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Time-frequency atoms-driven support vector machine method for bearings incipient fault diagnosis

Ruonan Liu [a,b], Boyuan Yang [a,b], Xiaoli Zhang [a,b], Shibin Wang [a,b], Xuefeng Chen [a,b,*]

[a] The State Key Laboratory for Manufacturing Systems Engineering, Xi'an, PR China
[b] School of Mechanical Engineering, Xi'an Jiaotong University, Xi'an, PR China

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ABSTRACT

Bearing plays an essential role in the performance of mechanical system and fault diagnosis of mechanical system is inseparably related to the diagnosis of the bearings. However, it is a challenge to detect weak fault from the complex and non-stationary vibration signals with a large amount of noise, especially at the early stage. To improve the anti-noise ability and detect incipient fault, a novel fault detection method based on a short-time matching method and Support Vector Machine (SVM) is proposed. In this paper, the mechanism of roller bearing is discussed and the impact time frequency dictionary is constructed targeting the multi-component characteristics and fault feature of roller bearing fault vibration signals. Then, a short-time matching method is described and the simulation results show the excellent feature extraction effects in extremely low signal-to-noise ratio (SNR). After extracting the most relevance atoms as features, SVM was trained for fault recognition. Finally, the practical bearing experiments indicate that the proposed method is more effective and efficient than the traditional methods in weak impact signal oscillatory characters extraction and incipient fault diagnosis.

1. Introduction

Condition monitoring of rotating machinery is important for system maintenance and process automation. Roller bearing, as an important component, is not only widely used, but also a common failure unit in rotating machinery due to its complex running conditions [1]. The accuracy of mechanical system is highly dependent on the dynamic performance of bearings [2]. Severe working condition such as heavy load, high speed and lubrication oil lackage makes bearing damage inevitable [3]. Therefore, faulty rolling bearings are often the root cause of faults and they must be detected as early as possible to avoid the financial loss and disasters.

However, the measured vibration signals are always complex and non-stationary with a large amount of background noise, and the useful fault information is usually too weak to be distinguished. Furthermore, the early fault symptoms hidden in signals are always quite difficult to be found [4]. To overcome this problem, numerous vibration signal processing approaches and feature extraction methods have been developed recently including probabilistic analysis, frequency

* Corresponding author at: The State Key Laboratory for Manufacturing Systems Engineering, Xi'an, PR China. Tel.: +86 29 82667963; fax: +86 29 82663689.
E-mail addresses: liuruonan0914@stu.xjtu.edu.cn (R. Liu), chenxf@mail.xjtu.edu.cn (X. Chen).

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analysis, time-domain analysis and various signal processing algorithms for the tasks of detection and diagnosis [5–7], such as Fourier transform [8], wavelet transform (WT) [9–12], empirical mode decomposition(EMD) [13–16], spectral kurtosis (SK) [17]. These methods can partition the time-frequency place and design innumerable linear time-frequency representation methods according to the requirements. However, the results of these methods are directly influenced by the base functions because signals can be analyzed very well only on the condition that the time-frequency structure of signal and base function are similar. And it is difficulty to choose proper base functions.

To avoid this problem and represent the complicate signal more efficiently, atom decomposition methods were proposed which is a signal representation method based on various parameterized basis functions library called the dictionary and have received increasing attention in signal and image processing. Matching pursuit (MP) algorithm is one of the most important atom decomposition methods which was proposed by Mallat and Zhang in 1993 [18]. At the same time, Qian and Chen proposed an idea which was similar with MP. MP is a typical greedy algorithm that chooses a waveform that is best adapted to approximate part of the signal at each iteration with a particular over-complete dictionary [19]. However, the over-complete dictionary may lead to huge computation in atom decomposition for signal processing and the decomposition results are directly influenced by the dictionary and the atoms should match with the structure characteristics of the signals [18].

Fault diagnosis often includes three steps: information acquisition, feature extraction and condition recognition. Another point of roller bearing fault diagnosis is pattern recognition [20,21]. Support vector machines (SVM) based on statistical learning theory that are of specialties for a smaller sample number and guarantee the solution are exactly same with the global optimal solution. Considering that it is hard to obtain sufficient fault samples in practice, SVM are applied to the bearing fault diagnosis because of their high accuracy and good generalization for a smaller sample number. However, it is not sensitive for incipient fault detection if use the traditional time domain indexes as inputs for SVM such as root means square (RMS), absolute average, kurtosis, square-root amplitude.

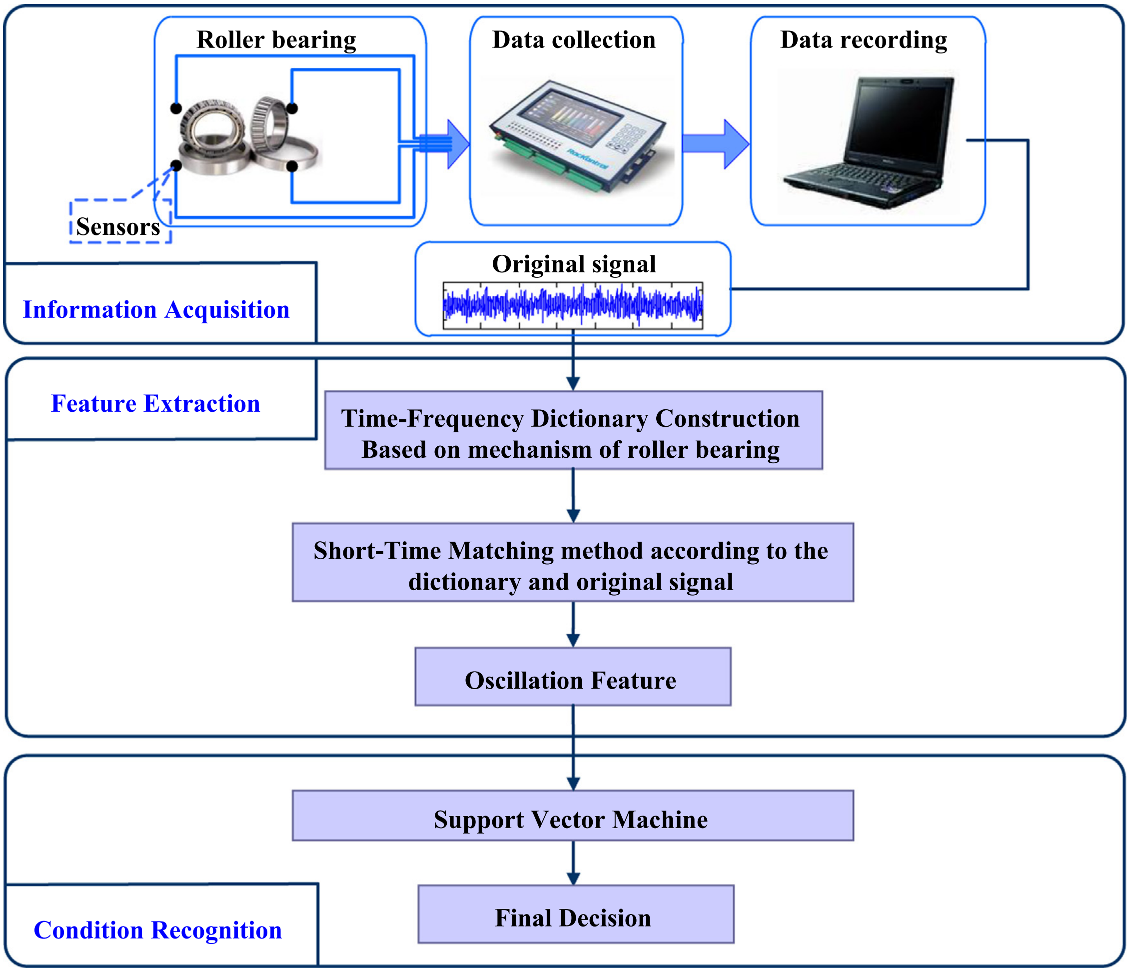

Fig. 1. Flow chart of the proposed method.