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Research Article

Research on Intelligent Power Marketing Inspection Model Based on Knowledge Graph

Jinghua Wang,[1,2] **Bingxu Chen**,[1] **Yue Wang**,[1] **Zihan Xu**,[1] **and Wanru Zhao**[1]

[1]*State Grid Shanghai Municipal Electric Power Company, Shanghai 200030, China*
[2]*Shanghai Jiao Tong University, Shanghai 200030, China*

Correspondence should be addressed to Jinghua Wang; jane950110@sjtu.edu.cn

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The traditional topic-based auditing model lacks the ability of multi-object and multi-abnormal correlation auditing, which makes it impossible to solve the multi-scenario and multi-factor correlation-based auditing problem. This paper designs an intelligent power marketing audit model based on a knowledge graph. First, an entity identification and relationship extraction method for power marketing business based on NLP (natural language processing) and sequence annotation technology is proposed, and the description content is imported into the knowledge graph database; then, semantic disambiguation and knowledge are carried out by using bidirectional encoder representation from transformers (BERT). Link to build a knowledge map of business audit rules: Finally, an experimental analysis is carried out by taking the copying and receiving business with a large business volume in the marketing audit work as an example, and it is verified that the proposed model can effectively improve the information analysis ability and the audit accuracy of the audit work.

1. Introduction

As a basic work of power supply enterprise, power marketing audit plays a very important role in ensuring the economic market order of power enterprises and improving their economic interests [1]. It is not only related to the survival and development of the power supply enterprise itself, but also directly affects the smooth operation of the entire power system and even determines whether the national economy can continue to develop rapidly [2]. The development process over the years can be roughly summarized into the following three stages. The first stage: According to the work experience, conduct random inspection of the marketing business, the main purpose is to find problems. The second stage: Based on the statistical sampling technology, referring to the business audit scoring system, the overall marketing business is audited, and the main purpose is to evaluate the marketing business of each department. The third stage: Build a three-in-one audit system, including online audit, sampling audit, and special audit, to supervise the quality of marketing business from different dimensions, the main purpose is to reduce the problem rate of marketing business to the greatest extent and improve the level of marketing business.

However, with the continuous acceleration of smart grid construction, the business scope of power marketing is more extensive [3]. The current electric power inspection work faces some difficulties, such as the traditional inspection work mode can no longer meet the requirements of current social development, and there are still problems such as backward inspection methods and low efficiency. Therefore, effective measures must be taken to solve these problems. It is necessary to reform and innovate it, use intelligent inspection to improve the continuity and integrity of marketing inspection work, and promote the continuous improvement of marketing management level [4].

As a new type of semantic network analysis technology, knowledge graph connects all knowledge points in series through the correlation between things, displays them in the form of graphs with different structures, and has significant information analysis capabilities [5–7]. In this paper, the construction of an intelligent power marketing audit model

based on knowledge graph is introduced by taking the copy-checking and collection business with a large business volume in the marketing audit work as an example. According to the traditional marketing audit sampling plan, this business will be allocated more audit samples, so it must invest more manpower and material resources. However, because the sample problem rate of this business is relatively low, most of the audit personnel's time is spent checking samples without problems, resulting in a waste of human resources. Through the use of deep learning algorithms to complete knowledge identification and extraction, realize the construction of business audit rules knowledge map, greatly improve the accuracy and control efficiency of this marketing business audit, and effectively ensure the management ability and work efficiency of business audits.

The main contributions of this paper are the following triple:

(1) Propose an entity identification and relationship extraction method for power marketing business based on NLP natural language processing and sequence labeling technology, break through the original audit topic labels, and realize the construction of a three-dimensional label database that combines the basic attributes of customers with hierarchies and classifications.

(2) Carry out semantic disambiguation and knowledge linking based on bidirectional encoder representation from transformers (BERT), generate a knowledge map of business audit rules, check and analyze business content according to its own search rules, and realize intelligent management and control of audit business.

(3) According to the constructed intelligent power marketing audit model based on knowledge graph, take the copying and receiving business with large business volume in marketing audit work as an example to carry out experimental analysis to verify that the proposed model can effectively improve the information analysis ability of audit work.

2. Status Quo of Electric Power Marketing Business Inspection and Research

2.1. Current Status of Research on Extraction of Knowledge Elements in Power Marketing Business Inspection. The research of foreign experts and scholars on power marketing audit management mainly focuses on the mode of marketing audit and the division of supervision power [8]. After research, Li et al. concluded that the functions of power inspection mainly include: inspection, investigation, and execution [9].

The degree of marketization of electricity in the United States is relatively high, and the state-level government enjoys great autonomy. Therefore, the supervision of marketing activities in the United States is not unified by the state, but each state conducts it separately under the guidance of national laws. This model makes the marketization of the power industry very deep, but it is not conducive to the overall regulation and management of the power grid [10].

From the perspective of foreign advanced power companies, some power companies with advanced management have incorporated marketing audit work into their daily marketing work, and rely on the strong support of information systems to effectively monitor data [11]. For example, the marketing information system of Tokyo Electric Power Company of Japan is inclined to the checking of relevant data and logic, and through the automatic review and judgment of the system, the correctness of business execution is ensured [12]. Due to the different business environment of foreign power companies, customers have less breaches of electricity usage and electricity theft, and the internal management of power supply companies is relatively complete. Considering the operating costs, they rarely consider setting up special inspection departments. The inspection of the industry mainly focuses on the supervision of the legal operation and service quality of the electric power enterprises by the electric power supervision department. Of course, in the foreign situation, through systematic analysis and design, streamlining business categories and simplifying business processes is also the key to improving the quality of marketing work [13].

In China, the State Grid Corporation of China was formally established on December 29, 2002. Its main business is power network operation and power market sales. It is mainly engaged in power transmission, and is responsible for voltage conversion, user power distribution, wholesale power sales, and other businesses. It is closely related to the country. The important state-owned backbone enterprises of energy security and national economic construction are the guarantee for the stable development of the national economy and society. The current development of my country's power industry has entered a new stage, and the market-oriented reform will be further accelerated. However, the current level of power marketing in our country cannot meet the needs of the development of the times, the development of demand-side response is not in place, power companies have not deeply studied the potential information of users, lack the necessary system support technology, and lack a perfect service system and user behavior analysis methods. We need to change marketing concepts, adjust marketing strategies, and study new marketing models to meet market demands [14].

The power marketing audit work is in the early stage, but the power enterprises have realized that in the current process of power system reform, the power marketing audit work, as a business control within the enterprise, is particularly important for the improvement of their own management quality [15]. In recent years, electric power companies have also attached more importance to marketing audit work, but it is only a staged and temporary work arrangement. Marketing audit has not been deeply studied and implemented as an independent topic, and a scientific and systematic management system has not been formed. Therefore, there are still many problems. For example, the closed-loop management of marketing audit work is not in place, and there is a lack of tracking and monitoring of the

work. Many of the problems found have not been solved in the end [16]; there is no effective real-time monitoring system for key business windows and front-line service specifications; it lacks a powerful online inspection function and fails to plug loopholes from the source [17]; at the same time, in the face of the ever-expanding mass of customer information and data, it is impossible to pass the traditional method. Effective inspections are carried out manually, and there are problems such as the lack of a professional work team.

In order to solve the work bottleneck of power marketing audit, in 2009, the State Electricity Regulatory Commission issued the "Opinions on Further Doing a Good Job in Electric Power Marketing Audit," requiring that the marketing audit work of power supply enterprises should be increased in all power systems and properly handled in accordance with the laws and regulations. Electricity violations of laws and regulations can comprehensively and effectively maintain the order of the electricity market [18]. On the basis of the theoretical research on marketing audit, State Grid Corporation has issued a series of guiding documents on marketing audit to guide the power supply enterprises in various provinces and cities to strengthen the construction of marketing audit, strive to improve the level of information management, and establish a unified power marketing audit and monitoring platform.

2.2. Research Status of the Construction of Power Marketing Business Inspection Rule Map. Through the vigorous promotion and widespread use of smart meters and power consumption information collection systems, researchers have a large amount of user power consumption data to carry out management and operation decisions based on power data analysis and optimize power supply services [19]. However, in the operation and maintenance business of the domestic power sector, most power sectors use traditional statistical analysis methods or simple threshold determination to detect abnormalities. This method has great limitations. Not only is it difficult to detect the event information contained in abnormal electricity consumption data, but the utilization rate and accuracy of electricity consumption data are also low. The earliest prototype of the knowledge graph was developed from the ontology knowledge base. With the development of time, the World Wide Web appeared, and the concept of data link was introduced, which made the nodes in the semantic web linked and formed a network-like structure. The concept of knowledge graph was formally proposed by Google in 2012 [20]. It is a semantic network knowledge base that stores, uses, and displays existing knowledge in the form of a structured multi-relationship graph. By fusing multiple entity-relationship triples, a multi-relationship graph containing multiple different entity nodes and multiple types of relationship edges is formed, that is, a knowledge graph. The existing larger knowledge graphs include the English Google Knowledge Graph, and the data comes from Freebase, CIA's World Profile and Wikipedia, etc.; the Chinese General Encyclopedia Knowledge Graph (CN-DBpedia) proposed by Fudan University [21], the data comes from many encyclopedia websites. The above knowledge graphs are all general domain knowledge graphs, and in recent years, research on the construction of domain knowledge graphs has also been widely carried out in the fields of power grid, medicine, and finance.

In the field of electric power, Meng et al. [22] used dependency parsing combined with rules to extract entity-relation triples in the electric power field. Based on the domain dictionary combined with the remote knowledge base, this paper aligns the entity-relationship triples of the encyclopedia corpus, uses the LTP tool to perform Chinese word segmentation, part-of-speech tagging and constructs the dependency syntax table, combines the rules to mine entity triples, and constructs the domain knowledge of power dispatching Atlas. Finally, Neo4j is used for storage, and the visualization page that comes with the graph database is used to display the knowledge graph structure. Based on the power user dictionary, Ref. [7] used syntactic information combined with part-of-speech association rules to analyze the main parts and components of the power transformer operation regulations. Knowledge extraction is performed for corresponding operations, a knowledge graph of power transformer operation specifications is constructed, and Neo4j is used to store it; in [23, 24], authors used deep learning and conditional random field model for entity extraction, and uses attention mechanism combined with bidirectional threshold recurrent neural network for relation extraction, build a power dispatching knowledge graph, and use the Redis database for storage.

3. Marketing Business Audit Rules Information Collection

To construct digital audit rules, first of all, we must collect and sort out the business audit information content required by the enterprise, and complete the work of entity extraction and relationship mining. For the marketing business, because the tasks undertaken by each department have a certain degree of dispersion and independence, it is necessary to collect scattered management rules in a unified database. The internal digital audit rules of each department are systematically copied and extracted, sorted by department, and the data is preprocessed according to the content of the business rules of the data processing system.

After integrating all the normal digital audit rules, the relationship mining of business rules is carried out. According to the audit theme and core rules formulated by the enterprise, relevant audit rules matching the theme core rules are formulated. In the business rule database, relevant keywords are extracted according to the content requirements of the rules and sorted according to the degree of association. The associated business rules construct the association relationship according to the business rules to which the keywords belong. The knowledge map information business relationship is shown in Figure 1.

The above analysis tentatively builds the connection between digital audit rules. To make the knowledge map of digital audit rules intelligent, it is necessary to use relevant

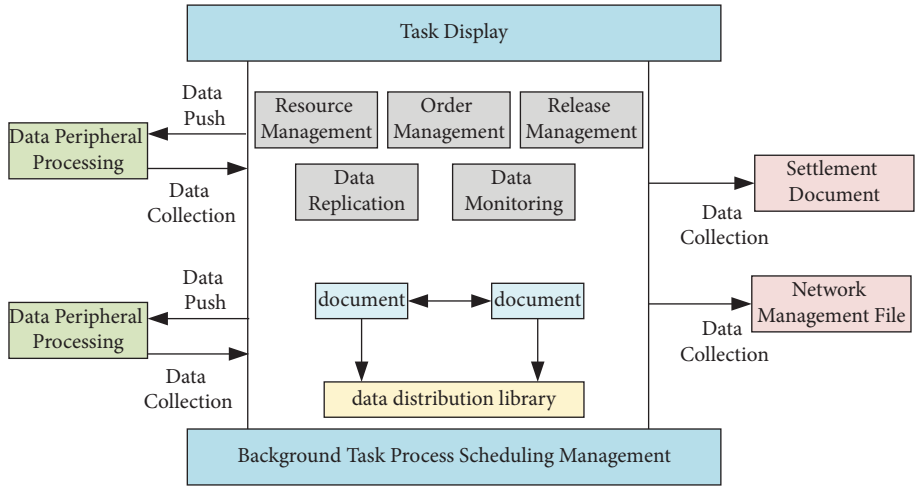

Figure 1: Knowledge graph information business relationship.

languages to describe the content and keywords of business rules. The content of the initially generated digital audit rules with associated relationships is retrieved through the system retrieval program to retrieve the relevant description content and participate in the knowledge map of the digital audit rules, which helps to make the knowledge map more intelligent.

4. The Construction of Intelligent Power Marketing Inspection Model

The construction process of the intelligent power marketing inspection model based on knowledge graph includes three main links: knowledge element identification, relationship analysis, and inspection rule graph construction.

4.1. Knowledge Element Identification and Relation Extraction of Power Marketing Business Audit Rules. Use natural language processing (NLP) and deep learning model algorithms to perform entity recognition on digital audit knowledge. The digital audit rule information source collected and sorted in the early stage is transmitted to the data processing system. The system data processing program first determines the content knowledge entity from the business rule content, extracts the keyword features of the determined knowledge entity, mainly including lexical features, language features, and related features, gives relevant descriptions of knowledge entities according to the characteristics, and then marks the description information as the content of knowledge entities accordingly.

NLP is mainly responsible for the mutual conversion of business rule content with relevant language descriptions in computer language and natural language, so as to realize natural language communication between humans and machines. Identify and analyze knowledge entities in knowledge graphs based on natural language processing technology. Knowledge entity recognition usually builds a knowledge map of digital audit rules based on related dictionaries, and the related dictionaries of business audit rules can be selected as the identification basis. The key words in the dictionary and their related features are introduced into the recognition program, and then the deep learning algorithm is used to realize the association operation of the power marketing business rules knowledge graph sample information data. The relationship between knowledge entities and related terms is determined based on the degree of association obtained by the operation. The keyword feature determination formula of knowledge entity and relationship recognition operation is as follows:

$$s = \left\{ \begin{array}{ll} 1, & e = E \\ 0, & e \neq E \end{array} \right\}. \tag{1}$$

In formula (1), s represents the feature determination result of the word, e represents its corresponding description feature, and E represents a related word. The closer the operation result is to 1, the higher the correlation between the two words, and the stronger the relationship between words. Then calculate the frequency of the word appearing in the document or web page to which it belongs. The formula is as follows:

$$P = c_i n_i \times \log \frac{W}{t_i}. \tag{2}$$

In formula (2), P represents the frequency of the word appearing in the document or web page to which it belongs, $c_i n_i$ represents the number of times the word c_i appears in the document or web page n_i, W represents the total number of documents in the knowledge graph database, and t_i represents the occurrence of the word c_i in the document. Related vocabulary tree: According to this formula, the importance of vocabulary and related documents can be obtained, and then the relationship between multiple documents can be obtained.

Based on the feature method, the relationship recognition and judgment of key words are carried out, and the obtained feature recognition result is shown in Figure 2.

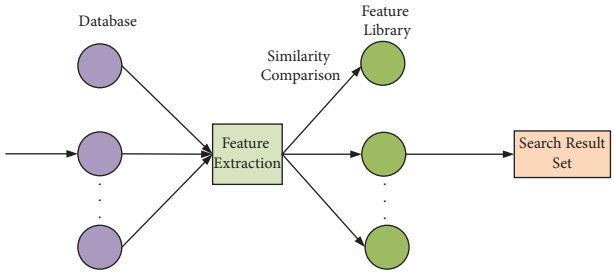

Figure 2: Feature recognition results.

It can be seen from Figure 2 that there is language processing and relationship recognition between the acquired knowledge entity vocabulary and its related vocabulary and documents. Taking knowledge entity language as the analysis object, various recognition methods such as character features, part-of-speech features, and meaning content are selected according to the description features. More specifically, the characteristic relationship can be determined based on the relevant vocabulary classification in the digital auditing rules, such as person name, place name, institution name, and professional work vocabulary. The key words or languages of the knowledge graph of digital audit rules mainly include audit targets, problem descriptions, quick output, audit topics that match the audit targets, and business control rules.

Based on the descriptive features, analyze the feature recognition of related words and sentences, infer the nature of the relationship between the two, give the definition of the relationship, add the description of the related entry, and the subordinate documents of both parties participate in the establishment of the relationship map between the two words or languages. For the determination of the content relationship of the document, it is necessary to take the correlation degree of the two sides of the keyword as the starting point, integrate the determination results of the relationship description in other languages and the relationship judgment results, establish the relationship, and annotate the relationship description entry.

4.2. Construction of Knowledge Map for Power Marketing Business Inspection. After the knowledge feature extraction and relationship identification of the power marketing business audit rules are completed, the relationship processing data resources between them are integrated into the construction of the knowledge map of digital audit rules. The knowledge entity information and related data after analysis and processing are divided according to a certain relationship, and imported into the model building system database in batches. The system uses Cypher language to write the framework program of the vocabulary and document relationship model. Cypher can perform key description queries on associated nodes and all relational features in vocabulary or documents on the system resource database and the Internet platform, and based on the retrieved relational results, further improve the relational network and relational description between words. The layers are progressive, and a network of interconnected relationships is established. At the same time, Cypher can also individually judge the degree of association between them according to the queried relational information, and construct relational networks with different degrees of closeness according to the degree of association. Therefore, after the user uses this knowledge graph, the system will recommend the information content with a greater degree of relevance according to the degree of relevance between the search keywords, while the number of recommendations for other content will decrease in turn according to the degree of relevance, and the user can enjoy the relative individuality, and intelligent retrieval services. In addition, the graph is in a synchronous connection state in the system database, the retrieval content will be associated and recorded, the input information resources will be updated constantly, and the knowledge graph will be maintained in real time, ensuring that the business audit rules and related work content of the enterprise unit are recorded truly and completely.

At the same time, the digital audit based on the knowledge graph has an inspection function, which can check and analyze the business content according to its own search rules. For the problematic parts, it can automatically point out errors, modify and correct, intelligently analyze the original information of the audit work order and the description of the reasons for the audit, and propose the audit. Verification steps, guidelines for rectification measures and other feedback information, judging the type of cause of abnormal situation, labeling the cause of the problem, assisting business personnel to operate, improving the efficiency of inspection rules creation and maintenance management, providing intelligent support for business management and control, using Python language to train knowledge graphs module operation. Figure 3 shows the workflow of digital inspection based on a knowledge graph.

Select the quarterly business work order of the enterprise as the experimental object to conduct problem inspection to examine the problem type. The content of the company's business work order and other information resources are sent to the knowledge graph processing system. Through vocabulary extraction, classification, and feature extraction, the relationship between vocabulary and language based on their respective characteristics and related descriptions is described and marked, and then the business rules are tested through the information dataset. Whether the content of the information is correct can be used to determine whether there is a problem with the work order information. The knowledge graph system internally judges the content of the information about the degree of association between different files or words based on its keywords and relationship descriptions. If there is a problem, mark the cause of the problem, and finally display it through the user. The interface outputs the test results.

5. Experimental Study

In order to test the practical application effect of the intelligent power marketing inspection model research based

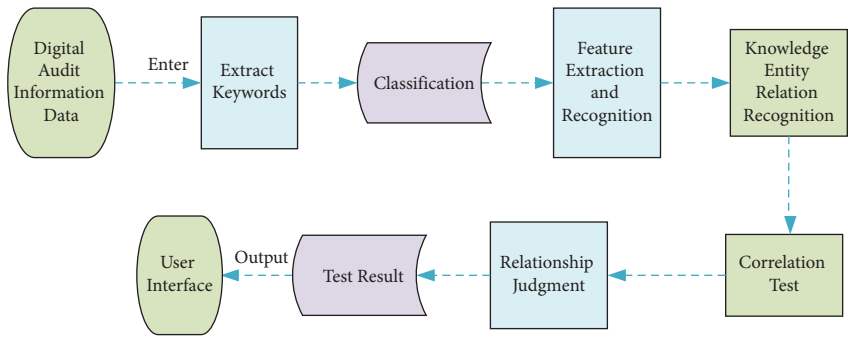

Figure 3: Digital audit workflow based on knowledge graph.

Table 1: Data information.

Abnormal electricity bill	Label
Community supporting charges are not standardized	Inaccurate billing standards Charges are not timely Inconsistency in the amount charged The supporting fee is not implemented for the newly built public-transformation station area Inaccurate billing standards
Abnormal charges for high reliability power supply	Receivable but not received Excess charge Wrong fee type Receivables do not match Escape fees
Abnormal charges	There is a record of overdue payment Payment takes too long Late payment of fees Phased allocation not implemented The same account pays more than 3 times in a single day Advance receipt is not timely
Abnormal refund	Too many cheques returned in the current year Irregular refund Cash refund is not standardized Cancellation prepaid but not refunded

on knowledge graph, this paper conducts experimental research. This paper uses Python as the programming language to simulate the running environment of the method in this paper as the following configuration: The system configuration is Windows 11 Home Chinese version, the processor configuration is 12th Gen Intel (R) Core (TM) i7-12700H 2.30 GHz, 16G RAM.

The data source selects the abnormal electricity bill label as the experimental sample, the collected information is shown in Table 1, and the knowledge map is drawn through the intelligent electricity marketing inspection model of the knowledge map.

According to Table 1, the knowledge graph construction based on tags is shown in the following figure.

From the information in Figure 4, it can be seen that the intelligent electricity marketing inspection based on the knowledge graph can construct a knowledge graph according to the abnormal electricity bill labels, and can intuitively see the connection between various abnormal expenses. Mining and integration. It connects structured and unstructured data and uses it as a whole to mine previous hidden knowledge and simplify complex business problems.

Combined with the characteristics of the audit model, it is fully applied to various channels such as online audit, special audit, and on-site audit. In the first half of 2021, the audit model was applied to mine 84 failure points of front-end risk management and control, and 67,300 cases of various businesses were corrected, mainly including: 12,400 cases of electricity and electricity billing, 13,700 cases of reporting and installation management, and 5,200 cases of electricity bill management. For example, 3,500 cases of meter reading management, 12,800 cases of electric energy meter elimination management; 16.32 million yuan of errors in electricity bills and business expenses were corrected.

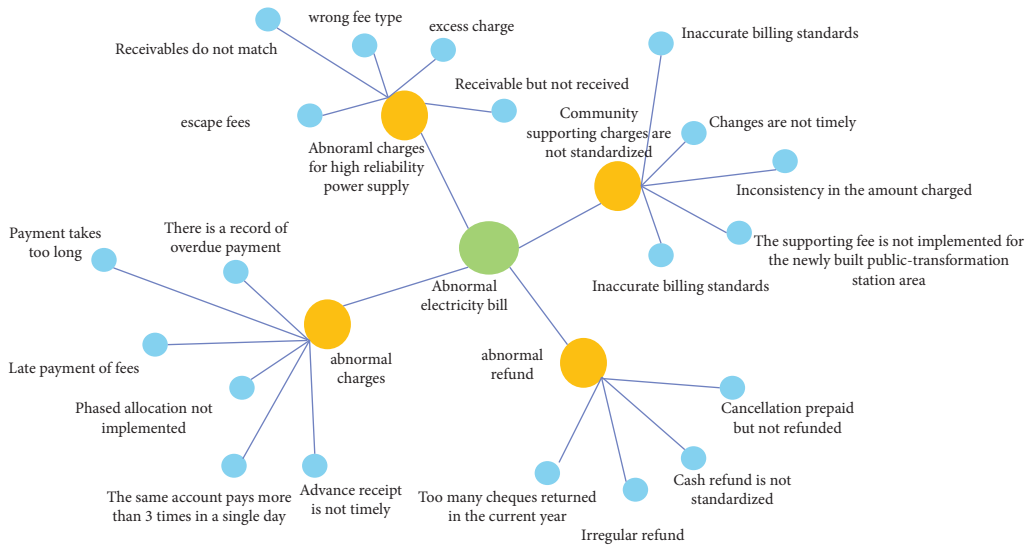

Figure 4: Construction of knowledge map of power marketing inspection rules.

6. Conclusion and Outlook

The application of the audit model in power marketing management gradually builds a closed-loop iterative closed-loop working method for online auditing of marketing business errors, including risk mining, model building, verification evaluation, and classified application. Based on the visualization value of knowledge graph, this paper proposes a new idea of applying knowledge graph to marketing audit work. And by selecting typical application scenarios in actual work, the practicability and effectiveness of the proposed model are verified by cases. The results show that the model can gradually restore complex scenes by using graphs, accurately find abnormal points, and effectively improve marketing lean, digital management level.

In the follow-up research, big data will become the basic driving force for power supply companies to mine risks and improve efficiency. Only by embedding "abstract" data into the audit model can marketing data reflect its value for me. In the future business process of big data, through data mining and knowledge graph to realize the visualization of audit management, look for business loopholes, innovate business methods, and constantly improve the defense system for marketing business errors.

Data Availability

The dataset can be accessed upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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