similar to a risk intelligent question-and-answer system, which receives problems in the enterprise risk domain and returns corresponding solutions [38]. With the help of the risk domain knowledge map, the enterprise risk management intelligent decision support system can extract the

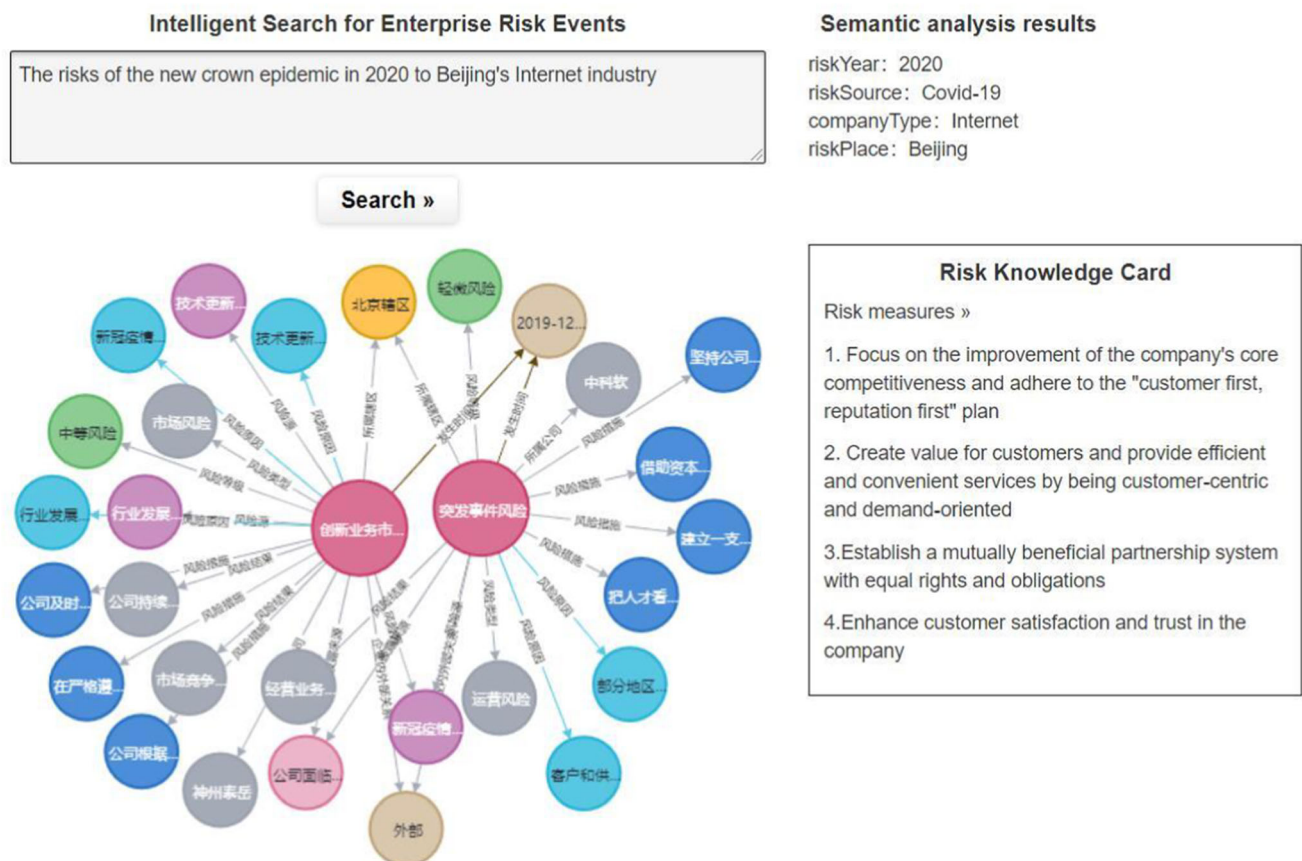


Fig. 12 Intelligent search for risk events

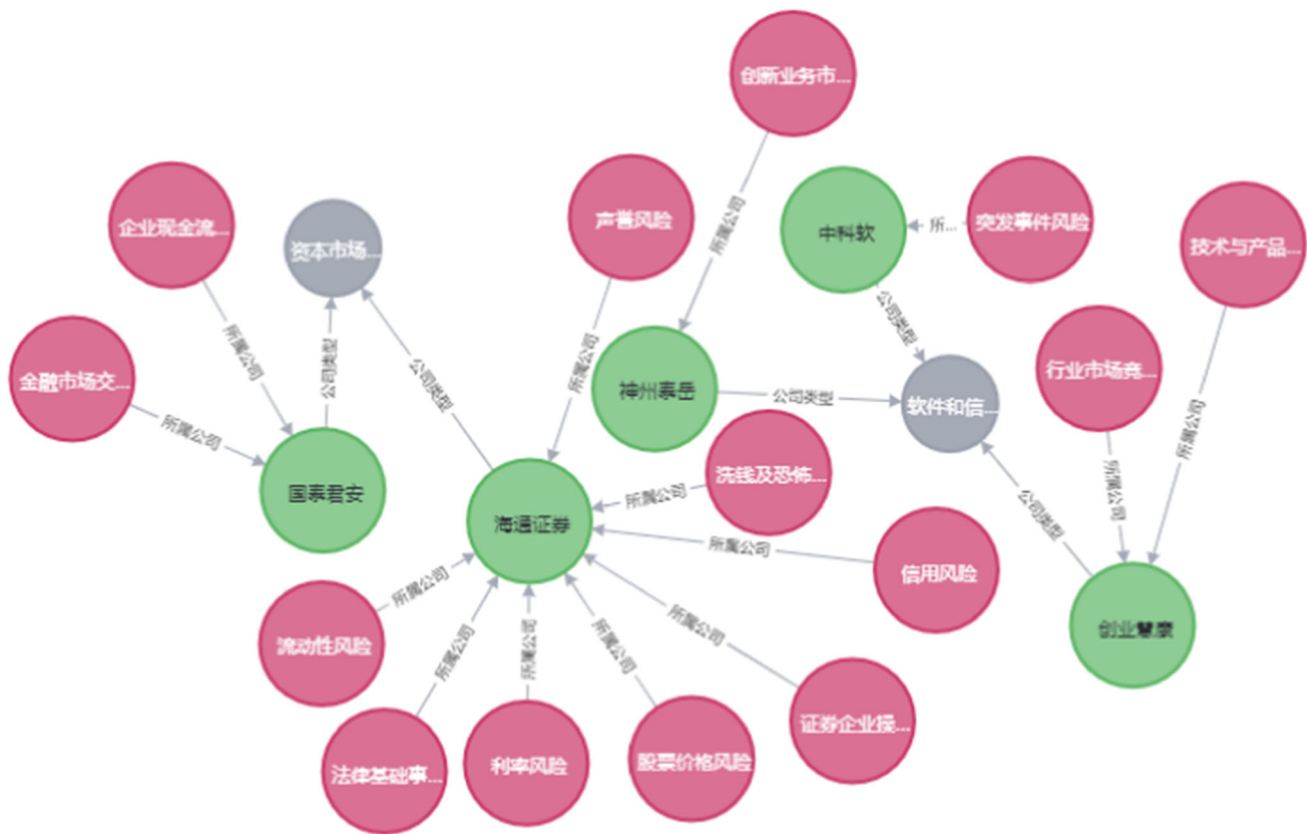


Fig. 13 Correlation path analysis of enterprise risk events

enterprise risk event source, risk factor, event cause, and other knowledge element data based on the current risk event description information; match similar risk events based on the risk knowledge element; predict and evaluate this risk event through known similar risk event cases and give recommended risk management solutions. Furthermore, it can also analyse and verify the risk control plan of enterprise risk decision makers to avoid the misjudgment of major risk events. For example, at the beginning of 2020, Baotou Iron and Steel Co., Ltd. was affected by the epidemic, the market stocks of steel were severely overstocked, and the company's products were difficult to ship, which adversely affected the company. In response to this risk event, the enterprise risk management intelligent decision support system can extract risk knowledge elements from it, such as the occurrence time of the risk event: 2020, the risk industry: steel, the source of risk: the epidemic, the steel inventory backlog, the difficulty of product delivery, etc. Then, according to the above risk knowledge elements, the system can give a risk management solution, as shown in Fig. 14. The figure shows that this risk event is an operational risk caused by the epidemic. The company can combine inventory and market demand to implement a blast furnace production reduction plan in the early stage. Furthermore, this risk may cause the company's stock price

to fall and lead to market risks. The company should attach great importance to the impact of stock price fluctuations to avoid major risks. Therefore, an efficient enterprise risk management decision support system cannot only alleviate the pressure on risk control decision makers but also realize accurate risk assessment and personalized recommendation of risk control solutions.

6 Conclusion

The identification and handling of enterprise risk events plays an important role in maintaining the stability of the market economy environment and is highly valued by the state. The report of the 19th National Congress of the Communist Party of China stated that it is necessary to improve the enterprise risk management system and protect the bottom lines of enterprises to not cause major systemic risks. In the big data environment, enterprise risk data present the characteristics of large capacity, frequent interaction, and multisource heterogeneity. This makes enterprises and risk control personnel establish higher requirements for knowledge services in the risk domain. At present, the knowledge service model in the field of enterprise risk has problems such as insufficient knowledge

Enterprise risk event description

At the beginning of 2020, Baotou Iron & Steel Co., Ltd. was affected by the epidemic, and the market stocks of steel were severely overstocked. The company's products were difficult to ship, which adversely affected the company.

Search »

Semantic analysis results

riskYear: 2020
companyType: Steel
riskSource: Epidemic, steel
inventory backlog, product
delivery difficulties

Enterprise Risk Management Intelligent Decision Support

Possible types of risks: » Operational risk

Risk solution:

» The company can combine the inventory situation and market demand to implement the blast furnace production reduction plan in the early stage

Associated risk analysis:

» This risk may cause the company's stock price to fall and cause market risks. The company should attach great importance to the impact of stock price fluctuations to avoid major risks.

Fig. 14 Intelligent decision support for enterprise risk management

organization and processing capabilities, a low level of intelligence in risk management, and ignoring the rich knowledge relevance between risk events. Based on this, this article explores the enterprise risk management knowledge service model driven by risk management issues at different stages such as risk event prevention, risk event contingency plans, and risk event handling. The system mainly includes the enterprise risk domain knowledge acquisition layer, knowledge organization layer, and knowledge service layer. The first two layers address enterprise risk knowledge, and the last layer emphasizes risk management knowledge services in addition to knowledge processing. This article first analyses the relationship between risk management and knowledge services, risk events, drivers, and knowledge services. Based on this, the article proposes a risk event-driven knowledge service model and elaborates on the construction of an ontological knowledge base in the field of enterprise risk management and multisource heterogeneity. Knowledge fusion and reasoning is conducted between knowledge bases. In response to problems in the field of enterprise risk management, this article proposes a knowledge service plan in the form of risk domain knowledge graphs, risk knowledge intelligent analysis and retrieval, and risk control plan recommendations. Finally, this article gives a concrete practical case of the application of an enterprise risk management knowledge service.

This article has a certain referential value for the acquisition, organization, and application of enterprise risk management knowledge driven by risk events, but there are

still some problems to be further studied. First, it is necessary to enrich the knowledge service model in the field of enterprise risk management to further realize the value of enterprise risk big data. Second, it is necessary to conduct in-depth research on specific issues in the field of enterprise risk management and give full play to the enterprise risk management knowledge service model to prevent and control enterprise risk and play an assisting role.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

References

1. Yabing Li, Yue Xia (2021) Identification and evaluation of the risk of retail enterprise business model innovation under the new crown pneumonia epidemic[J]. *Statist Decis* 37(2):163–167
2. Baichen Yang, Yi Zhang, Wei Guo (2021) Research on financial distress diagnosis of enterprises based on logistic regression model[J]. *J Syst Sci* 29(3):84–87
3. Zhongyi Wang, Rong Huang, Xin Zheng et al (2019) Research on the multi-granularity integrated knowledge service in digital libraries[J]. *J China Soc Sci Tech Inform* 38(2):143–158
4. Cheng G, Wu DM (2018) Research on knowledge service mode of knowledge innovation in scientific and technological small and medium-sized enterprises[J]. *Info Stud Theory Appl* 41(4):38–43

5. Wang F, Ding YF, Zhou XM et al (2015) Design and Implementation of Knowledge Service Platform for Enterprises[J]. *J Intell* 34(8):204–207
6. Li Z Y, Ding X, Liu T. Constructing narrative event evolutionary graph for script event prediction[C]// Proceedings of the 27th International Joint Conference on Artificial Intelligence, California: International Joint Conferences on Artificial Intelligence Organization, 2018: 4201–4207
7. Li SP (2020) Construction of enterprise risk control system[M]. China Industry and Information Publishing House, Beijing
8. Kathryn Schumann-Foster, Elias Semaan, Hui Sono. The local market perception of firm risks during cross-listing events[J]. *Social Science Electronic Publishing*, 2020, 55(2):221–246.
9. Yang JP, Peng XB, Liao TT (2015) Network heterogeneity, knowledge heterogeneity and new venture innovation[J]. *Info Sci* 33(4):40–45
10. Ning FW, Feng JW (2012) The risk evaluation model of high-tech enterprise information management[J]. *Info Stud Theory Appl* 35(9):98–102
11. Alaka HA, Oyedele LO, Owolabi HA et al (2018) Systematic review of bankruptcy prediction models: towards a framework for tool selection[J]. *Exp Syst Appl* 94:164–184
12. Esposito Christian, Ficco Massimo, Palmieri Francesco, Castiglione Aniello (2015) A knowledge-based platform for big data analytics based on publish / subscribe services and stream processing[J]. *Knowl Based Syst* 79:3–17
13. Yusoff MNH, Zainol FA, Ismail M et al (2021) The role of government financial support programmes, risk-taking propensity, and self-confidence on propensity in business ventures[J]. *Sustainability* 13(1):380–380
14. Zhang T, Li G, Cheng TCE et al (2020) Consumer inter-product showrooming and information service provision in an omnichannel supply chain[J]. *Decis Sci* 51(5):1232–1264
15. Mai G C, Yan B, Janowicz K, et al. Relaxing unanswerable geographic questions using a spatially explicit knowledge graph embedding model[C]// Proceedings of the 22nd AGILE Conference on Geographic Information Science. Cham: Springer, 2020: 21–39.
16. Shravan Kumar B, Ravi Vadlamani (2016) A survey of the applications of text mining in financial domain[J]. *Knowl Based Syst* 114:128–147
17. Tang XB, Tang ML, Li SX et al (2020) Research on knowledge aggregation model based on risk phrase mining[J]. *Info Stud Theory Appl* 43(8):152–158
18. Kardara M, Papadakis G, Papaioikonomou A et al (2015) Large-scale evaluation framework for local influence theories in Twitter[J]. *Info Process Manage* 51(1):226–252
19. Francisco J, Poblacion G (2017) Financial Risk Management[M]. Springer International Publishing, Berlin
20. Ping Ke (2021) Emergency knowledge management: theoretical basis, research field and application prospect[J]. *J Info Resour Manage* 11(1):8–16
21. Liu W, WenboQiao Y, Wang ZX (2021) Patent transformation opportunity to realize patent value: Discussion about the conditions to be used or exchanged. *Inf Process Manag* 58(4):102582
22. Davenport TH, Barth P, Bean R (2012) How big data is different. *MIT Sloan Manage Rev* 54(1):43–46
23. Chen GQ, Zeng DJ, Wei Q et al (2020) Big data behavioral research trends: a time-space-connection perspective[J]. *Manage World* 36(2):95–105
24. Tang XB, Liu GC (2018) Research on financial knowledge service model based on two-tier knowledge fusion [J]. *Res Lib Sci* 16:79–85
25. Tsai MF, Wang CJ, Chien PC (2016) Discovering finance keywords via continuous-space language models[J]. *ACM Transact Manage Info Syst* 7(3):1–17
26. Lee CH, Geng X, Raghunathan S (2016) Mandatory standards and organizational information security[J]. *Infor Syst Res* 27(1):70–86
27. Kim H (2017) Building a K-Pop knowledge graph using an entertainment ontology[J]. *Knowl Manage Res Practice* 15(2):305–315
28. Tang XL, Xiao MQ, Hu B et al (2018) Exchanging knowledge for testbased diagnosis using OWL Ontologies and SWRL Rules[J]. *Procedia Comp Sci* 131:847–854
29. Tang XL, Ma FC, Fu WG et al (2019) Research on financial knowledge representation and risk identification from knowledge connection perspective[J]. *J China Soc Sci Tech Info* 38(3):286–298
30. Smirnov A, Levashova T, Shilov N (2015) Patterns for context based knowledge fusion in decision support systems[J]. *Info Fusion* 21(1):114–129
31. Hajek Petr, Henriques Roberto (2017) Mining corporate annual reports for intelligent detection of financial statement fraud—a comparative study of machine learning methods[J]. *Knowl Based Syst* 128:139–152
32. Song M, Zhao W, HaiHong E (2020) KGAnet: a knowledge graph attention network for enhancing natural language inference. *Neural Comput Appl* 32:14963–14973
33. Lin J, Zhao Y, Huang W et al (2021) Domain knowledge graph-based research progress of knowledge representation. *Neural Comp Appl* 33:681–690
34. Kraus M, Feuerriece S (2017) Decision support from financial disclosures with deep neural networks and transfer learning[J]. *Decis Support Syst* 104(10):38–48
35. Wang Qi, Ji Yuede, Hao Yongsheng et al (2020) GRL: Knowledge graph completion with GAN-based reinforcement learning[J]. *Knowl Based Syst* 209:1–8
36. Răbiger S, Spiliopoulou M (2015) A framework for validating the merit of properties that predict the influence of a twitter user[J]. *Exp Syst Appl* 42(5):2824–2834
37. Jia Y, Wang Y, Jin X et al (2018) Path-specific knowledge graph embedding[J]. *Knowl Based Syst* 151:37–44
38. Cai W, Cao J (2015) A method of fuzzy case-based reasoning emergency decision-making for unconventional emergency based on knowledge management[J]. *Soft Sci* 29(9):135–139

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