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State Identification of Hoisting Motors Based on Association Rules for Quayside Container Crane

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Abstract: Quay container crane hoisting motor is a complex system, and the characteristics of long-term evolution and change of running status of there is a rule, and use it. Through association rules analysis, this paper introduced the similarity in association rules, and quay container crane hoisting motor status identification. Finally validated by an example, some rules change amplitude is small, regular monitoring, not easy to find, but it is precisely because of these small changes led to mechanical failure. Therefore, using the association rules change in monitoring the motor status has the very strong practical significance.

1. Introduction

In the past, most of the researches on association rules mining in engineering field only analyzed the association rules and did not analyze and analyze the long-term evolution and minor changes of association rules [1-3]. Association rules are used to monitor the change of mechanical state of shore-bridge hoisting motors, so it is necessary to carry out association rules mining for long-term monitoring information of quayside bridge. Therefore, the proposed partition association rule-similarity [4-5], that is, The Similarity Degree of Mechanical Information Association Rules of Hoisting Motors.

2. Similarity criteria

The similarity between association rules and the formula is as follows:

$$S_{ij}=\begin{cases} \dfrac{l_{ij}\sum_{p} X_{ijp}}{|A_{ij}|}\times\dfrac{h_{ij}\sum_{q} Y_{ijp}}{|B_{ij}|} & \text{if } |A_{ij}|\neq 0 \text{ and } |B_{ij}|\neq 0 \quad (1-1) \\ 0 & \text{if } |A_{ij}|\neq 0 \text{ or } |B_{ij}|=0 \quad (1-2) \end{cases}$$

Among $1_{ij}=\dfrac{|A_{ij}|}{\max(|M_i^{t_1}|,|M_j^{t_2}|)}$,

$$H_{ij}=\frac{|B_{ij}|}{\max(|N_{\mathrm{i}}^{t_1}|,|N_j^{t_2}|)} \quad (1-3)$$

L_{ij} and $H_{ij}$are used to represent the axial similarity of the regular lift motor and the hoist motor respectively. The similarity S_{ij} is the general rule similarity of the motor, and its range is [0,1]. After the rule similarityity is calculated, we can use the maximum similarity of rit1 and rjt2 to measure the rule change at time t1 and t2 [6-10].

The maximum similarity formula is:

$$S_{\mathrm{i}}^{t1}=\max(S_{\mathrm{i1}}^{\mathrm{t1}},S_{\mathrm{i2}}^{t2},\ldots,S_{\mathrm{iRt2}}^{t1})$$

$$S_{\mathrm{j}}^{t2}=\max(S_{\mathrm{j1}}^{t2},S_{\mathrm{j2}}^{t2},\ldots,S_{\mathrm{jRt1}}^{\mathrm{t2}})$$

If the maximum similarity S_{ij} = 1 of the association rule, the association rule exists at any time, so it is called stationary rule. If the support of association rules is increasing, the rules are becoming stronger and more stable. On the contrary, if the support is decreasing, the rules are becoming weaker and there is a tendency to disappear.

If the maximum similarity of association rule 0 <S <1, it means that the left and right association rules are partially similar. (RMT) is set. If the maximum similarity S> RMT and disappears at time t2, the rule is the disappearance rule. If the maximum similarity of the association rule S <RMT, and the time t2 is different from the time t1, the rule is a new rule.

3. Categories of association rules

In this paper, a large number of association rules mining for lifting motors of a bridge crane from January to June of 2015 are carried out, and some interesting results are obtained (GA - kmeans result is taken as an example). But some of these rules have always existed, some have disappeared over time, and others have changed over time. Therefore, according to the regularity of these rules, into the similarity of the formula, the association rules will be divided into four categories, including the stability of the rules, changes in the rules, the disappearance of the rules and new rules.

3.1. The stability of the rules

During the months of January through June 2015, there have been some fixed rules that do not change much in the numerical range or number of projects, as shown in Table 1.

Table 1. Steady Rules (January and February)

Lifting Motor Radial Frequent Itemsets	Lifting Motor Axial Frequent Itemsets	Support (%)	Confidence (%)

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L[0.0532 0.8655]	R[0.0513 34.4633]	65.16 56.35	70.41 68.86

The left side of the association rule is the vibration intensity in the radial direction of the hoist motor, and the right side is the vibration intensity in the axial direction. When the time t12 in January and February, respectively, the support of the rule is 65.16 and 56.35, and the confidence is 70.41 and 68.86, the changes are small. According to the formula to calculate the maximum similarity and are 1, and the support will be in the range of 32 - 38%. The rule states that the mechanical condition of the hoist motor remains stable during the two months without any major change. Therefore, this rule is called a stable rule.

3.2. The rules of change

Container crane hoisting motor with the continuous wear and tear of mechanical components, various parts of the state continue to occur in subtle changes, so the overall state of the bridge crane is always changing, it will produce a lot of fine rule changes.

Some of the rules found in January are shown in Table 2.

Table 2. Rules for Changes (January)

Lifting Motor Radial Frequent Itemsets	Lifting Motor Axial Frequent Itemsets	Support（%）	Confidence（%）
L[0.0532 0.8655]	R[0.0513 24.4633]	62.22	66.87

Some of the rules found in March are shown in Table 3.

Table 3. Rules for Changes (March)

Lifting Motor Radial Frequent Itemsets	Lifting Motor Axial Frequent Itemsets	Support（%）	Confidence（%）
L[0.0570 0.8578]	R[0.0513 35.4633]	50.93	59.20

Some of the rules found in May are listed in Table 4.

Table 4. Rules for Changes (May)

Lifting Motor Radial Frequent Itemsets	Lifting Motor Axial Frequent Itemsets	Support（%）	Confidence（%）
L[0.0586 1.3763]	R[0.0622 22.0970]	35.50	54.28

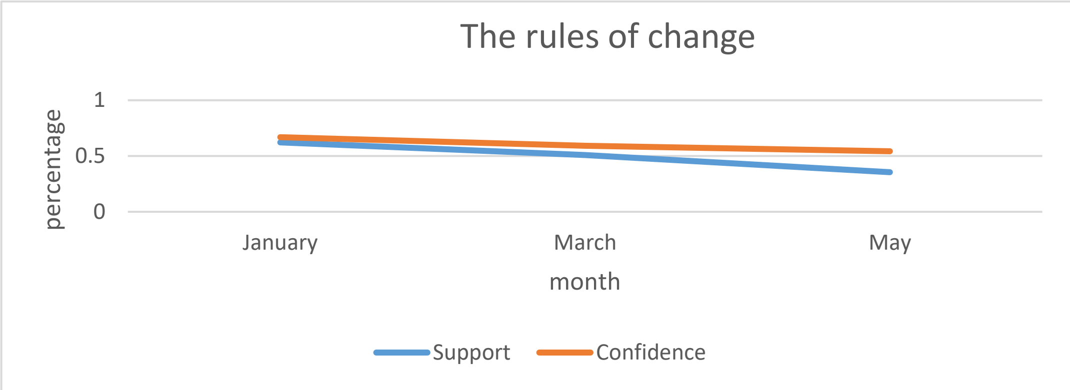

Figure 1. The rules of change

From the above 3 months, the same radial and axial vibration intensity,as shown in Figure 1. Support and confidence were high in the January rule, but in the May change, support and confidence fell by about 10%. During this period, a new rule interval was found in which the range of values from R [0.0513 24.4633] to R [0.0513 35.4633] in March was larger, but the number remained unchanged, indicating a change rule.

3.3. The rules of disappearance

From January to June 2015, some rules will suddenly disappear, the phenomenon often occurs in a part of the parts change, and then rule disappears. As shown in Table 5:

Table 5. Rules for Disappearance (February)

Lifting Motor Radial Frequent Itemsets	Lifting Motor Axial Frequent Itemsets	Support（%）	Confidence（%）
L[0.0.640 1.0621]	R[0.0663 15.7336]	30.19	47.26

The rule of disappearance shown in the above table is obtained in February. From the table, the association rules of the motor radial and axial vibration can be obtained, but the rule disappears in March, and the maximum similarity S = 0, Set RMT = 0.5. That is, the rule is disappears.

3.4. New rules

Usually some rules will disappear after the new rules will appear with the emergence of new rules in June as shown in Table 6:

Table 6. Rules for New Students (June)

Lifting Motor Radial Frequent Itemsets	Lifting Motor Axial Frequent Itemsets	Support (%)	Confidence (%)
U1[0.0534 0.9177]	U2 [0.0399 0.5484]	63.78	79.82

Prior to June, the association rules did not exist, the rule of support and confidence are high, indicating that the new rules are significant. The maximum similarity of the rule S = 0, so this is a new rule.

4. Summary

In this paper, we first propose to identify the change of hoist motor state of the quayside bridge by using the change of association rule. The similarity degree is used as the measure of association rule partitioning. According to this standard, the association rules are divided into: stable rules; disappearing rules, changing rules and new rules. In order to make better use of association rules to identify the mechanical state of hoisting motor of quayside crane, the real-time data of field hoisting crane is analyzed, which further proves the above viewpoints. This view can find the change of the state of the quay crane from the subtle changes of the monitoring data, which is very important for the condition monitoring, diagnosis and evaluation of the quayside container crane.

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