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Monitoring and Troubleshooting Alstom Locomotive Blowers using Vibration Analysis and Support Vector Machine

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ABSTRACT: Vibration analysis is one of the most practical methods for monitoring and troubleshooting rotating equipment. In this research, vibration analysis and support vector machine algorithms were used for monitoring and troubleshooting Alstom locomotive blowers. First, vibration data were collected from the blowers and the received signals were categorized into four groups: healthy blowers and blowers with problems of unbalance, loose shaft (base), and warped blades. Sixteen frequency and time features were then extracted from the received signals. Because in rotating systems, the ratio of the intensity of vibrations in the harmonics of the rotation of the machine can help diagnose the faults, the ratios of all features were calculated and defined as new features. The accuracy of the network can be sometimes lowered by the multitude of features, thus, a t-test filter was inserted into the support vector machine algorithm to select the features. The results show that the t-test filter increased the accuracy of the support vector machine algorithm. Finally, the feature selection of this network was compared with the feature selection by the genetic algorithm. The results show that the network designed in this research has a better performance in feature selection than the genetic algorithm.

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1- Introduction

It is necessary to monitor and troubleshoot the locomotive parts because their defects can cause plenty of repair costs as well as railway blockage. Blowers are very important parts of the locomotives, which are in charge of cooling the generator and the traction motor. Thus, it is very important to diagnose their defects in time. The use of vibration analysis is very common in detecting faults in rotating machines, and many manuals have already been published in this regard [1-3]. In recent years, the use of machine learning algorithms such as K-Nearest Neighbors (KNN), Artificial Neural Networks (ANN), and Support Vector Machines (SVM) have become common for detecting and classifying defects [4, 5]. Feature selection is one of the most important issues in machine learning. In this research, the t-test and SVM algorithm are combined to yield an intelligent algorithm for feature selection, which can determine the optimal feature vector for a support vector machine and select features that are effective in decision-making.

2- Methodology

At first, vibration data were collected from the blower of Alstom locomotives, and 16 frequency and time features were extracted from the vibration signals. Defects in the rotating parts such as unbalance, misalignment, and blade warp can cause an increase in the intensity of vibrations at a frequency of one, two, and three times rotation. In order to identify the defects from one another, the ratios of the intensity of vibrations at the frequencies had to be taken into consideration. Therefore, the ratios of extracted features were also calculated and defined as new features. Next, a t-test was used in the support vector machine algorithm to remove the ineffective features and select the best feature vector to obtain the highest accuracy of classification in the network. The T-test is a statistical test that compares the mean and variance of features extracted from two separate groups and selects the features with a significant difference in different groups. There is a coefficient called alpha coefficient in the t-test, which determines the significance level of the test. When the alpha coefficient changes, the degree of strictness in selecting the feature changes (The lower the alpha coefficient, the lower the number of selected features). Because the number of selected features and the accuracy of the network changes as the alpha coefficient changes, the MATLAB program is written in such a way that the alpha coefficient varies from 0.001 to 0.1. Then, for each alpha, the selected feature vector is given to the support vector machine algorithm. Finally, the optimal alpha and feature vector are selected according to the accuracy of the network.

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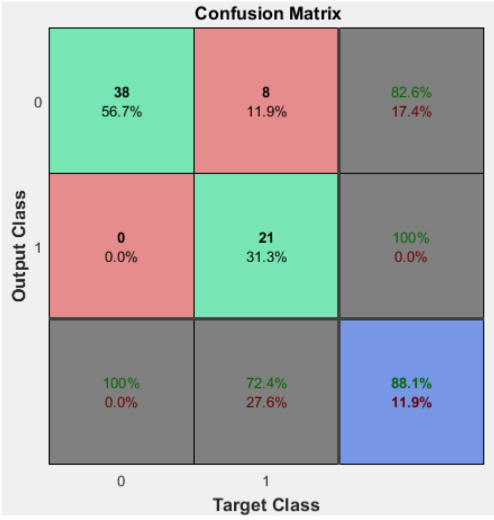

Fig. 1.Confusion matrix of the neural network without t-test filter

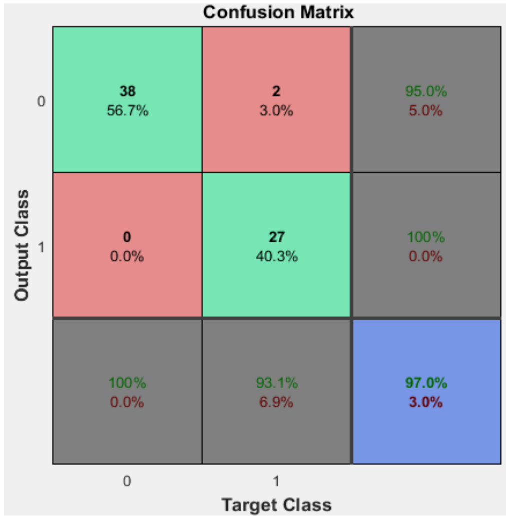

Fig. 2. Confusion matrix of neural network with t-test filter

3- Discussion and Results

In order to check the effectiveness of the method proposed in this research, first, 136 features detected from the vibration signals of healthy and defective blowers, without a T-test filter, were given as input to the support vector machine network. The overall accuracy of the network was 1.88, whose confusion matrix is shown in Fig. 1. After using the t-test filter, 65 features out of 136 features were extracted, selected, and given as input to the support vector machine network. As a result, the accuracy of the network increased to 97%, which shows the positive effect of the t-test filter on the classification accuracy (Fig. 2).

4- Conclusion

This paper reports on proposing a new method for feature selection and the classification of blower defects via the use of a t-test in the support vector machine algorithm. The results showed that the proposed method can identify the effective data in decision-making well and increase the classification accuracy by choosing the proper feature vector. The method could detect the unbalance defects, looseness of the shaft, and warped blades with an accuracy of more than 90% and identify the effective features in the diagnosis of these defects. The results showed that the unbalance defect can result in a noticeable increase in the intensity of vibrations at 1X frequency, the blade warping defect can cause an increase in the intensity of vibrations at frequencies 2X, 3X, and 10X, and the loose shaft defect can cause an increase in the intensity of vibrations at frequencies from one to ten times the nominal speed of the blower as well as increased time features such as root mean square and signal energy.

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