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Signal processing methods in fault detection in manufacturing systems

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Abstract

The paper gives a short introduction to the problem of fault detection in manufacturing systems using digital signal processing methods. Usually, in manufacturing systems faults can occur in electrical drives, transmission lines, power management systems and can be detected through sensor data acquisition. Important task of the diagnosis is to differentiate normal operating condition from faulty condition. Detection of occurred faults in manufacturing systems depends on how efficiently erroneous features are extracted from acquired signals. This work focuses on signal processing based methods using Discrete Wavelet and Wavelet Packet Transforms for detection and classification the occurred faults. The faults are simulated using test signals with different time and frequency properties and the results obtained from different approaches are evaluated and compared. The simulation results prove that the proposed techniques handle the problem of fault detection and may even predict abnormalities exploring long term tendencies of the detected signals.

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1. Introduction

The most important task of the manufacturing system's management is to maintain the functional continuity even when unwanted events occur. Usually it is very hard or impossible to avoid consequences of equipment failure

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which results in short-circuits, voltage falls or loss of power. Generally, a system protection is the set of procedures which provide maximum sensitivity to faults and malfunctions and also avoids invalid alarms during normal operating conditions. The faults must be detected as univocally signal difference between normal (or tolerable) and abnormal function of the system. The key point of fault diagnosis is the fault feature extraction. During the past decades the use of signal processing methods in fault feature detection has gained important attention. Performances of these techniques are assessed through simulation experiments and compared for several types of fault, broken mechanical parts, power falls or bearing damages.

In this paper, simulated discrete waveforms are used for detection and classification of the corresponding faults. Any significant changes in the parameters of these signals can be detected through digital signal processing methods, especially time-frequency analysis. The wavelet transform is able to offer the time and frequency information about the studied signal at the same time providing a time-frequency representation of the signal.

This paper is organized as follows. Section 2 presents the theoretical background concerning wavelet analysis, section 3 describes the applied signal processing techniques and section 4 provides experimental results and a comparison of these methods.

2. Signal processing methods in fault detection

There are many signal processing methods to detect changes in signals, changes which can be interpreted as consequences of abnormalities in function of a system. Fault detection techniques can be roughly classified into two categories. These include model-based and signal processing based fault detection. This work deals with the second category and presents wavelet transform based methods to detect abnormal changes in signals. Basic theory of wavelet transform as potential fault analysis tool can be found in several papers (e.g. [7], [8], [9]). The results of wavelet transform, the wavelet coefficients show how well a basic function (mother wavelet) correlates with the analyzed signal in different time-frequency scales. If the signal has a major frequency component corresponding to a particular scale then the wavelet coefficients have a large value at that location.

2.1. The Discrete Wavelet Transform

The Discrete Wavelet Transform (DWT) decomposes the signal into mutually orthogonal set of functions which are generated by translations and dilations of a main analyzing function known as the mother wavelet. The discrete decomposition can be made in pyramidal or packet mode. Usually, the DWT employs a dyadic (power of 2) grid and orthonormal wavelet basis functions exhibiting zero redundancy [7]. The discrete wavelet transform returns a data vector of the same length M as the input is according to the equation below [9].

$$s[n]=\frac{1}{\sqrt{M}}\sum_{k}W_{\phi}(j_0,k)\phi_{j_0,k}(n)+\frac{1}{\sqrt{M}}\sum_{j=j_0}^{\infty}W_{\psi}(j,k)\psi_{j,k}(n) \tag{1}$$

where $s[n]$, $\phi_{j_0,k}(n)$, $\psi_{j,k}(n)$ are discrete functions defined in $[0, M-1]$ totally M points. The sets $\phi_{j_0,k}(n)$ and $\psi_{j,k}(n)$ are orthogonal to each other. The wavelet coefficients are obtained simply by taking the inner product:

$$W_{\phi}(j_0,k)=\frac{1}{\sqrt{M}}\sum_{n}s[n]\cdot\phi_{j_0,k}(n)=A_{j_0,k} \tag{2}$$

$$W_{\psi}(j,k)=\frac{1}{\sqrt{M}}\sum_{j=j_0}^{\infty}s[n]\cdot\psi_{j,k}(n)=D_{j,k}\,,\quad j\geq j_0 \tag{3}$$