Chapter 12

Intelligent Fault Recognition and Diagnosis for Rotating Machines using Neural Networks

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ABSTRACT

Monitoring industrial machine health in real-time is not only in high demand, it is also complicated and difficult. Possible reasons for this include: (a) access to the machines on site is sometimes impracticable, and (b) the environment in which they operate is usually not human-friendly due to pollution, noise, hazardous wastes, etc. Despite theoretically sound findings on developing intelligent solutions for machine condition-based monitoring, few commercial tools exist in the market that can be readily used. This paper examines the development of an intelligent fault recognition and monitoring system (Melvin I), which detects and diagnoses rotating machine conditions according to changes in fault frequency indicators. The signals and data are remotely collected from designated sections of machines via data acquisition cards. They are processed by a signal processor to extract characteristic vibration signals of ten key performance indicators (KPIs). A 3-layer neural network is designed to recognize and classify faults based on a pre-determined set of KPIs. The system implemented in the laboratory and applied in the field can also incorporate new experiences into the knowledge base without overwriting previous training. Results show that Melvin I is a smart tool for both system vibration analysts and industrial machine operators.

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1. INTRODUCTION

Various studies have been done on the application of neural networks to provide intelligent solutions for machine condition monitoring and fault diagnosis (Samhouri et al., 2009; Peng, 2004; Srinivasan, 2003; McCormick & Nandi, 1996; Umesh & Srinivasan, 2005; Gerlad et al., 2010; Aravindh et al., 2010; Yangwen, 2009; Tetsuro & Wang, 2008; Balakrishnan & Honavar, 1995; Saxena & Saad, 2004; Shiroishi et al., 1997). For example, Srinivasan (2003) described a neural network to identify the approximate location of damage due to cracks through the analysis of changes in the neural frequencies. McCormick and Nandi (1996) described neural network methods for automatically classifying machine conditions from the vibration time series. Umesh and Srinivasan (2005) carried out studies on experimental data simulation of faults such as parallel misalignment, angular misalignment, unbalance, crack, light and heavy rubs, looseness and bearing clearance. Saxena and Saad (2004) carried out research on fault diagnosis in rotating mechanical systems using Self-Organizing Maps.

Despite these theoretically sound findings on developing intelligent solutions based on neural networks for machine condition based monitoring, there are virtually no commercial tools in the market that can be readily used. This paper reports the design and implementation of a tool that uses neural network technology for deriving intelligent fault recognition based on observation of changes in various fault frequency indicators.

An Artificial Neural Network (ANN) is an intelligent information processing paradigm that imitates the biological nervous systems. In the brain, electrochemical signals pass between neurons through the synapses. In neural network analysis, the signal between neurons is simulated by interlinked circuits and software, which apply weights to the input nodes and use an activation function to scale the neuron’s output to an acceptable range. Thus, the basic element in an ANN is the artificial neuron node, which receives and combines signals from many other neurons through input paths in the same way as the biological neuron receives and processes signals via axons. The output of a neural network is therefore a linear combination of inputs, determined by weights that simulate synapses in the biological neural system. The weights are usually selected such that when the element is presented with input data, the output is as close to the desired output as possible. A typical neuron in an ANN has two modes of operation - the training mode and the using mode. In the training mode, the neuron can be trained to fire (or not) for particular input patterns, while in the using mode, when a taught input pattern is detected at the input, its associated output becomes the current output of the ANN. If the input pattern is not yet present in the trained set of the input patterns, a predetermined firing rule is used to determine whether to fire or not.

Neural networks make use of two types of values – weights and thresholds. Weights define the interaction between the neurons, while thresholds define what it takes to get a neuron to fire.

In condition based monitoring systems, data is acquired from various types of machines via sensors. By analyzing the collected vibration data, possible faults such as unbalance, bent shaft, shaft crack, bearing clearance, rotor rub, misalignment, and looseness can be identified. Because a lot of industrial machines operate in remote areas, they are often inaccessible at certain periods of the year. A system that remotely collects vibration data in real-time, processes it, detects possible faults and makes recommendations on predictive maintenance will certainly reduce downtime and associated consequences.

This paper is an extended version of Ngolah et al. (2011) and presents the development of a mechanism for fault recognition and classification based on fault frequency indicators using the neural network technology. In this paper, Section 2 gives an overview of the set of tools that have been developed to provide intelligence on online