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Bearing Fault Diagnosis Using Feature Ranking Methods and Fault Identification Algorithms

V.Vakharia[a]*,V.K.Gupta[b],P.K.Kankar[b]

[a]*Medi-Caps Group of Institutions, Indore, 453331,India*
[b]*PDPM IIITDM, Jabalpur, 482005, India*

Abstract

Diagnoses of bearing faults are important to avoid catastrophic failures in rotating machines. This paper presents a methodology to detect various bearing faults from the measured vibration signal. Features such as kurtosis, skewness, mean, root mean square and complexity measure such as Shannon entropy are calculated from time domain ,frequency domain and discrete wavelet transform. In total 40 features are calculated from bearing conditions such as Healthy bearing, Inner race fault, Outer race fault and Ball fault. Feature ranking methods such as Chisquare, ReliefF method are used to select most informative feature and subsequently to reduce size of feature vector. Comparison has been made between feature ranking methods and classifiers to obtain best diagnosis result with reduce feature set. Our results shows good fault identification accuracy with minimum number of features.

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Keywords: Bearing;Fault diagnosis; Feature ranking method; Classifiers

1. Introduction

The fault diagnosis technique of complex rotating components using vibration analysis has gained considerable attention from researchers across the globe. Majority of problems in rotating machinery are caused by faulty gears, bearings etc. Failure in bearing is one of the primary causes of breakdown in rotating machines. Such breakdowns can lead to expensive shutdowns, drifts in production and even human casualties.

* Corresponding author. Tel.: +91-835-988-1214.
*E-mail address:*vinayvakharia4343@gmail.com

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Nomenclature

Yj	number of observations in category j
μ_j	expected value of Yj
p_{io}	known probability of occurrence
$f_{t,i}$	value of instance x_i on feature f_i
P	distance measurement

In data driven techniques for condition monitoring, vibration signals are obtained from rotor bearing test rig and this signals are processed to extract relevant features which contains information about state of the system. A review of several vibration and acoustic measurement methods used to detect defects in rolling element bearings was presented by Tandon and Choudhury [1]. Advantage of vibration based fault diagnosis technique is that there is no stoppage of machinery required during maintenance. Signals extracted from rolling element bearing for the fault diagnosis are broadly categorized in to three domains: time domain, frequency domain and time-frequency domain. Time domain signal generally gives information how signal amplitude is varied with respect to time. The drawback of features calculated by time domain method is that it is unable to detect faults at early stage [2].Frequency domain method is another technique for fault diagnosis of bearing. Every bearing component has its own characteristic frequency. With the help of Fast Fourier Transform (FFT) defects in bearing component can be identify. Disadvantage of Frequency domain method lies in its inability to analyze the non-stationary signals which are generally related to component/machinery defects [3,4].

In recent years, the time-frequency methods such as Wavelet Transform (WT) have been suggested by authors to extract very weak signals [5,6].To enhance fault related information and to reduce noise, DWT based denoising technique was used by Du et al. [7] for bearing condition monitoring. Discrete wavelet transform produces wavelet coefficients after transforming original time domain signal in to the wavelet domain. DWT is applied to discrete data sets and it produces discrete outputs. While using wavelet transform challenge is to choose most appropriate wavelet. Therefore, mother wavelet selection methodologies were proposed based on maximum energy to Shannon entropy ratio and multiscale permutation entropy [5, 8]. Estimating the quality of features is an important issue in the field of machine learning. The criteria used to select the useful features entirely depend on the nature of the feature ranking technique used. In feature ranking method effectiveness of each individual feature is calculated and then the analyst selects features which are appropriate from a given dataset.

In present study, a generalized approach to select optimal number of feature set using gain ratio and ReliefF feature ranking method has been proposed and is evaluated with different classifiers. The combination of feature ranking technique and classifier is used to select the optimum number of feature set which gives maximum efficiency. Fig.1 shows the proposed methodology for fault diagnosis using feature ranking method.

2. Machine Learning Techniques

3.1 Artificial Neural Network (Multilayer Perceptron)

Artificial intelligence techniques such as fuzzy logic, artificial neural network (ANN) have been continuously and successfully applied for bearing fault detection and diagnosis. ANN [9] are made up of interconnected processing units known as neurons and it is adaptively changes its structure during learning phase. ANN usually consists of inputs which are multiplied by weights where weights denote the strength of signal and the computation is done by a mathematical function which denotes the activation of neuron. Based on the signal received neuron computation will be different. Thus higher the weight of artificial neuron stronger the input and by adjusting the weights of a neuron we can able to obtain desired output for a pre-specified inputs. ANN is a type of supervised learning methods which can be trained by supplying data. Multilayer perceptron algorithm is used for testing purpose during which weights are adjusted for error minimization between ANN predictions and outputs [10].