2012 International Conference on Computer Science and Information Processing (CSIP)

Research of Elevator Fault Diagnosis Based on Decision Tree and Rough set

Chen-Guang Zhao, Hong-Yu Xu, Liang Jia
Department of Electronic Information Engineering
Shenyang Aerospace University
Shenyang P.R.China
Zcg0975@tom.com

***Abstract*— With the development of urbanization, more and more attention has been put on the safety and reliability of elevators. The elevator faults influence the effectiveness of whole mechanical transmission system, even lead to serious injuries. It is vital that real-time monitoring of the elevator status and accurate fault diagnosis to satisfy the high safety demand. In this study, an intelligent fault diagnosis approach is proposed, which combine the decision tree with rough set theory. First, the basic knowledge of decision tree and rough set techniques is briefly introduced which consists of classifier selection and decision rules. Next, this paper discussed the developed decision strategy and reasoning process in detail. Finally, the elevator fault diagnosis system is constructed, the results indicates the presented method can provide quick location of faults and solutions to deal with the problem.**

Keywords- ***elevator; decision tree; rough set; fault diagnosis***

I. INTRODUCTION

The industry improving trends demands elevators keeps increasing as the rapid development of modern urbanization, the fast growing estate led to the mature of elevator market, customers come to focus on the safety and quality of elevator more and more. Elevators have complicate mechanical structures according to the rating speed and the load capacity. Obviously, it needs to explore some strategy to monitor and guarantee the security of operating process of elevator long-time continuous usage, reduce fault-occurrence probability, which requires trouble-shooting quickly[1]. The target of elevator fault diagnosis is to find the potential fault, improve equipment safety and reliability, minimize the accident rate, even prolong the equipment life. In recent years, many researchers have carried on different solutions to solve fault diagnosis of large complex electrical equipment, data mining methods are adopted, such as neural network, multi-agent system, association rule, fuzzy control, etc. Decision tree is widely used data classification technology. According to the character of elevator status data collected by sensors, data uncertainty is common, it can be caused by various factors including measurements precision limitation, data sets, sensor errors, field condition[2]. In this paper, the traditional decision tree is enhanced by applying the rough set to improve the diagnosis accuracy. To reduce the probability of elevator breakdowns and increase reliability, the method we propose can satisfy the requirement. For the complex structure and the strict request for reliability, the monitoring running status and fault information of elevator is significant to its management, maintenance and security operation.

II. PRELIMINARY WORK

A.Elevator possible accident and inducement

It is well known that the possibility of faults is unavoidable. The faults may be caused by the machine or operating conditions[3]. As for elevator, the accidents are increasing year after year. It is necessary to collect the fault symptom and corresponding reason as possible as we can. The following steps are carried on:

1. To collect the system data information, including the elevator control centre operating theory at different parameter condition, conserve each port change situation in operational process.
2. To define the diagnosis basis, describe clearly all functions of the elevator control system and the required condition.
3. To list each possible fault type and analyze the formation and characteristic of faults, detect the influence for the elevator control center
4. To decide the method for fault monitor and diagnosis by means of analysis of the elevator fault dynamics.

The structure of elevator mainly consists of traction system, guidance system, door system, elevator car, load balance system, electric drive, etc. Based on the requirement of the project, raw data are collected from multiple sensors and values of features of the raw data are calculated to extract the important information. The parameters will be the foundation of fault diagnosis knowledge, the formation reason of some fault and the method to resolve the problem can be obtained by statistical analysis. The origin of symptom including two categories:

1. The remote monitor, data can be transferred to the diagnosis system through the web service port, the decision tree will analyze it, the symptom may be constant or enumeration.
2. The operator inputs the relevant data, including the symptom and the possible result.

In this study, the cause and effect of each hazard in terms of probability of occurrence and the severity of its effects should be assessed.

Take the elevator control system as an example, the fault pattern and the effects analysis results is shown partly in

978-1-4673-1411-4/12/$31.00 ©2012 IEEE

Authorized licensed use limited to: Southern University of Science and Technology. Downloaded on October 16,2023 at 04:15:57 UTC from IEEE Xplore. Restrictions apply.

Table 1.

Table1. Fault and its corresponding reason

Name	Function	Fault Pattern	Fault reason
Lift controller	Control the elevator operation according to the input order	the elevator can't run correctly	Parameter or power supply is wrong
Frequency converter	Control tractor speed and direction	Self protection, wrong speed and direction	Frequency converter parameters
Safety loop	Safety protection for elevator running	Circuit always open or close	Relay adherence or wrong connection
Floor call circuit	Afford the floor call command to the elevator control system and display the reaction	The floor command can't be selected or the call is different with the display result	The interface loose contact

Through analysis of elevator control system fault phenomenon, to develop an intelligent fault diagnosis for elevator operating safety is imperative.

B.The statistical model design

It is essential for decision tree to have a proper method for classifier selection because the explicit probabilistic rules can affect the diagnosis accuracy[4]. When we face with many branches and sensor data sets, how to select them is often a problem before a final strategy employed. The decision tree we proposed utilized the C4.5 algorithm. The C4.5 algorithm has the ability quick classify and memorize random sample, the generation rule is constructed as a tree structure, the rules relationship is clear, the reasoning result is easy to explain, but the calculation amount is large and the time spent in constructing the tree is long. In this thesis, the rough set theory combined with decision tree C4.5 algorithm, which can smooth away the defects mentioned above. Combing the fault tolerance of rough set theory and fast classification of decision tree, the solution for diagnosis based on rough decision tree is described in Figure 1.

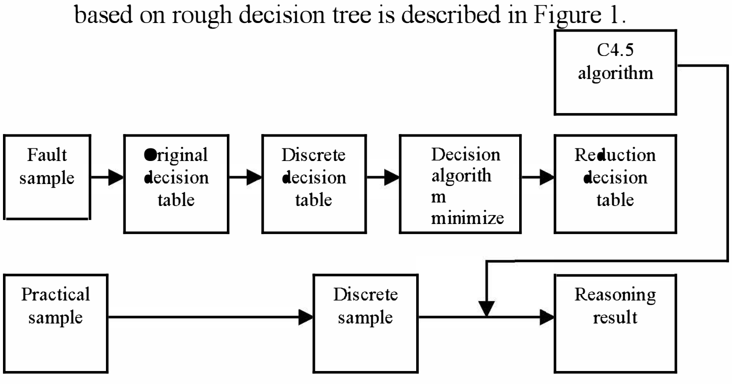

Fig.1 Rough decision tree diagnostic method

According to the structural characteristics of the elevator control system and its function, the method shown in Fig1 presents the rudimental diagnosis procedure. Firstly, the original decision table is created based on the elevator history fault samples, the samples are conveyed by the distribute sensors. Secondly, the discretization of continuous attributes is carried out based on minimum entropy of Information， the discrete decision table is obtained. Then, the characteristic vector reduction based on classify matrix is acquired, the best reduction result can be selected according to maximum cluster ratio, the decision table after reduction can be defined. Then, applying the C4.5 algorithm, the diagnosis decision tree is built. Finally, the elevator fault diagnosis system can realize the anticipated function by using the decision tree. The method can decrease the fault character obtain workload, realizing quick and accurate fault pattern classification.

III. Rough Decision tree fault diagnosis

A.Diagnosis decision table

According to rough set theory, the original diagnosis decision table is created based on the history data[5]. The table structure is shown in Eq.(1)

$$T=(U,C,D) \qquad (1)$$

Where, U stands for nonempty finite set, which called fault state domain, C, D means fault condition value set and fault decision property set respectively, and $C \cap D = \phi$. For each sample X_j, C_{ij} is fault character, $D(X_i)$ is fault type.

B.Discretization of continuous attributes

Discretization for the continuous property value in T is needed because the rough set theory only solve the discrete data. Supposing there are N fault samples $X_i\ (j=1,2,...N)$ in T, M fault condition properties, K fault types. As for continuous condition property C_i, the discretization algorithm based on minimize entropy is designed. The steps can be summarized as :

Step 1: Let the continuous property value $C_{i1},...C_{iN}$ in ascending order, the sorted property is recorded as $C'_{i1},...C'_{iN}$, calculating the average between neighbor attribute values, is noted as $\overline{C'_{i1}},...\overline{C'_{iN}}$.

Step 2: Define the discrete classification number r.

Step 3: For each $\overline{C'_{ij}}(j=1,2,...,N-1)$,the interval $[C'_{i1},C'_{iN}]$ is divided two partition $[C'_{i1},\overline{C'_{ij}}]$ and $[\overline{C'_{ij}},C'_{iN}]$, is p and q partition respectively. According to the Eq.(2)-Eq.(5) , the entropy $S(\overline{C'_{ij}})$ can be calculated in the interval division $[C'_{i1},C'_{iN}]$,and the minimize entropy

Authorized licensed use limited to: Southern University of Science and Technology. Downloaded on October 16,2023 at 04:15:57 UTC from IEEE Xplore. Restrictions apply.

$\overline{C_{ij}^{'}}$ is PRI_i.

$$S(\overline{C_{ij}^{'}}) = p(\overline{C_{ij}^{'}})S_p(\overline{C_{ij}^{'}}) + q(\overline{C_{ij}^{'}})S_q(\overline{C_{ij}^{'}}) \quad (1)$$

$$S_q(\overline{C_{ij}^{'}}) = -\sum_{k=1}^{K} p_k(\overline{C_{ij}^{'}}) \ln p_k(\overline{C_{ij}^{'}}) \quad (2)$$

$$S_q(\overline{C_{ij}^{'}}) = -\sum_{k=1}^{K} q_k(\overline{C_{ij}^{'}}) \ln q_k(\overline{C_{ij}^{'}}) \quad (3)$$

$$p_k(\overline{C_{ij}^{'}}) = (n_k(\overline{C_{ij}^{'}})+1)/(n(\overline{C_{ij}^{'}})+1) \quad (4)$$

$$q_k(\overline{C_{ij}^{'}}) = (N_k(\overline{C_{ij}^{'}})+1)/(N(\overline{C_{ij}^{'}})+1) \quad (5)$$

Where k is the sample fault type number, $p_k(\overline{C_{ij}^{'}})$ and $q_k(\overline{C_{ij}^{'}})$ is the k type fault and the condition probability in $[p,q]$, $n_k(\overline{C_{ij}^{'}})$ and $N_k(\overline{C_{ij}^{'}})$ is the k type fault sample number in p scope and in q q scope respectively , $n(\overline{C_{ij}^{'}})$ and $N(\overline{C_{ij}^{'}})$ is the total numbers of samples in p and q domain.

Step 4: Aiming at each $\overline{C_{ij}^{'}}$ ($\overline{C_{ij}^{'}} < PRI_i$), the entropy will be calculated again in the domain $[C_{i1}^{'}, PRI_i]$ according to Eq.(1)-Eq.(5), let the minimum entropy $C_{i1}^{'}$ is $SEC1_i$. Aiming at each $\overline{C_{ij}^{'}}$ ($\overline{C_{ij}^{'}} > PRI_i$), the entropy will be calculated again in the domain $[PRI_i, C_{iN}^{'}]$ according to Eq.(1)-Eq.(5), let the minimum entropy $\overline{C_{ij}^{'}}$ is $SEC2_i$ .Therefore, we obtain three key values $SEC1_i, PRI_i, SEC2_i$.

Step 5: Based on the maximum membership degree, the continuous property $C_{i1},\ldots,C_{iN}$ need to be discrete according to Eq.(6), the discretization condition property is regarded as $Cd_{i1},\ldots,Cd_{iN}$.

$$Cd_{ij} = \begin{cases} 1, C_{ij} \le P1_i \\ 2, P1_i < C_{ij} \le P2_i \\ 3, C_{ij} > P2_i \end{cases} \quad (6)$$

Where $j = 1,2,\ldots N$, $P1_i$ and $P2_i$ is two breakpoints for continuous property C_i discretization, and $P1_i = (SEC1_i + PRI_i)/2$, $P2_i = (SEC2_i + PRI_i)/2$.

All the continuous condition property in table T is discrete, the discrete diagnosis decision table can be achieved.

C.Decision tree C4.5 algorithm

The classic ID3 algorithm adopts the mutual information, suitable for the property which has more values, but the classification result is not the best. Therefore, C4.5 algorithm apply the information gain ratio as tested property select standard, the classified result is ideal[6-7].

Suppose that $T^{'} = (U^{'}, C^{'}, D)$, which contain N discrete samples Y_j ($j = 1,2,\ldots,N$), M condition properties, K fault categories. Based on the principle of decision table discernable matrix and maximum cluster ratio, the property reduction method is presented in this thesis.

First, The discernable matrix of $T^{'}$ is calculated. Let $S = (s_{ij})_{N\times N}$. The condition property which property combination value in discernable matrix S is 1 would be listed to core property set $core(S)$ .If s_{ij} includes core property, then let $s_{ij} = 0$. Otherwise, remain invariant, A new matrix will be drown $S^{'} = (s^{'}_{ij})_{N\times N}$.

Second, the S discernable function $f(S^{'})$ is calculated, and converted $f(S^{'})$ to disjunctive normal form. All the properties of $core(S)$ is added to each conjunctive normal form of disjunctive form, the whole reduction set can be obtained. Finally, the cluster ratio of each reduction set is calculated using follow equation:

$$R_a = (N - N_R)/(N-1) \quad (7)$$

Where, R_a is the reduction set cluster ratio, N_R is universe numbers according to $T^{'}$ reduction result, and let the maximum reduction set as the best reduction ,which is regarded as diagnosis decision table $T^{''}$.

D.Rule extraction

The diagnosis rule extraction is a procedure of acquiring the reasoning rule from reduction decision table $T^{''}$, creating a diagnosis strategy for new fault sample classification[6]. Suppose that $T^{''} = (U^{''}, C^{''}, D)$, where $U^{''}$ includes $N^{''}$ discrete fault sample $Z_j (j = 1,2,..N)$,the number of Z_j is $|N_j^{'}|$,condition property $C^{''}$ number is $M^{''}$ .There are K fault types, the number of fault type D_i is $|D_i|$,and satisfy the condition $|D_1| + \ldots + |D_k| = N$, the

Authorized licensed use limited to: Southern University of Science and Technology. Downloaded on October 16,2023 at 04:15:57 UTC from IEEE Xplore. Restrictions apply.

probability distribution is $P_i = |D_i|/N$ .Finally, The diagnosis decision tree is constructed by applying C4.5 algorithm. The following shows the steps:

Step 1: The initial information entropy is calculated using the Eq.(8)

$$I(P) = -\sum_{i=1}^{K} P_i lb P_i \qquad (8)$$

Step 2: A selected condition property is used as decision tree root. As for condition property $C_j^{"}$, the fault sample can be divided into different sample group $T_1, T_2, \ldots, T_m$ according to the property value, then the branch entropy is calculated through following Eq.(9), the information gain caused by $C_j^{"}$, separation information $I_s(C_i^{"}, T)$ and $G_R(C_j^{"}, T)$ is calculated as Eq.(9)-Eq.(12).

$$I(C_j^{"}, T) = \sum_{i=1}^{m} (|T_i|/N) I(T_i) \qquad (9)$$

$$G(C_j^{"}, T) = I(P) - I(C_j^{"}, T) \qquad (10)$$

$$I_s(C_j^{"}, T) = -\sum_{i=1}^{M} (|T_i|/N) lb(|T_i|/N) \qquad (11)$$

$$G_R(C_j^{"}, T) = G(C_j^{"}, T) / I_s(C_j^{"}, T) \qquad (12)$$

At last, the maximum information gain $C_j^{"}$ is selected as decision tree root node. According to Eq.(8)-Eq.(12), each branch is calculated as Step 2 until the whole diagnosis tree is accomplished.

IV. Elevator fault diagnosis Experiment Based On rough decision tree

Take the FUJI elevator TKJ1000-VVVF as example, the system applies VB as developing mean and SQL Server as background database. The state variables are be obtained, the necessary procedure information is extracted. The original data help us to construct the information system

$$T = (U, C, D)$$

Suppose there are 15 samples in T, 5 fault character properties in C , C_1 stands for floor signal, C_2 stands for speed signal, C_3 stands for opening and closing door signal, C_4 stands for the direction signal, C_5 stands for the instruction inside of the bridge. There are 5 fault types in D , D_1 is sudden stop circuit fault, D_2 is over speed governor fault, D_3 is frequency converter trouble, D_4 is safety chain fault, D_5 is photoelectrical switch fault.

The original fault diagnosis decision table is created first, then the discretization and attribution reduction of decision table is carried on, the discretization table T1 is drawn as Tab 2.

Table2. The discretization diagnosis decision table T1

U'	C_1	C_2	C_3	C_4	C_5	D
1	1	1	0	1	1	D_1
2	1	0	1	1	1	D_1
3	1	0	1	1	0	D_1
4	1	2	1	1	0	D_1
5	1	2	0	1	0	D_1
6	1	1	0	1	2	D_1
7	1	2	0	1	1	D_1
9	1	1	0	1	2	D_1
9	0	1	2	2	0	D_2
10	1	0	0	0	2	D_2
11	1	1	2	1	1	D_3
12	1	0	2	1	2	D_3
13	0	0	1	2	1	D_4
14	0	2	1	2	1	D_4
15	1	1	1	0	1	D_5

The property reduction of T2 can make 5 reduction set, {C_1, C_3, C_4}, {C_1, C_3, C_5},{C_1, C_2, C_4, C_5},{C_2, C_3, C_4, C_5}. Because of {C_1, C_3, C_4} cluster rate is maximal, the best reduction is it. The optimal reduction diagnosis decision table T3 is shown in Tab 3.

Table3. The reduction table T3

U'	number	C_1	C_3	C_4	D
1	5	1	0	1	D_1
2	3	1	1	1	D_1
3	1	0	2	2	D_2
4	1	1	0	0	D_2
5	2	1	2	1	D_3
6	1	2	1	1	D_4
7	1	0	1	2	D_4
8	1	1	2	2	D_5

Using C4.5 to analyze T3, the information gain of fault character C1 C1 C1 is 3.572, 6.428, 7.650 respectively. Thus C5 is selected as root for partition of nodes, each branches are made by repeat using C4.5, the diagnosis decision tree is constructed shown as Fig.2.

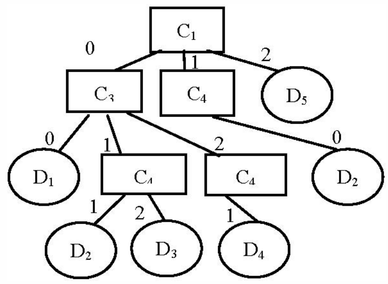

Fig.2 Diagnosis decision tree using C4.5

Finally, to certify the method efficiency, 10 discrete testing samples are selected. The testing set is selected randomly. The diagnosis result is described in Tab.3.

Table3. Result of fault diagnosis

U'	C_1	C_2	C_3	C_4	C_5	Real fault	Diagnosis result
1	1	1	0	1	1	D_1	D_1
2	1	0	1	0	1	D_1	D_1
3	1	0	1	1	0	D_1	D_1
4	1	2	1	1	0	D_1	D_1
5	0	2	2	2	0	D_2	D_2
6	1	1	0	0	2	D_2	D_2

Authorized licensed use limited to: Southern University of Science and Technology. Downloaded on October 16,2023 at 04:15:57 UTC from IEEE Xplore. Restrictions apply.

7	1	1	2	1	0	D_3	D_3
8	0	0	1	2	0	D_4	D_4
9	1	0	2	2	1	D_5	D_5
10	1	1	2	2	1	D_5	D_5

The result of the test is analyzed and discussed, from the above table, the rough decision tree mentioned in the paper can reflect the relationship between the fault character and final result. The diagnosis result is completely right. By the means of rough set, the amount of samples is decreased greatly, the property discretization lead to the main character highlighted, which make the users can find the fault easily and judge it promptly[8-10]. The diagnosis experiment demonstrates the method is practical and efficient.

V. CONCLUSION

The paper presents an intelligent elevator fault diagnosis system based on the decision tree, try to improve the result by applying the rough set. The result acquired in the fault diagnosis system is ideal. It shows the experiment is effective and cost saving to discover the possible accident. The improved decision tree obtained a satisfactory classification accuracy rates.

The potential value of the system is to provide a new method to predict elevator fault, prolong the instruments life, even eliminate the inconvenience of elevator downtime.

REFERENCES

[1]Seung-Tae Park,"An implementation of risk -based for elevator maintenance",Jounal of Mechainical Science and Technology , 2010,24(12)2367-2376

[2] Guangming Zhang, Shuixia Huang,"The Study of Elevator Fault Diagnosis Based on Multi-Agent System", International Conference on Computational Intelligence and Software Engineering, 2009,123-128

[3]Gang Niu, Sun-Soon Lee, "Decision fusion system for fault diagnosis of elevator traction machine", Jounal of Mechainical Science and Technology , 2009,22(1)85-95

[4]Wojciech Ziarko "Stochastic Approach to Rough Set Theory", Lecture Notes in Computer Science, 2006, Volume 4259/2006, 38-48

[5]Sonajharia Minz, "Rough Set Based Decision Tree Model for Classification",Lecture notes in computer science, 2003, Volume 2737/2003, 172-18

[6]GRZYMALA-BUSSE J W,HU M."A comparison of several approaches to missing attribute values in data mining", Lecture Notes in Computer Science, Springer Vedag,2001,378-385.

[7]ZIARKO Wojciech,"Rough sets:the classical and extended views",Journal of Chongqing University of Posts and Telecommunications(Natural Science Edition) , Vol.20 No.3 Jun 2008 254-265

[8]Ramadevi Yellasiri,"Decision Tree Induction Using Rough Set Theory Comparative Study", Journal of Theoritical and Applied Information Technology, 2007, Vol12 110-114

[9]Binoy.B.Nair, "A Decision Tree- Rough Set Hybrid System for Stock Market Trend Prediction", International Journal of Computer Applications (0975 – 8887)Volume 6– No.9, September 2010

[10] SANG-WOOK HAN, "Rough Set-Based Decision Tree Using A Core Attribute", International Journal of Information Technology & Decision Making, Volume: 7, Issue: 2(2008) . 275-290

Authorized licensed use limited to: Southern University of Science and Technology. Downloaded on October 16,2023 at 04:15:57 UTC from IEEE Xplore. Restrictions apply.