Detection and analysis of the stored grain insect creeping sound

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Abstract: With the random acoustic source model as the theory model of the stored grain insects creeping, the sounds, of 20 Alphitobius diaperinus Panzer in wheat and 20 Tribolium castaneum Herbst adults in corn, are detected, respectively. By using Matlab, the original sound signals are reproduced and the de-noised signals are obtained. The power spectrums characteristics analysis are made. It is shown that the random acoustic source model is effective for the stored grain insect creeping sound detection, and their power spectrums are all discrete, where the highest frequency is 1600 Hz, the main frequency 205 Hz in the former, and the highest frequency is 800 Hz, the main frequency 350 Hz the latter, which may be used to distinguish different types insects in grain.

1. Introduction

To detect insects by using their action sound is a quick and practical method to detect insect in agricultural post-harvest commodities to be newly developed in recent years [1-3]. The numbers of insect activity sound have been used to measuring insects numbers in grain [4-6]. To use insects activity sound to identify them is an important in detecting insects. Coggins etc have used artificial neural network to study the sound of insects in corn and classificatie insects by the time domain features of insect acoustical signal [7]. It can be rarely reported to study the spectrum of activity sound in grain to identify insects. Guo Min etc study the creeping sound of insects on film and find that the basic frequency of acoustical signal has to do with the insect species [1,8]. In the paper, the power spectrum of activity sound of insects in stored grain will be studied, which has a role in promoting to implement the acoustic differentiation technique of insects in grain.

2. The random acoustic source model

The creeping sound of single insect in grain is generally not easy to be detected for it being weak，additionally absorbed and scattered by grain, but if we regard the creeping sound as random acoustic source, we can achieve detecting it.

For 2 random acoustic sources with the phase position varying according to certainly statistical law, the sound pressures are written as, $p_1 = p_{1a} \cos(\omega_1 t + \varphi_1)$ and $p_2 = p_2 \cos(\omega_2 t + \varphi_2)$, where φ_1 and φ_2 are the initial phase of p_1 and p_2, respectively, and p_{1a} and p_{2a} are the amplitude of p_1 and p_2, respectively. With φ_1 and φ_2 taking any value between 0 and 2π, the total sound pressure

is $\quad p = p_1 + p_2 = p_a \cos(\omega t - \varphi)$, where p_a is the amplitude of p, $p_a^2 = p_{1a}^2 + p_{2a}^2 + 2 p_{1a} p_{2a} \cos(\varphi_1 - \varphi_2)$, and φ is the initial phase of p, $\varphi = \arctan((p_{1a} \sin \varphi_1 + p_{2a} \sin \varphi_2) / (p_{1a} \cos \varphi_1 + p_{2a} \cos \varphi_2))$, where φ_1, φ_2 and φ randomly vary with time. The total average acoustic energy density [9] $\bar{\varepsilon} = p_a^2 / 2\rho_0 c_0^2 = \bar{\varepsilon}_1 + \bar{\varepsilon}_2 + \overline{\cos(\varphi_2 - \varphi_1)} p_{1a} p_{2a} / \rho_0 c_0$, where $\bar{\varepsilon}_1$ and $\bar{\varepsilon}_2$ are the average acoustic energy density of p_1 and p_2, respectively, and ρ_0 and c_0 are medium density and acoustic propagation velocity, respectively. With a sufficient time, we thick $\varphi_1 - \varphi_2$ take any value between 0 and 2π at an equal probability, $\overline{\cos(\varphi_1 - \varphi_2)} = 0$, or $\bar{\varepsilon} = \bar{\varepsilon}_1 + \bar{\varepsilon}_2$ [9]. The same conclusion can apply to two or more random acoustic sources. We consider that for the same species insects being in the same growth phase, the creeping frequencies are the same, only the initial phase take random value. Except the energy is different, the creeping sound requency of insects in grain is the same as one of single insect. The creeping sound of insects in grain may be regarded as random acoustic source, therefore we may overcome the shortcomings of single insect creeping sound too weak to be detected. In experiment, we find that insect in grain has the characteristic of apparent death and the all insects seldom act together. Only when most of insects creep in grain all at once, the obvious creeping sound signal appear.

3. The sound signal collection

3.1 The Main Experimental Apparatuses and Samples

The Microphone Shuer BG4 model with frequency response from 40 Hz to 18000 Hz and output impedance 600 ohms; Professional sound card MAYA44 with frequency response from 20 Hz to 20000 Hz, the highest sampling rate being 48 k Hz and analog-to-digital conversion being 18 bits; The ordinary earphone; PC with Celeron(R) CPU2.40GHz, memory 128MB,WindowsXP; The sound-proof chamber with about 22dB average acoustic insulation mass[10]; The barrel，which is cylindrical glass barrel with 15 cm tall and 8 cm long diameter; Grain samples with wheat and corn; Insect samples with *Tribolium castaneum Herbst* adults and for *Alphitobius diaperinus Panzer* adults.
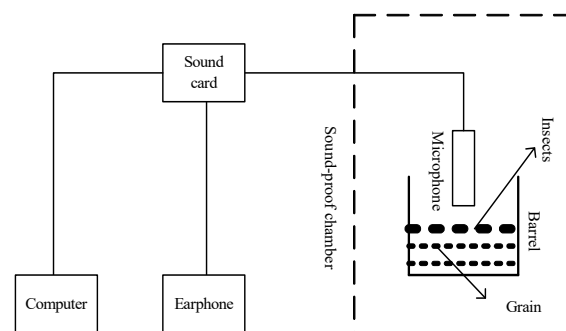
3.2 The Experiment

FIGURE 1. The scheme of sound detection setup

The scheme of sound collecting setup is shown in Fig.1. The barrel and microphone are placed in the sound-proof chamber. Put insects in the barrel with grain. The microphone is placed about 4 cm opposite from the grain surface. When insects move in grain, sound signals are sampled by sound card, which is saves in PC with format wav. Ear phone is used to listen to sound, so that the best time and duration may be determined. The 30 sound sample to each kind of sound are sampled so as to do the statistical analysis. When detecting, select sampling frequency 22050 Hz, adjust temperature 28°C and relative humidity 79%, and get 20 insects and sample 30 acoustical specimens with 5 minutes duration

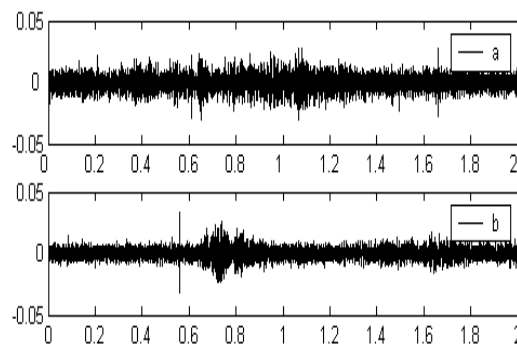every time. The signals collected are sent to the computer so as to be further processed in off-line.

FIGURE 2. The creeping sound signal .   x 10^4
a *Alphitobius diaperinus Panzer* adults in wheat ,
b *Tribolium castaneum Herbst* adults in corn.

For *Alphitobius diaperinus Panzer* adults in wheat, and for *Tribolium castaneum Herbst* adults in corn, the creeping sound signals are detected, respectively. By use of MTLAB, selecting the clearest of acoustical specimens, the creeping sound signals are reproduced shown in (a) and (b) in Fig.2, respectively, where the x-axis is sampling point, y-axis is relative amplitude. From Figures 2, it can be seen that for the acoustical specimen studied, the creeping sound of *Alphitobius diaperinus Panzer* adults in wheat happens to about point 7000 and point 11000, about point 8000 for *Tribolium castaneum Herbst* adults in corn, respectively. In addition, some sharp pulses appear in the individual parts, and the background noise is amplified because of preamplifition, and the creeping sound signal is almost drowned.

4. The sound signal processing and power spectrum analysis

A one-dimensional sound signal containing noise may be represented as a function: $x(i) = f(i) + \sigma \times e(i)$, $i = 1, 2, 3, \cdots, n - 1$. where $f(i)$ is real signal, σ is the coefficient, $e(i)$ is the noise signal depending on the noise type, and $x(i)$ is the signal containing noise. In general, how to process noise signal depends on the noise type. In the experiment, there are two type noise in the sound signal, which are the background noise and the sudden noise, where the former is from thermal motion continuous interference in the circuit, presenting uniform amplitude distribution and wide frequency range, and the latter from the insect collision with the environment, presenting bigger amplitude and shorter duration, frequency distribution in bigger frequencies. The insects creeping sound is distribution in shorter frequencies [11].
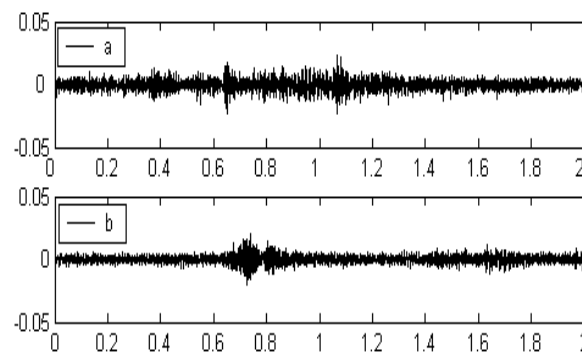
4.1 The Filter De-Noising

FIGURE 3. The creeping sound signal after filter .
a *Alphitobius diaperinus Panzer* adults in wheat ,
b *Tribolium castaneum Herbst* adults in corn.

According to the characteristics of the insects creeping sound, the filter de-noising may be used. The digital filter contains two type filters of IIR and FIR, where the former has bitter function in pass band and stop band, and in the same performance , the order is higher and the delay time is longer than the latter's. In the sound signal processing, the bitter function in pass band and stop band meet the requirements, and so IIR filter may be used. Considering the sound frequency being from 50 Hz to 1500 Hz, IIR Elliptic low pass digital filter is designed by using minimum order time estimation, where pass band frequency is 2000 Hz and the sampling frequency is 22050 Hz, and it is to be sure that the higher sampling frequency do not reduce high frequency components but only the computer memory. The filtered signals are as shown in Fig.3. It is can be seen that the spike pulse noise signals are filtered, the background noises are a certain degree of reduced and the signal to noise ratio is greatly improved, but the background noises show that the signal frequency and the noise frequency overlap each other.
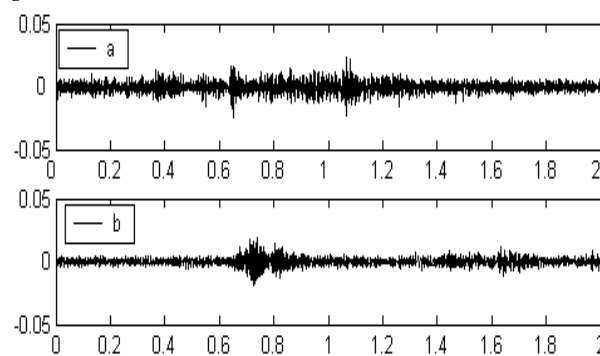
4.2 The Wavelet De–Noising

FIGURE 4. The creeping sound signal after wave-let .
a *Alphitobius diaperinus Panzer* adults in wheat ,
b *Tribolium castaneum Herbst* adults in corn.
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The wavelet de-noising to processing signal is through decomposing signal into layers, then selecting threshold and quantifying for each layer. The key is the selection of threshold value. There are four principles in threshold selecting which are unbiased likelihood estimation, fixed, heuristic and mini max principle. There are 3 methods in the wavelet de-noising: ① Forced de-noising, it is complete through setting all of high frequency coefficients to zero in the wavelet decomposition structure, or

filtering all of high frequencies, then reconstructing the signal, which is simple and reconstructed signal curve is smooth, but only the useful signal compose is easily loss; ②   The default threshold de-noising, it is complete by calculating the threshold value, which is useful to the signal with higher signal to noise ratio and signal frequency to noise frequency ratio; ③ Given the soft (hard) threshold, it is complete by the empirical threshold, which has better credibility than the default threshold. In the actual signal de-noising, the threshold generally is empirically determined, where if T (T > 0) is for the threshold, the signal becomes $y = x \cdot (|x| - T)_+$, or the points which are equal to or less than the threshold are set to zero, and the points which are more than threshold are set to the difference between the point and the threshold. The signals after the hard threshold generally are represented as $y = x \cdot 1_{(|x|>T)}$, or, comparing signal value with threshold, the points which are equal to or less than the threshold are set to zero, and the points which are more than threshold remain the same. Generally, the hard threshold signals are rough than the soft threshold signals. In order to get more high frequency signal, the unbiased likelihood estimation adaptive threshold is selected in the experiment. Through calculating, the creeping sound signal soft threshold for *Alphitobius diaperinus Panzer* is 0.0014 and 0.0197 for *Tribolium castaneum Herbst.* After the wavelet function selected is "dB5", the decomposition layer number is 5, and the global variable is used and the low frequency coefficient keeps immutable, the filtered signals are processed shown as in Fig.4. It can be seen that after given the soft (hard) threshold processing, the background noise in the signal is reduced a lot and signal curve is clearer. The duration is about 0.2 s for *Alphitobius diaperinus Panzer,* and about 0.4 s for *Tribolium castaneum Herbst.* Repeating the experiment shows that changing parameters to deduce the background noise must be at the expense of damaging useful signal.
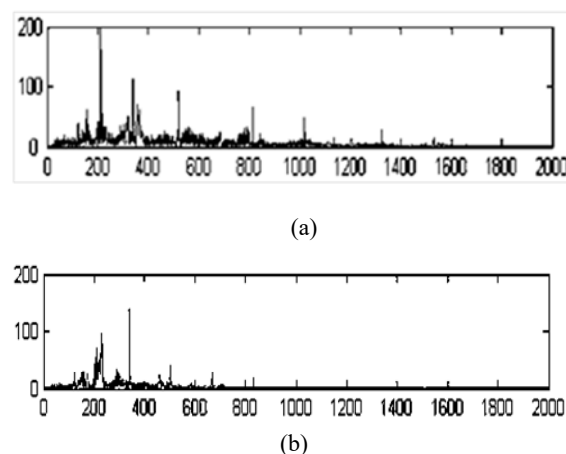
4.3 The Power Spectrum

(a)

(b)

FIGURE 5. The creeping power frequency
(a) *Alphitobius diaperinus Panzer* adults in wheat ,
(b) *Tribolium castaneum Herbst* adults in corn.
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In order to estimate the power spectrum, the data is first captured. Generally, only the data length is minimally the eight power of 2, or 256, can all the information be contained, and there is no limit to the upper limit of the data, only the processing signal runs fast with integer power of 2. Selecting 2048 for the signal data, the power spectrum curve of the signal is shown as in Fig.5, where the x-axis represents frequency (Unit: Hz), and y-axis relative amplitude (the same below). It can be seen that the power spectrum presents the discrete. For *Alphitobius diaperinus Panzer* adults in wheat, the highest frequency is 1600 Hz and the main peak frequency is 205 Hz. for *Tribolium castaneum Herbst* in corn, the highest frequency is 800 Hz and the mine peak frequency is 350 Hz. From the signal waveform the

duration of the former is smaller, which is caused not only insect species but also grain species.

5. The conclusion

The sounds of the same kinds of insects creeping in the same grain to the same growth stage , because of the small differences in size、 physical and structure, have same frequency. While the many pests creep in the same time, the sound can be regarded as the random acoustic source model. For *Alphitobius diaperinus Panzer* adults in wheat and *Tribolium castaneum Herbst* adults in corn, respectively, the creeping sound signals are detected. According to the noise characteristics, filter method and wavelet method are used to reduce the noise to get clear noise signals. The power spectrums of two kinds are all discrete spectrum.

Acknowledgements

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