Application of Variable Precision Rough Set Model and Neural Network to Rotating Machinery Fault Diagnosis

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Abstract. An integration method of variable precision rough set and neural network for fault diagnosis is presented and used in rotary machinery fault diagnosis. The method integrates the ability of variable precision rough set on reduction of diagnosis information system and that of neural network for fault classification. Typical faults of rotating machinery were simulated in our rotor test-bed. The power spectrum data are used as rotating machinery fault diagnosis signal. For inconsistent data and noise data in power spectrum, variable precision rough set model allows a flexible region of lower approximations by precision variables. By attribute reduction based on variable precision rough set, redundant attributes are identified and removed. The reduction results are used as the input of neural network. The diagnosis results show that the proposed approach for input dimension reduction in neural network is very effective and has better learning efficiency and diagnosis accuracy.

1 Introduction

Fault diagnosis can generally be treated as a pattern classification task [8]. Neural network for pattern recognition has good adaptability and self-learning ability, which makes neural network to be applied in fault diagnosis [4], [11]. For applications of fault diagnosis it requires outputs with high accuracy, especially for fault diagnosis of rotating machinery. However, neural network based fault diagnosis systems is often too slow and inefficient. The main reason is that neural network can't deal with the redundant information from the fault diagnosis vibration signal. The redundant information will easily lead to some problems such as too complex network structure, long training time and even diagnosis mistakes. Because of these disadvantages the further application of neural network in the fault diagnosis is limited. Rough set theory is a mathematical tool for dealing with vagueness and uncertainty, which was introduced and studied by Z. Pawlak [9],[10]. In the rough set theory, the approximation region is determined through

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the indiscernible relations and classes. By the knowledge reduction, the redundant information is deleted and the classified knowledge rules are induced. As an extension of original rough set model, the variable precision rough set (VPRS) model is defined by W. Ziarko [6],[13]. This model inherits all basic mathematical properties of the original rough set model but allows for a predefined precision level β, which can avoid high sensitivity of computation to small misclassification errors. This is an important extension which will give us a new way to deal with the noisy data such as fault diagnosis vibration signal.

VPRS model and neural network show respectively advantages in fault diagnosis. How to integrate VPRS model and neural network together and make use of their respective advantages for fault diagnosis is an important issue. In this paper, VPRS model is taken as a preprocessing unit of fault diagnosis neural network. By VPRS model, redundant diagnosis information is reduced and the reduction results are handled as inputs of neural network. Therefore, dimensions of input data are decreased and structures of neural network are improved. For rotary machinery, typical faults were simulated in our rotor test-bed. The power spectrum data are used as rotating machinery fault diagnosis signal. For inconsistent data and noise data in power spectrum, VPRS model allows a flexible region of lower approximations by precision variables. The diagnosis results show that the proposed approach has better learning efficiency and diagnosis accuracy.

2 An Overview of Variable Precision Rough Set Model

VPRS model extends the original rough set model by relaxing its strict definition of the approximation boundary using a predefined precision level β. Hence some boundary regions are included in the positive region. It uses 'majority inclusion' relations for classification rather than 'equivalence relation' of original rough set [3]. Therefore, the VPRS model enhances discovery capabilities of the original rough set model and tolerates the inconsistent data of information system.

For a given information system $S = (U, A, V, f)$, $X \subseteq U$, $B \subseteq A$, lower approximation and upper approximation are defined with precision level β. The value β denotes the proportion of correct classifications [1], in this case, the domain of β is $0.5 < \beta \leq 1$. $\underline{B}^{\beta}(X)$and $\overline{B}^{\beta}(X)$ are respectively called the lower and upper approximation of X with precision level β.

$$\underline{B}^{\beta}(X) = \bigcup \{[x]_B : P\left(X/[x]_B\right) \geq \beta\} \tag{1}$$

$$\overline{B}^{\beta}(X) = \bigcup \{[x]_B : P\left(X/[x]_B\right) > 1 - \beta\} \tag{2}$$

Here, $[x]_B$ is the equivalence class, $x \in U$. $P\left(X/[x]_B\right)$is referred as conditional probability function [2],[3],[13].

$$P\left(X/[x]_B\right) = |X \cap [x]_B| / |[x]_B| \tag{3}$$

Where $|X|$is the cardinality of the set X.