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Bearing performance degradation assessment using locality preserving projections and Gaussian mixture models

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ABSTRACT

The sensitivity of various features that are characteristics of machine performance may vary significantly under different working conditions. Thus it is critical to devise a systematic feature extraction (FE) approach that provides a useful and automatic guidance on using the most effective features for machine performance prediction without human intervention. This paper proposes a locality preserving projections (LPP)-based FE approach. Different from principal component analysis (PCA) that aims to discover the global structure of the Euclidean space, LPP is capable to discover local structure of the data manifold. This may enable LPP to find more meaningful low-dimensional information hidden in the high-dimensional observations compared with PCA. The effectiveness of the proposed approach for bearing defect and severity classification is evaluated experimentally on bearing test-beds. Furthermore, a novel health assessment indication, Gaussian mixture model (GMM)-based negative log likelihood probability (NLLP) is developed to provide a comprehensible indication for quantifying bearing performance degradation. The proposed approach has shown to provide better performance than using regular features (e.g., root mean square (RMS)). The experimental results indicate potential applications of LPP-based FE and GMM as effective tools for bearing performance degradation assessment.

1. Introduction

Bearing is one of the most important components in rotating machinery. During operation, the bearings are often subjected to high loading and severe conditions. Under this severe operating condition, defects are often developed gradually on the bearings. If no effective actions are taken, bearing failures in rotating machines can cause machine breakdown and economical loss. Therefore, it is of prime importance to detect accurately the presence and propagation of faults, especially at their early stage, in bearings to prevent the sequent damage and reduce the costly downtime. To date, the process of monitoring the operating conditions of machines for advanced warning of defects has received considerable attentions in industrial maintenance [1,2]. These techniques can be classified into three domains: frequency domain analysis [3–5], time domain analysis [6,7], and time–frequency domain analysis [3,8]. These frequency or time domain analysis methods look for periodically occurring high-frequency transients, which however is complicated by the fact that this periodicity may be suppressed. Moreover, classical Fourier methods tend to average out transient vibrations and therefore become more sensitive to background noise. To overcome this problem, the time–frequency domain analysis,

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