

Quayside Crane Hoist Motor State Recognition Based on Hierarchical Clustering Algorithm

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Abstract: To analyze the dynamic performance of quayside crane, Hierarchical Clustering Algorithm is applied to recognise the different states of Quayside Crane Hoist Motor. The experiment is based on the data collected by NetCMAS (Condition Monitoring & Assessing System on Network). Provided that without knowing the dynamic performance of quayside crane, the vibratory intensity of hoist motor output to the left of quayside crane (sensor location: L1V) is divided into four different states: starting status, lightly vibrating status, moderate vibrating status and severe vibrating status, meanwhile, the floating upper limit and lower limit could be observed.

1. Introduction

With the development of international trading, freight transportation plays a very important part in promoting trading economic development. As necessary large equipment during freight transportation, quayside crane should be monitored in real time to prevent unnecessary loss during work, which is regarded as an urgent work recently.

Before data mining, the priori knowledge is unknown. State recognition, namely, cluster analysis, is an effectual method to monitoring dynamic performance of quayside crane. Unsupervised learning method could be used to solve the above problem[1].

For the problem listed above, this paper presents a cluster analysis method: Hierarchical Clustering Algorithm to classify the data form hoist motor output to the left of quayside crane for recognizing the different status of dynamic performance of quayside crane.

2. Position of Sensors on Quayside Crane

The data from NetCMAS(Condition Monitoring & Assessing System on Network) collected from quayside crane makes sure the authenticity and reliability of this analysis.

In this analysis, using Hierarchical Clustering Algorithm to analyze the vibratory intensity of motor output to the left of quayside crane (sensor location: L1V). Figure 1 displays the positions of sensors on hoist motors & gearbox. As shown in figure 1.



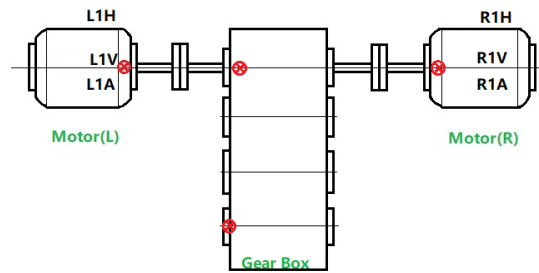


Figure 1. The positions of sensors on hoist motors & gearbox

3. Concept of Hierarchical Clustering Algorithm

Use cluster analysis to cluster something with the same property, which makes the elements in different clusters are less similar, and the elements in the same clusters are more similar. Hierarchical Clustering Algorithm is widely applied to many different fields, such as statistics, machine learning, space database, biology and marketing[2]. For example, in management and engineering, Hierarchical Clustering Algorithm is used to deal with the relationship of customers of bank[3]; for clustering stock samples, and define the investment portfolio on the basis of the result[4] etc. in geography, Hierarchical Clustering Algorithm is applied to regionalism[5]; applied to analyze the structure of consumption[6] etc. in information and communication engineering, Hierarchical Clustering Algorithm is used to traffic communication in real time[7]; used to filter junk e-mail[8] and test mendacious ID[9]; recognition and classification of digital pictures and videos[10] etc. in biology, Hierarchical Clustering Algorithm is used to analyze the system and dynamics of biological networks[11]; used for multi-clustering analysis for different kinds of animals[12]; used to classify the protein clusters, and rank the effectors of the protein for the fungi[13].

Clustering is an unsupervised learning process; the difference between classification and clustering is that it is necessary to know the data characteristics in advance for classification. Thus, in many applications, as a kind of data pre-processing, clustering analysis is the basis of further data analysis and processing[3]. For quayside crane, the machine status of related data collected by NetCMAS is unknown, so that clustering analysis is used to handle this kind of problem. Comparing to K-mean Clustering Algorithm, it is unnecessary for Hierarchical Clustering Algorithm to define the initial value during the data processing, which simplified the data processing; comparing to SOM(Self-organizing Maps), the calculation of Hierarchical Clustering Algorithm is easier and better-understanding, which saves the computer memory.

Hierarchical Clustering Algorithm and Partitional Clustering Algorithm are two mainstays for clustering analysis. Both of them are simple and could be used for handle large size of database.

Hierarchical clustering method is carried out according to distance measure criterion among clusters. Structure and maintain clustering tree made up of clusters and subsidiary clusters, and put it to an end until the specific condition is met. Hierarchical clustering method is divided into agglomerative and divisive according to whether the process is from the bottom to the up or from the up to the bottom. The quality of a simple Hierarchical clustering method is limited by the following condition: once a process of combining or splitting is carried out, it could not be modified.

AGNES(Agglomerative NESTing) of which principle is from the bottom to the up, first consider every element as a cluster, and then, combine the clusters into larger clusters until all elements are included to one cluster, or until the specific condition is met. Most Hierarchical clustering methods belong to the above content; they differ from the definition of similarity[14].

Using Hierarchical Clustering Algorithm to cluster the data, choose one of the “bottom-up” AGNES (Agglomerative NESTing) method:

- (1) Euclidean distance calculation method is used to calculate the distance between two elements; Ward's linkage is used to calculate the distance between two clusters:

$$d(r, s) = \sqrt{\frac{2n_r n_s}{(n_r + n_s)}} \|\bar{x}_r - \bar{x}_s\|_2 \quad (1)$$

where: n_r is the number of elements in cluster r

n_s is the number of elements in cluster s

\bar{x}_r is the average value of elements in cluster r

\bar{x}_s is the average value of elements in cluster s

- (2) (initialized) regard every element as one cluster, and calculate the distance between them. The distance also called the similarity between two samples.
 - a) search for the nearest distance, and consider them as one cluster;
 - b) repeat to calculate the distance between the new cluster and the old clusters (use the above equations), and repeat a) and b);
- (3) condition of convergence: repeat a) and b), until all elements are clustered to one cluster, and then end the process. As shown in Figure 2.

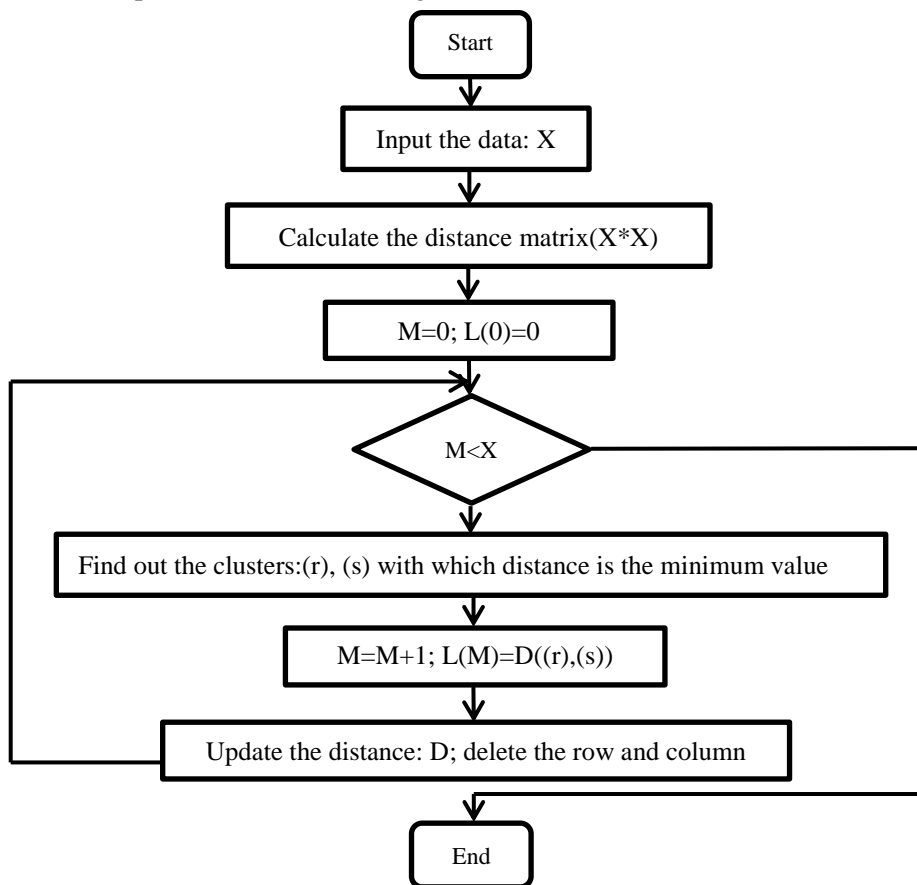


Figure 2. The flow diagram of AGNES (Agglomerative NESTing)

4. Data Analysis

Choosing the vibratory intensity from 25th, January, 2010 to 7th, February, 2010, from the motor output to the left of quayside crane (sensor location: L1V), use Hierarchical Clustering Algorithm to cluster the data. The following table is the clustering result, which presents the vibratory intensity interval, classification, and the proportion of every classification. As shown in table 1, table 2, table 3, table 4, table 5, table 6, and table 7.

Table 1 Hoist motor vibratory intensity intervals

Date	1-25	Point	%	1-26	Point	%
I	[0.043 1.806]	5692	74.62	[0.035 0.788]	3332	42.00
II	[1.809 4.150]	1536	20.14	[0.789 2.326]	3548	44.73
III	[4.171 8.443]	341	4.47	[2.329 4.179]	685	8.64
IV	[8.543 13.981]	59	0.77	[4.202 14.325]	367	4.62

Table 2 Hoist motor vibratory intensity intervals

Date	1-27	Point	%	1-28	Point	%
I	[0.034 0.898]	5927	70.22	[0.036 0.645]	4529	54.59
II	[0.900 0.971]	1798	21.30	[0.647 1.898]	2667	32.15
III	[1.975 5.482]	617	7.33	[1.900 3.721]	841	10.14
IV	[5.793 13.413]	97	1.15	[3.750 14.011]	258	3.11

Table 3 Hoist motor vibratory intensity intervals

Date	1-29	Point	%	1-30	Point	%
I	[0.037 1.198]	6028	73.66	[0.041 0.603]	3138	38.63
II	[1.200 2.197]	1457	17.80	[0.605 1.629]	3399	41.84
III	[2.202 5.537]	554	6.77	[1.630 5.310]	1440	17.73
IV	[5.594 13.603]	144	1.76	[5.366 13.142]	146	1.80

Table 4 Hoist motor vibratory intensity intervals

Date	1-31	Point	%	2-1	Point	%
I	[0.025 0.354]	3677	44.60	[0.050 0.868]	3089	39.12
II	[0.355 1.910]	3648	44.25	[0.869 2.592]	4042	51.19
III	[1.912 4.132]	739	8.77	[2.601 5.340]	538	6.81
IV	[4.167 16.501]	179	2.13	[5.372 15.681]	227	2.87

Table 5 Hoist motor vibratory intensity intervals

Date	2-2	Point	%	2-3	Point	%
I	[0.031 0.800]	4257	54.22	[0.034 0.643]	3712	45.74
II	[0.804 3.557]	3184	40.55	[0.644 1.843]	3182	39.21
III	[3.571 7.334]	318	4.04	[1.844 4.340]	959	11.82
IV	[7.476 14.535]	93	1.18	[4.363 13.246]	263	3.24

Table 6 Hoist motor vibratory intensity intervals

Date	2-4	Point	%	2-5	Point	%
I	[0.049 0.790]	4274	57.11	[0.037 0.630]	2763	37.77
II	[0.792 3.160]	2929	39.14	[0.631 2.830]	4080	55.77
III	[3.172 7.086]	236	3.15	[2.835 6.690]	405	5.54
IV	[7.178 12.762]	45	0.60	[6.820 13.776]	68	0.93

Table 7 Hoist motor vibratory intensity intervals

Date	2-6		Point	%	2-7		Point	%
I	[0.046	1.137]	5283	62.39	[0.060	1.453]	5867	70.52
II	[1.138	2.164]	2301	27.17	[1.454	3.014]	1958	23.53
III	[2.168	5.284]	696	8.22	[3.024	7.159]	418	5.02
IV	[5.335	14.282]	188	2.22	[7.254	14.717]	77	0.93

According to the above analysis, Hierarchical Clustering Algorithm divides the vibratory intensity into four parts, the first part I present the hoist motor stays in starting status, the second part II stands for the hoist motor stays in lightly vibrating status, the third part III means the hoist motor stays in moderate vibrating status and, the fourth part IV indicates the hoist motor stays in severe vibrating status. Take the average value of every interval. As shown in table 8:

Table 8 Hoist motor vibratory intensity intervals

classes	Intervals (vibratory intensity)
I	[0.040 0.900]
II	[0.902 2.446]
III	[0.254 5.717]
IV	[5.800 14.141]

According to analysis, 80% points are included to part I and part II, which means the hoist motor stay in starting status and lightly vibrating status.

5. Conclusion

Using Hierarchical Clustering Algorithm to analyze the vibratory intensity of motor output to the left of quayside crane (sensor location: L1V), from 25th, January, 2010 to 7th, February, 2010. The data is divided into four parts(I,II,III,IV), which separately stand for the hoist motor staying in starting status, lightly vibrating status, moderate vibrating status and severe vibrating status. 80% points are included to part I and part II, which means the hoist motor stay in starting status and lightly vibrating status. The final vibratory intensity interval is defined by taking the average value of every data interval of every day.

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