Research on Extension Method of Knowledge Graph of Power Equipment Health Management based on Blockchain

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Abstract. To effectively integrate electrical equipment data and achieve collaborative knowledge building and sharing, this paper proposed a blockchain-based method for expanding the knowledge graph in power equipment health management.Firstly, considering the characteristics of power equipment health management, the overall framework of the knowledge graph was presented, and entity concepts and entity relationships were extracted using rule-based methods and deep learning techniques. Secondly, a blockchain architecture model is designed based on power equipment health management methods, utilizing blockchain technology to enhance the content and functionality of the knowledge graph through data storage, data chaining, and knowledge authentication.Finally, the neo4j diagram database is used for visual display.Experimental results show that this method effectively improves the comprehensiveness of the power equipment health management knowledge graph, achieves knowledge graph expansion, and further enhances the efficiency of power equipment health management.

Keywords: knowledge graph; Electrical equipment; Blockchain; Health management; Data storage; Neo4j

1 Introduction

With the rapid development of smart grid and power equipment, the power grid is developing in the direction of digitization, information, intelligence and openness[1], and the health management of power equipment is becoming more and more important.In order to solve these problems, researchers began to try to combine emerging technologies with power equipment health management[2].

Some studies have introduced the knowledge map into the power system[3]. Literature[4] constructed a knowledge graph of power grid emergency plans through deep learning and rule-based knowledge extraction methods.Literature[5-7]introduces knowledge mapping technology into power grid dispatching system.As a decentralized system, blockchain has the characteristics of immutable data, smart contract, stability and reliability[8].Literature[9] proposes a new

MSIEID 2023, December 08-10, Guangzhou, People's Republic of China

DOI 10.4108/eai.8-12-2023.2344475

platform for data exchange within smart grid using blockchain.Literature designed a state management system for power transmission and transformation equipment based on blockchain technology to realize intelligent discrimination of equipment.

To sum up, knowledge mapping and blockchain technology have begun to be applied in all walks of life in the power system. This paper proposes a method to expand the knowledge map of power equipment health management based on blockchain, which can improve the safety and reliability of power equipment and protect the knowledge rights and interests of employees.

2 Construction of power equipment health management knowledge map

2.1 General framework of knowledge graph

Knowledge graph is essentially a knowledge network that connects and organizes entities and attributes through relationships.The overall framework of power equipment health management knowledge graph construction is shown in Figure 1.The framework includes basic data layer, graph generation layer, knowledge computing layer, analytical reasoning layer and application layer.

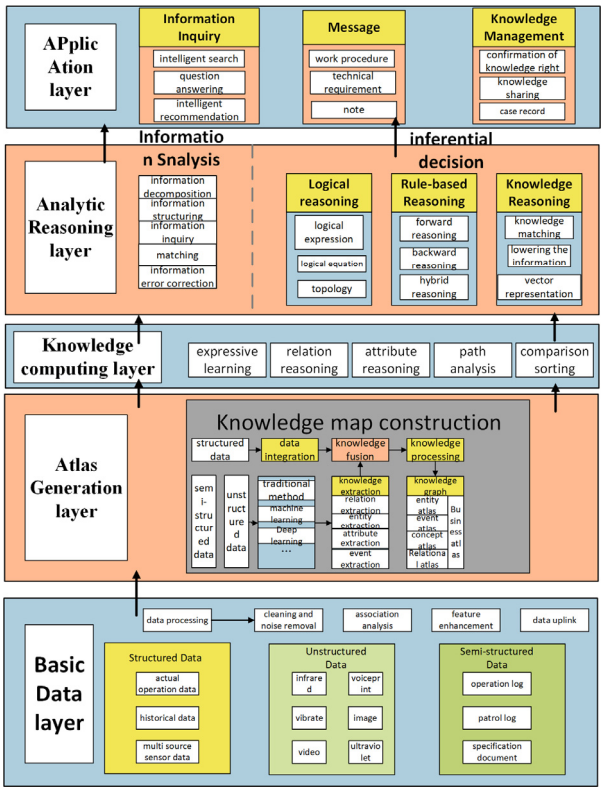

Figure 1. General framework for the construction of power equipment health management knowledge graph

2.2 Key technologies involved in knowledge graph construction

2.2.1 Knowledge Extraction

The so-called knowledge extraction refers to extracting useful information from massive data and storing it, including entity extraction and relationship extraction.

(1) Entity extraction

According to the work logs of daily operation and maintenance of power equipment, the entities mainly concerned in this paper are summarized as equipment name, working group, personnel and operation content.The extracted entity types and extraction methods are shown in Table 1.

Table 1. Entity category and extraction method.

	Type	Example	Extraction mode
Entity Concept	Device Name	Equipment name: Relay{ *type* = Secondary equipment， *state* = Before the equipment is put into operation}	Deep Learning
	Working Group	Working Group: Maintenance leading group{ *state* = equipment maintenance， *condition* = timely maintenance}	Deep Learning
	personnel	Personnel: Members of the operation and maintenance team { *state* = Before the equipment is put into operation， *condition* = Pay attention to monitoring}	Deep Learning
Entity Attribute	*type*	{ *type* = Primary equipment}， { *type* = Secondary equipment}	rule-based
	state	{ *state* = Before the equipment is put into operation}， { *state* = Routine operation of equipment}， { *state* = Equipment maintenance}	rule-based

The forgetting gate determines the discarded information, which is determined by formula (1) :

$$f_t = \sigma(W_f * [H_{t-1}, X_t] + b_f) \tag{1}$$

Where: X_t is the input of the current time t ; H_{t-1} is the output of the hidden layer at $t-1$; W_f and b_f indicate the weight matrix of the forgetting gate. σ is the activation function.

The input gate determines how much information the LSTM network will hold when it updates the cell, filters the information from all inputs, and updates the information according to the DAMTC, which is determined by formula (2) and formula (3) :

$$i_t = \sigma(W_i * [H_{t-1}, X_t] + b_i) \tag{2}$$

$$\hat{c}_t = \tanh(W_C * [H_{t-1}, X_t] + b_c) \tag{3}$$

Where: W_C and b_i are the weight matrices of the input gates.Update information for the Bi-LSTM unit c_t is available from the enter and forget gates:

$$c_t = f_t * c_{t-1} + i_t * \hat{c}_t \tag{4}$$

The output gate determines the output of the LSTM model:

$$o_t = \sigma(W_o * [H_{t-1}, X_t] + b_o) \tag{5}$$

$$h_t = o_t \tanh(C_t) \tag{6}$$

Where: W_o and b_o represent the weight matrix of the output gate; h_t is the final output of the current LSTM; o_t is the vector from which the element in o is activated by the sigmoid function.

(2) Relationship extraction

According to the work logs of daily operation and maintenance of power equipment, the relationship between entities is summarized as shown in equation (7) :

$$relationship = (node_{start} - [rel] \rightarrow node_{end}) \tag{7}$$

Where: $node_{start}$ and $node_{end}$ respectively indicate the head and tail entities, and the arrows indicate the direction; *rel* indicates the relationship name.Partial extraction rules are shown in Table 2.

Table 2. Entity Relationship Extraction Rules (part).

Head Entity	Tail Entity	Relation	Example	Relative words (part)
Working group	Working group	Set up	The company set up an operation and maintenance branch maintenance work group	Set up, Subset, Llocated, Established, Established
Working group	Personnel	Dispatch	An operation and maintenance branch sent team members to the scene	Identify,dispatch,organize
Personnel	Device name	Carry out	Team members perform routine maintenance of the transformer	Responsible,strengthen, respond, promptly, carry out

2.2.2 Knowledge fusion

Knowledge fusion represents multiple entities with the same meaning as a single entity.Knowledge fusion mainly includes entity disambiguation, entity alignment and knowledge merging.Entity disambiguation mainly solves the problem of "same-name heterogeneity", that is, to distinguish different entities and devices with the same name, thus establish precise physical links.Entity alignment mainly solves the problem of "synonyms", that is, normalizing the same entity that represents different names.Knowledge merging mainly starts from the overall level of knowledge graph, and mainly solves the problem of knowledge duplication and error caused by the diversity and heterogeneity of knowledge sources.

3 Application of blockchain in Knowledge graph

3.1 Data Storage

In the power equipment health management system, each department monitors the power equipment in operation in real time, and the detected data is uploaded to the block in real time.Because of different data contents, nodes are divided into data nodes, information nodes,

report nodes and decision nodes .Data nodes are used for employees to quickly check and learn.These data points can tell if a device is functioning properly and quickly deal with failures when they occur.Information nodes are used to monitor power equipment, which requires manual monitoring and uploading of relevant information, which can provide a basis for determining responsibility for an incident.The report nodes exist in the form of monitoring reports to provide ideas for decision makers and facilitate the management of power equipment.The decision node is used to issue regular maintenance or troubleshooting methods for the network, and it is responsible for issuing commands.All nodes form a whole in the management system of the blockchain and play their respective roles.

3.2 Data Linking

Employees can digitally sign the status or knowledge of the uploaded power equipment and package it to a new block. The new block is certified by consensus on the consensus mechanism. After the consensus is passed, the new block is updated to the original blockchain.Each block is connected in chronological order, the last state of the previous block must be the initial state of the new block, and the latest block represents the latest state of the ledger, which in this case is the latest state of the power equipment.The link data items related to equipment status and employee knowledge are shown in Table 3.

Table 3. Power equipment status and employee knowledge link data table**.**

Label	Description
INSTLN_id	Equipment number
INSTLN_type	Equipment type
INSTLN_name	Equipment name
STAFF_Pubkey	Employee public key
KNWL_type	Knowledge type

3.3 Knowledge confirmation

Power grid power equipment variety, different structure, some experienced front-line employees can know a variety of power equipment, based on this, this paper put forward a blockchain-based knowledge confirmation method, through the blockchain non-tamperable, high security characteristics to protect the intellectual property rights of employees, the knowledge in the mind into the employees' personal digital assets.The process of confirming knowledge rights is shown in Figure 2.

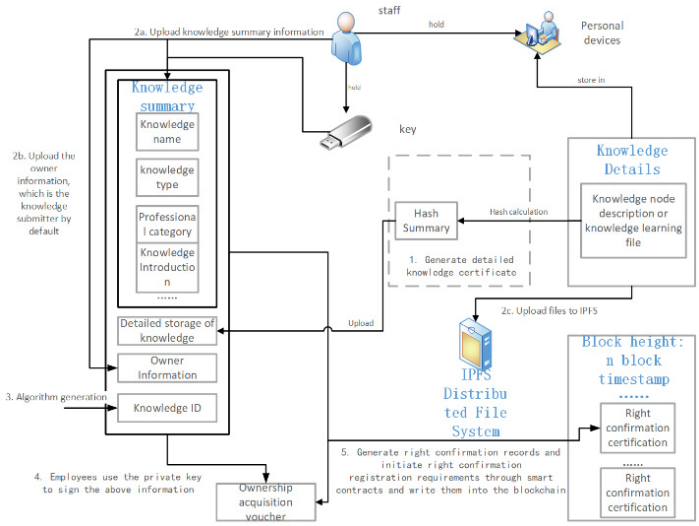

Figure 2. Right confirmation registration process

4 System Implementation

Visualize the knowledge graph through the graph database Neo4j, and some of the results are shown in Figure 3.

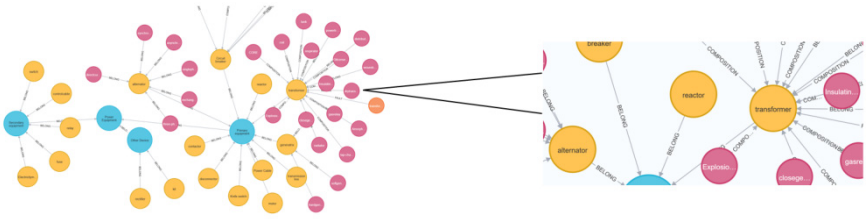

Figure 3. Visualization of Knowledge Graph for Health Management of Power Equipment

The power equipment health management system based on knowledge graph displays the power stations/lines/converter stations where abnormal equipment is located, and the lines where risk warning channels are located. It summarizes and displays the risks of equipment at levels 1-8 within the jurisdiction of provincial/municipal (ultra-high voltage)/county companies. Click on the corresponding statistical data to view the detailed data. The system page is shown in Figure 4.

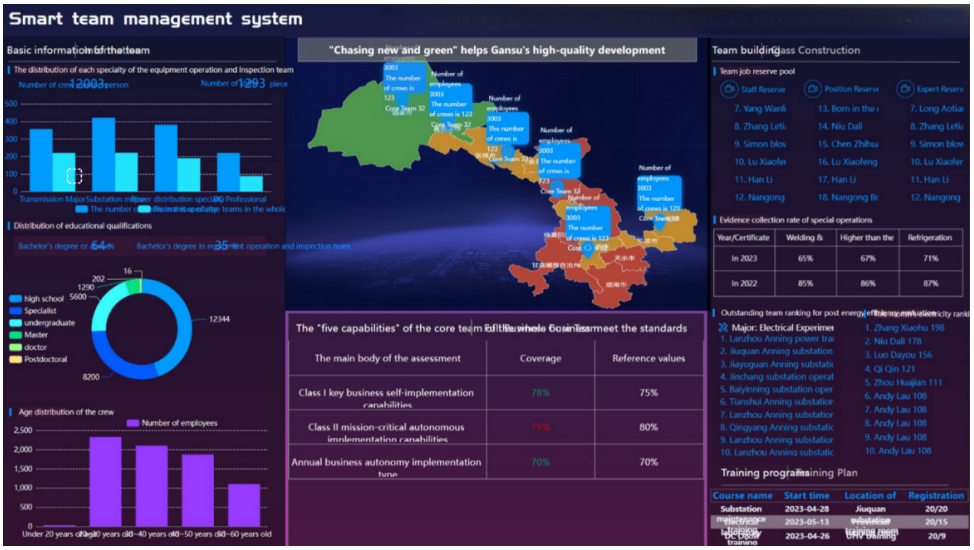

Figure 4. System page

5 Conclusions

The main conclusions are as follows:

(1) A method of building the knowledge graph of power equipment health management is proposed, and the knowledge graph is displayed through Neo4j graph database.

(2) Employees' knowledge is authenticated through blockchain to effectively protect the experience and knowledge of front-line employees and realize the co construction and sharing of knowledge map.

(3) This paper proposes a blockchain based knowledge map expansion method for power equipment. The function of knowledge map is enhanced, and the efficiency of condition assessment and troubleshooting of power equipment is further improved.

Acknowledgments. This work was supported by the State Grid Gansu Electric Power Company Electric Power Scientific Research Institute Costly Science and Technology Project((No.522722300018).

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