Automatic Machine Fault Detection based on Vibration Signal

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Machine maintenance is important in the smart factory, which requires lots of attention to improve both accuracy and general performance. Nowadays, predictive maintenance and automatic fault detection are improving due to the application of IoT networks and real-time analysis in the factory environment. One of the main signals that can be used for predictive maintenance is the machine vibration signal, which can be collected, analyzed with high accuracy and efficiency, make fault detection easy to implement. In our study, we use the Spectra Quest’s Gearbox Prognostics Simulator data as the input data for the classification system. The AI algorithms are Artificial Neural Network, Linear Regression, and Support Vector Machine. The highest accuracy reached is 100%.

Keywords—Machine Learning, ANN, LR, SVN, Vibration Signal.

I. INTRODUCTION

Machine maintenance is a critical field in the manufacturing industry, that has a high contribution to the operation of a smart factory. Recently, predictive maintenance has been a significant acceptance in manufacturing due to accessibility and handling the manufacturing process data in real-time, inexpensive sensors and software that is capable of handling big data and performing real-time data analytics. Today, predictive maintenance involves collecting machine data, performing signal processing, early fault detection, fault diagnosis, time to failure prediction, maintenance resource optimization, and scheduling by using concepts from statistics, machine learning, and data mining [1]. Based on the following components, various architectures and processing models have been proposed over the years, and most of the architectures use supervised learning. The vibration signal is the main data resource for the fault detection application with high accuracy and low cost. In this paper, we propose a machine fault detection method using vibration signal. The Machine Learning algorithms applied are Artificial Neural Network (ANN) [2], Linear Regression (LR) [3], and Support Vector Machine (SVN) [4].

II. FAULT DIAGNOSIS METHODS

A. Gearbox data

The Gearbox data is collect from Spectra Quest’s Gearbox Prognostics Simulator (GPS) and uploaded to OpenEI home page [5]. The GPS gearbox is designed to simulate gearbox configurations with different options and working behaviors. Based on these configurations, the GPS can simulate gearbox dynamics and acoustic behavior, health monitoring, and vibration-based diagnostic data for further study.

The basic GPS includes replaceable parts which are combined for Gearbox operation simulation:

- One shaft test gearbox with two parallel stages.
- Different torsion and radial loading.
- Replaceable gears with large places for additional devices.
- Parallel gearbox which can support rolling element bearings or sleeve bearings.
- Intentional error gearing can be installed to study changing the vibration signature.

Based on these characteristics, the GPS can be customized to handle and examine heavy loads. GPS is also designed with a large reserve space so that the users can place, set up, and install new monitoring devices. In this paper, we collected data in the four directions: g_x, g_y, g_z, and g_t. The GPS is set at 50% of the load condition, and we record the vibration signal under normal conditions and the broken tooth condition (Figure 1).

![G_x vibration signal of (a) normal machine and (b) broken machine](image_url)

Figure 1: G_x vibration signal of (a) normal machine and (b) broken machine

B. Data processing

In the first phase, we extract significant characteristics of the input signal by performing feature extraction. These characteristics vary from signal to signal and are statistical,
domain-specific features, or both. The vibration data are collected and stored as the time series, and we transform it into the frequency domain using FFT (Figure 2). The main purpose of this study is to generate and evaluate broken data that is limited in the experiments. Therefore, we need to analyze both the original and generated data with different approaches and AI models that can affect final results.

The FFT requires lower computation as compared with the original FFT, which is suitable for real-time applications. In this study, we focus on the commercial application in the industrial environment, which requires both high accuracy and real scenario response. Due to these reasons, FFT would be a better choice compared to the DFT. The advantage of FFT is that we can process more significant features in the frequency domain classification between the normal and broken machine signals. For the fault diagnosis methods, the FFT is the best way to extract the input pattern for further analysis, so we keep it as the primary preprocessing process. Based on the FFT input signal, we apply different AI models that can affect Fault Diagnosis results.

The proposed ANN model for full FFT signal has 200 input neural, 100 hidden units, and 2 output neural with softmax activation function for classification. The input of ANN has the shape of 200x4, which contains 4 FFT signal of g_x, g_y, g_z, g_T. The weights of all LSTM cells are initialized as per Xavier and are applied DROP with 0.7 keeping probability. The activation function for the input and hidden layer is Leaky ReLU, and the loss function is sparse categorical cross-entropy. We adaptive momentum (ADAM) as the iterative optimization algorithm. The proposed ANN model for a fully FFT signal was trained over 1000 epochs. The LR and SVN are configuration as in our previous research, applied in [6].

<table>
<thead>
<tr>
<th>AI algorithms</th>
<th>Accuracy</th>
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<tbody>
<tr>
<td>ANN</td>
<td>100%</td>
</tr>
<tr>
<td>LR</td>
<td>100%</td>
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<tr>
<td>SVN</td>
<td>100%</td>
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III. CONCLUSIONS

The role of fault detection in industrial manufacturing is more and more important and requires more effort to improve its accuracy as well as efficiency. With vibration signal combine with machine learning techniques, fault detection becomes easy to implementation with low cost and high accuracy, satisfy the requirement of the commercial applications.

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REFERENCES