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Research on Fault Diagnosis Method of Hoist in Semantic Environment

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Abstract: Mine hoist is the key equipment in mine safety production which is a large and complex system of machine, electric and hydraulic pressure. Because of the complexity of its own structure and the uncertain factor in operation conditions, the faults may be multiple failures, associated faults or other complex forms. So, it is essential to study on the effective technology of fault diagnosis for the mine hoist. Based on the analysis of traditional fault diagnosis method, this study proposed a new one which is in semantic environment. First of all, it constructed the fault diagnosis system structure based on ontology and described the function of each part, the next; it analyzed and established the mine hoist fault ontology. Once more, the mapping is achieved from fault phenomenon ontology to the fault cause one through the new association rules algorithm of affairs reduction, it solved the matching problem of fault ontology and provided a strong theoretical basis to hoist fault diagnosis. So the fault source is located and the most suitable fault solution is found out. In the end, the result is tested by experiment. Experiment results show that the method can solve the problem of knowledge sharing and reuse in fault diagnosis system and accurately and effectively realize the fault diagnosis for hoist and provide a reasonable proposal for diagnostic decision.

Key words: Ontology, semantic, fault diagnosis, ontology mapping, hoist

INTRODUCTION

Mine hoist is the crucial equipment in underground transport. The particularity of its operation conditions, the complexity of its own structure (Du, 2012) and the diversity of its fault phenomena and fault cause lead to some distinctive characteristic of its fault knowledge data, such as large quantity, multidimensional and complicated type, varied data constitute forms and the complex between the data characteristics. So the key technology to make fault diagnosis much accurate is to study the knowledge system which is needed for the mine hoist diagnosis and make deeply analyzed to the fault phenomenon, cause and their relationship. Then, the fault source can be located. In recent years, artificial intelligence and knowledge engineering are applied to fault diagnosis by many researchers and they provide a new train of thought for fault diagnosis methods (Chen *et al*., 2011; Chengmao, 2010; Liao *et al*., 2009). But these methods failed to analyze the relationship between the fault phenomenon and fault cause in the process of fault diagnosis. Fault diagnosis methods based on the ontology are introduced in literature (Pamuk and Uyaroglu, 2012; Rajpathak *et al*., 2012), they had realized the sharing and reuse of knowledge. But how to analyze the fault cause on the basis of the fault phenomenon effectively still haven't come up with a good solution. Literature (Dou *et al*., 2009) gives the basic idea of deducing fault cause on the basis of fault phenomenon using ontology and provides semantic relations between fault phenomenon and fault cause at the same time, but its matching algorithm is too cumbersome. This article takes the braking system of mine hoist as an example, introduced ontology into fault diagnosis system and gives the method of diagnosis knowledge establishment and representation, solves the problems of the heterogeneity of knowledge, the knowledge acquisition and representation of the hoist fault diagnosis system. On this basis, using a new improved algorithm based on association rule, it solved the matching problem of fault ontology and provided a strong basis to hoist fault diagnosis, besides, some detailed diagnostic decision-making recommendation are also listed.

HOIST FAULT DIAGNOSIS SYSTEM STRUCTURE BASED ON ONTOLOGY

Hoist fault diagnosis system based on ontology is composed of user interface, knowledge base, knowledge acquisition module, database, inference engine, explanation module, knowledge extraction module, ontology knowledge base, fault diagnosis module and so on; the internal structure is shown in Fig. 1.

User interface: Used to establish link and exchange information between the user and the computer. Through the user interface, user can obtain or entry data and expert knowledge and the result of the fault diagnosis can also be feed backed to the user.

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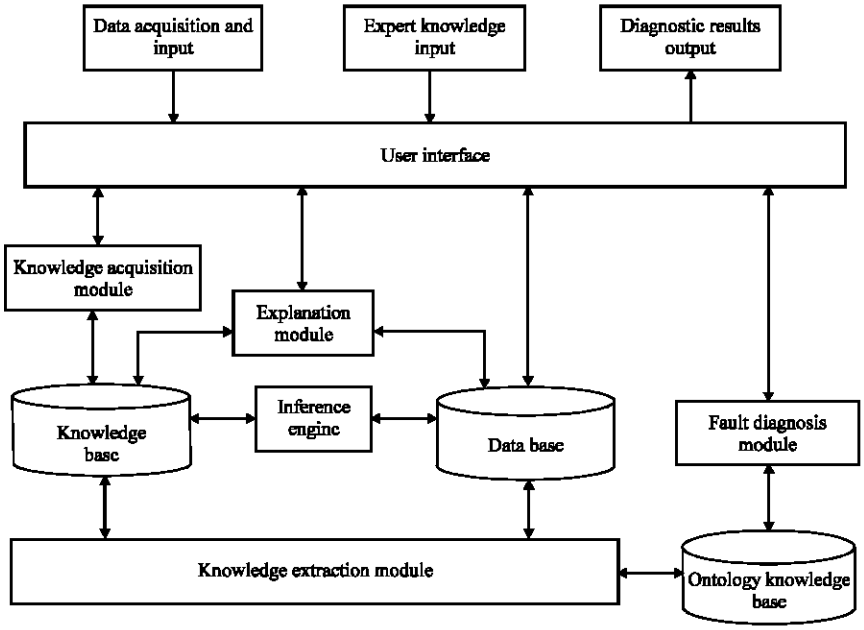

Fig. 1: Hoist fault diagnosis system structure based on ontology

Knowledge base: Used to store all kinds of previous diagnosis knowledge and the new knowledge that the fault diagnosis module generated.

Knowledge acquisition module: Used to establish and expand the knowledge base and is responsible for the increase, modify, or delete records in the knowledge base, besides, it also inspect and maintain the consistency and completeness of the knowledge base.

Database: Used to store all kinds of initial information that direct input by the user or acquired by the sensors. It also store all sorts of intermediate information generated in the process of commutating and reasoning.

Inference engine: Reasoning and judging the current information of the database based on the knowledge base and modifying the database continuously until finally solve the problem.

Explanation module: Used to illustrate the solving and calculating process and answer the user's question. It could help checkout the rationality of the diagnosis method.

Knowledge acquisition module: Used to extract fault information and diagnosis knowledge from the knowledge base and the database, classify the fault phenomenon and fault cause, all of the knowledge extracted will provide basis to the establishment of ontology.

Ontology knowledge base: Used to store the ontology knowledge of fault phenomenon, fault cause, diagnosis knowledge and other related knowledge.

Fault diagnosis module: Used to establish the mapping relationship between the fault phenomenon and fault cause through the matching algorithm, find the fault source, give the diagnosis decision-making and update the new fault knowledge generated to the ontology knowledge base.

In order to guarantee the simplicity and effectiveness of the fault diagnosis knowledge system, decrease the data redundancy as far as possible, solve the problem of the mine hoist diagnosis field effectively and realize the intelligent diagnosis, in this study some important concepts of the fault diagnosis process were extracted and a hoist fault knowledge system through semantic expression on the basis of deeply analysis of the fault and diagnosis knowledge of the mine hoist were found.

ANALYSIS AND ESTABLISHMENT OF HOIST FAULT ONTOLOGY

The analysis of hoist fault ontology knowledge: In order to state the fault phenomenon, fault cause and their relationship clearly, a good deal of knowledge that is relevant and construct the ontology of the hoist fault has been collected. All of the information is from the book of hoist fault, the data collected at the scene and the communicating with the technical staff as well as the exchanging of the domain experts. Firstly, valuable vocabularies for describing the related concept in the field

of the hoist fault based on the analysis of this knowledge are extracted. Then, this study divides the structure and hierarchy of ontology, constructs ontology classes, properties and examples (Feng *et al*., 2007) according to the structure of the mine hoist system.

The classes in ontology of the hoist fault constitute the system of the hoist fault field. Classes and their relationship are shown in Fig. 2.

The fault is external form or the result caused by them. Fault phenomenon is the signs of abnormal hoist may show in some ways before or during the process of the fault happen. Fault cause is the fundamental attribute set that lead to fault happen; the fault source means to analyze and positioning the fault happened components accurately and processing methods are the corresponding treatment measures to the fault.

The establishment of ontology of the hoist fault: In order to diagnose and process the fault conveniently, in this study, the fault of the hoist braking system is classified, according to the monitoring parameters of the mine hoist braking system and the knowledge the domain experts provided. It is also on the basis of the analysis of the structure and common fault of the hoist. Broadly speaking, braking system failure can be divided into brake failure and hydraulic station failure. Brake failure can be subdivided step by step, form a fault model that is similar with the tree hierarchy structure. And detailed failure causes and phenomenon examples respectively belong to these classes. The structure of the ontology of the hoist braking fault cause is shown in Fig. 3.

After established the structure of the hoist fault ontology, this study uses protégé to compile the hoist

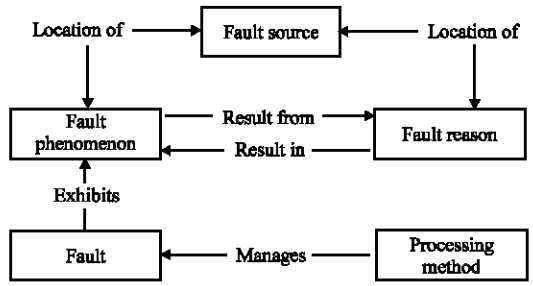

Fig. 2: Relationship diagram of hoist fault diagnosis knowledge classes

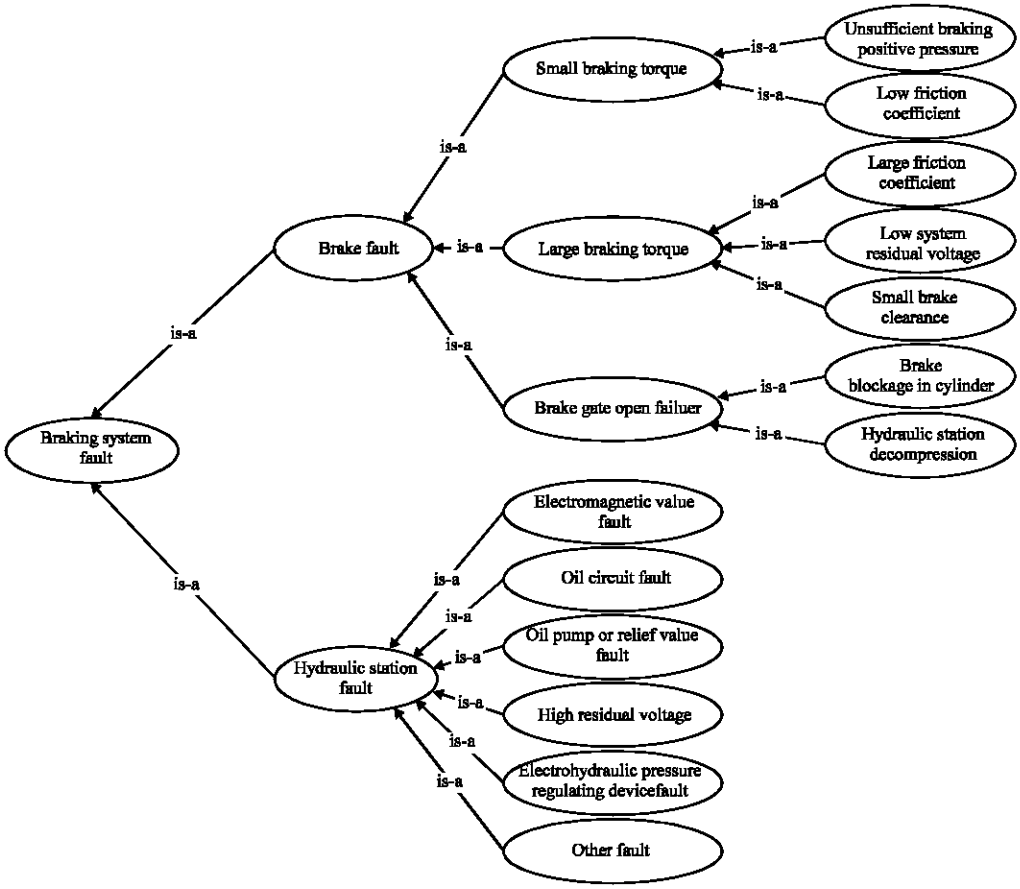

Fig. 3: Structure of the ontology of the hoist braking fault cause

fault ontology, documents the established ontology and generates corresponding OWL document. Because there is no limitation of the platform to use OWL document and the existed document can also import to the ontology development system, meanwhile, it also allow to do the format transformation among ontologies, so it makes the hoist diagnosis knowledge sharing and reuse possible from another point of view.

RESEARCH ON FAULT DIAGNOSIS REASONING METHOD BASED ON ONTOLOGY

The basic idea of mine hoist fault diagnosis based on ontology shows that using the algorithm to analysis the mapping relationship between fault phenomenon and fault reason is the key of in the fault diagnosis process.

Apriori algorithm: At first, this study analyzed the classical association rules algorithm-Apriori algorithm; it firstly identifies all the frequent item sets and then structures association rules from those sets. Steps of generate frequent item sets are as follows: Firstly, this algorithm scans the transaction database, computes all the elements of a collection frequency, gets 1-dimension candidates C_1 and finds those project sets who do not smaller than the smallest support which is 1-dimension frequent item L_1. Then, the algorithm joins the L_1, gets 2-dimension candidates C_2, scans the transaction database again, finds 2-dimension frequent item L_2 that is bigger than the smallest support. And then finds L_3 by L_2 and cycles until the all the frequent item sets are found.

Apriori algorithm based on data reduction: Find the association rules the users appointed from the large amount of data is just the purpose of the association rules mining. In order to improve the effectiveness of the apriori algorithm, reduce the times of scanning database and curtail the candidate items which may not become the frequent itemsets. This study improves the algorithm from the following several aspects and puts forward a new apriori algorithm based on data reduction.

Transaction compression and reduction: Through performance analysis of the mining frequent itemsets and infrequent itemsets process, reduction properties of transaction can be deduced from the database transaction, specific is as follows (Aouad *et al.*, 2010; Liu *et al.*, 2003):

Step 1: Set I as the total sets of all affairs, $Y \subseteq I$, $X \subseteq Y$, if Y is frequent itemset, then X is frequent itemset certainly, conversely, if X is non-frequent itemset, then Y is non-frequent itemset too

Step 2: Set L_k is k-dimension frequent item, if $T \subseteq I$ and $|T| = k$, then T can be removed in next steps

Step 3: Set $X \subseteq I$, $Y \subseteq I$, $X \subseteq Y$ and $|Y| = |X|+1$, if X is non-frequent itemset, then Y is non-frequent itemset and Y and the subset of Y can be deleted

Step 4: Set $X \subseteq I$, $Y \subseteq I$ and $|Y| = 2$, $|X| \geq 2$, if X and Y are frequent itemsets, then $X \cup Y$ is non-frequent itemset and $X \cup Y$ and the subset of $X \cup Y$ can be deleted

Mining in high layer: In practical applications, the significant correlations in the data item often emerge in the higher concept layer, rather than the bottom. According to the analysis of class's hierarchy on above section, it is difficult to find out the high support degree mode from the primary instance concept layer. Because the case itself is only a case-by-case, it is not representative. Such as the brake clearance in this case has a specific numerical value and the "coal mine safety regulations "regulates that the clearance between the brake shoes and the brake disc should less than 2 mm (SAWS, 2010), so what it should do is just to divide the knowledge from the cases into two classes compared with 2 mm. Therefore, it is very important to mine the frequent item sets from the generalized abstraction layer or the more concept layer and ontology provide a safeguard for such a request realizing.

The apriori algorithm itself has the structure of generalized data, one of the broadening of the algorithm refer to is-a layer, it contains the more abstraction layer information that existed in the database structure. This study uses is-a method to embody the relationship in all kinds of classes.

Based on the above deduction and analysis, the performance of apriori algorithm can be improved greatly.

EXPERIMENTAL VERIFICATION

Take the hoist braking system common fault as an example, a on-line monitoring system of JKTP-1.2 M mine hoister test-bed was built and 22 variable values were obtained by using different kinds of sensors to monitor the hoist braking system and saved all variable data in a process of hoist running. Then the variable data as the initial data directly was imported into the database. Using the algorithm, the result could be found that 4 brake shoe displacement and spring force didn't change in a period of time. According to this phenomenon, it could be deduced that the corresponding fault cause is gate 4 blockage piston in the cylinder. Following the diagnosis results are validated.

During the experiment, after the creep phase, it takes an overlong time for the creep speed reduced to zero; the

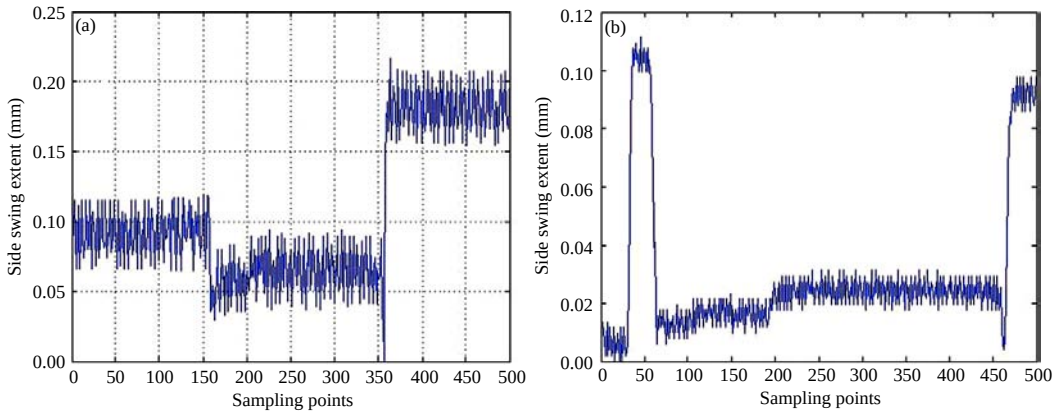

Fig. 4(a-b): Data graph of left and right side swing extent (a) Left side swing extent and (b) Right side swing extent

deceleration value of this phase is partial small. This process is the very decelerating phase that the reducer plays a role. The braking time and deceleration value are not within the scope of regulation; it shows that the braking time is too long. The reason that the braking time is overlong is the deficiency of the braking torque caused by the spring fault, brake-shoe fault, besides, weather the deflection of the brake disc overrun and the residual pressure overtop are the possible reasons. Before the experiment, each brake spring precompression and stiffness of spring were tested and exchanged, make sure that all of the spring reached the standards, therefore, spring failure was eliminated. The left and the right deflection quantity were drawn in the historical data diagram (Fig. 4), it is shown that the curve graph is normal during the whole operation process. Next, the brake-shoes were continued to be analyzed, the brake shoes' temperature was normal and free from contamination. Then, through examining the brake shoe displacement diagram, it can be sure that each of them was normal. But from the brake shoe displacement diagram (Fig. 5), it can be found that the number 4 brake takes a significantly greater time than the others and there was some intermediate sampling point values remain unchanged. So, the next step is to judge whether the residual pressure overtop, it is natural in the oil pressure diagram (Fig. 6). Combined with Fig. 5 and 6, a phenomenon could come to that during the stick brake process, as the oil pressure changing continuously, the displacement of the number 4 brake remain unchanged for a while, it is in line with the blockage piston in the cylinder mechanism, meanwhile, idle motion time overlong could also be eliminated. Above all, the cause can be predicated that

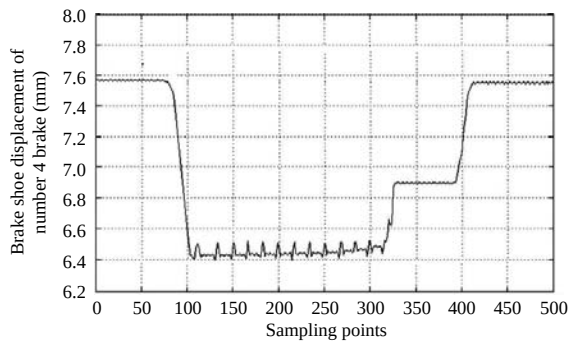

Fig. 5: Brake shoe displacement of number 4 brake

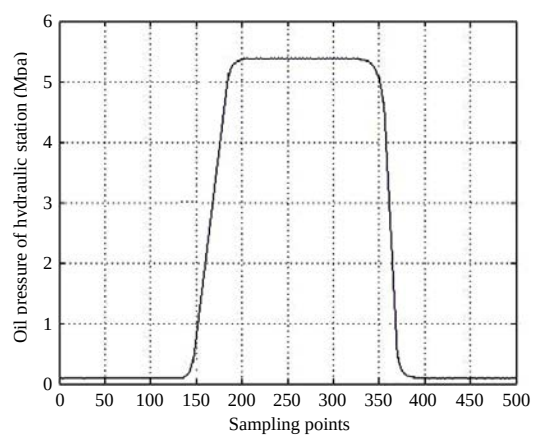

Fig. 6: Oil pressure of hydraulic station

is the blockage piston in the cylinder fault. The corresponding solution is to check up whether the piston cup is aging or the piston rod is decantation.

CONCLUSION

Above all, this study established the hoist fault ontology and solved the problem of heterogeneity of knowledge in the hoist fault diagnosis system. On that basis, the mapping between hoist fault phenomenon and fault causes has been realized used the improved association rules algorithm based on things reduction, analyze the fault cause through fault phenomenon and positioning the fault source simultaneously, besides, the suggestions for the decisions are also listed. In the end, an application example is given to validate the feasibility and effectiveness of the method. The experiment shows that the method used to the fault diagnosis system of hoist is able to predicate the fault cause accurately. It can provide effective treatment advices for diagnosing and decision making.

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