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Wavelets and wavelet packets applied to detect and characterize transient alarm signals from termites

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Abstract

In this paper we show the possibility of using wavelets and wavelet packets to detect and characterize alarm signals produced by termites. A set of synthetics have been modelled by mixing the real acquired transients with computer generated noise processes. Identification has been performed by means of analyzing the impulse responses of three sensors undergoing natural excitations. De-noising exhibits good performance up to SNR = −30 dB, in the presence of white gaussian noise. The test can be extended to similar vibratory or acoustic signals resulting from impulse responses.

Keywords: Acoustic emission; Seismic accelerometer; Termite characterization; Transient detection; Ultrasonics; Vibratory signal; Wavelets; Wavelet packets

1. Introduction

In acoustic emission (AE) signal processing a customary problem is to extract some physical parameters of interest in situations which involve join variations of time and frequency. This situation can be found in almost every non-destructive AE tests for characterization of defects in materials, or detection of spurious transients which reveals machinery faults [1]. The problem of termite detection lies in this set of applications involving non-stationary signals [2].

When wood fibers are broken by termites they produce acoustic signals which can be monitored using ad hoc resonant acoustic-emission (AE) piezoelectric sensors which include microphones and accelerometers, targeting subterranean infestations by means of spectral and temporal analysis. The drawback is the relative high cost and their practical limitations [2].

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In fact, the usefulness of acoustic techniques for detection depends on several biophysical factors. The main one is the amount of distortion and attenuation as the sound travels through the soil ($\sim$600 dB m^{-1}, compared with 0.008 dB m^{-1} in the air). Furthermore, soil and wood are far from being ideal acoustic propagation media because of their high anisotropy and frequency dependent attenuation characteristics [3]. This is the reason whereby signal processing techniques emerged as an alternative.

Second order methods (i.e. correlation and spectra in the time and frequency domains, respectively) failure in low SNR conditions even with ad hoc piezoelectric sensors. Higher order statistics, like the bi-spectrum, have proven to be a useful tool for characterization of termites in relative noisy environments using low-cost sensors [4,5]. The computational cost could be pointed out as the main drawback of the technique. This is the reason whereby diagonal bi-spectrum have to be used.

Numerous wavelet-theory-based techniques have evolved independently in numerous and different signal processing applications, like wavelets series expansions, multiresolution analysis, sub-band coding, image compression, etc. The wavelet transform is a well-suited technique to detect and analyze events occurring to different scales [6]. This suggests the possibility of concentrating on transients and non-stationary movements, making possible the detection of singularities and sharp transitions. And this in turn, points to the idea of decomposing a signal into frequency bands, conveying the possibility of extracting sub-band information which could characterize the physical phenomenon under study [7–9].

In this paper we show an application of wavelets and wavelets packets' de-noising possibilities for the characterization and detection of termite emissions in low SNR conditions. Signals have been buried in gaussian white noise to deteriorate them to the limit. Working with three different sensors we find that the estimated signals' spectra matches the spectra of the acoustic emission whereby the species of termites are biologically identified.

The paper is structured as follows: Section 2 summarizes the problem of acoustic detection of termites; Section 3 remembers the theoretical background of wavelets and wavelet packets, focussing on the analytical tool employed. Section 4 is intended for use as a tool for interpreting results from a wavelet-based experiment. Finally, experiments and conclusions are drawn in Section 5.

2. Acoustic detection of termites

2.1. Characteristics of the AE alarm signals

Acoustic emission (AE) is defined as the class of phenomena whereby transient elastic waves are generated by the rapid (and spontaneous) release of energy from a localized source or sources within a material, or the transient elastic wave(s) so generated (ASTM, F2174-02, E750-04, F914-03[1]). This energy travels through the material as a stress or strain wave and is typically detected using a piezoelectric transducer, which converts the surface displacement (vibrations) to an electrical signal.

Termites use a sophisticated system of vibratory long distance alarm. When disturbed in their nests and in their extended gallery systems, soldiers produce vibratory signals by drumming their heads against the substratum [10]. The drumming signals consist of pulse trains which propagate through the substrate or air (mechanical vibrations), with pulse repetition rates (beats) in the range of 10–25 Hz, with burst rates around 500–1000 ms, depending on the species [10,11]. Soldiers produce such vibratory signals in response to disturbance (1–2 nm by drumming themselves) by drumming their head against the substratum. Workers can perceive these vibrations, become alert and tend to escape. Alarms signals are characterized by high intensity as compared to normal activity signals (movement and feeding), which have low amplitudes. Besides, as said above, alarms have distinctive time patterns.

Fig. 1 shows one of the impulses within a typical four-impulse burst and its associated power spectrum. Significant drumming responses are produced over the range 200 Hz–10 kHz. It is in this interval where the spectral identification of the specie (*Reticulitermes lucifugus*) is performed. The carrier frequency of the drumming signal is defined as the main spectral component, which keeps with longer attenuation time, and in this case is around 2600 Hz.

The spectrum is not flat as a function of frequency as one would expect for a pulse-like event.

[1] American Society for Testing and Materials. F2174-02: Standard Practice for Verifying Acoustic Emission Sensor Response. E750-04: Standard Practice for Characterizing Acoustic Emission Instrumentation. F914-03: Standard Test Method for Acoustic Emission for Insulated and Non-Insulated Aerial Personnel Devices Without Supplemental Load Handling Attachments.