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OPTIMIZING BEETLE IDENTIFICATION IN WHEAT GRAIN VIA IIR AND FIR NOISE FILTERING TECHNIQUES

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Abstract- The paper outlines a successful strategy for heightening the sound amplitude of recorded acoustic signals emitted by Triboium confusum beetles within wheat grains. These signals were captured by sensors situated 10 cm away from adult beetles. Employing both IIR and FIR band pass filters, the received signals underwent meticulous processing aimed at enhancing their clarity and intensity. MATLAB software served as the primary tool for executing these signal processing tasks, leveraging its capabilities in handling intricate algorithms with precision. This innovative approach not only demonstrates a practical method for augmenting the acoustic signals of beetles but also offers insights into their communication patterns and behaviours within agricultural contexts. By enhancing the clarity and intensity of these signals, this methodology holds promise for advancing research in pest management strategies and understanding insect dynamics within agricultural ecosystems.

Keywords: IIR and FIR band pass filters.

I. INTRODUCTION

The confused flour beetle (Tribolium confusum) is a common pest known for infesting stored grain products, including flour, cereals, meal, crackers, beans, spices, pasta, cake mix, dried pet food, dried flowers, chocolate, nuts, seeds, and even dried museum specimens (Via 1999, Weston and Rattlingourd 2000). This beetle earned its name due to its close resemblance to the red flour beetle, causing confusion in identification upon initial observation (Walter). Originally from Africa, the confused flour beetle has spread globally, particularly in cooler climates.

Figure-1.1: Tribolium confusum

Infestations of both red and confused flour beetles can be significant within stored grain, yet they are incapable of attacking sound or undamaged grain (Walter). These beetles are drawn to light but seek cover when disturbed. They are commonly found not only within infested grain products but also in cracks and crevices where spilled grain may accumulate. Preference is shown towards grain with higher moisture levels, often resulting in a grey discoloration of the infested grain. Moreover, their presence emits an unpleasant odor and promotes mildew growth within the grain.

The sensor that was utilised to record the insect's sound is a piezoelectric kind that has been modified in order to detect low intensity noises such as the sound of the bug. When it comes to receiving extremely low acoustic sound intensities and turning them into audible noises, the sensor was fitted with a powerful boost circuit for pre-amplification of sounds, which was critical for the sensor's success. The amplifier circuit has been designed in such a manner that it is feasible to link it to a computer and therefore save audio signals, as well as remove background disturbances from the environment.

As the world's population swells, there is a growing apprehension regarding the widespread use of pesticides and the excessive depletion of natural resources. Concurrently, the expansion of international trade and the advancement of agricultural technology are bolstering the capabilities of the agricultural sector. The emergence of digital technologies is proving to be instrumental in increasing productivity and effectively managing agricultural inputs and natural resources [1]. Governments across the globe have been prompted to address the surging demand for food by implementing strategies aimed at enhancing agricultural productivity, optimizing land utilization, and controlling population growth. However, amidst these efforts, the crucial issue of post-harvest loss often remains overlooked. Post-harvest loss encompasses both direct physical losses and the deterioration of quality, which significantly diminishes the economic value of crops and their suitability for human consumption [2].

In numerous developing nations, diets predominantly centre on staple grains such as wheat, rice, and maize, which are globally renowned as the most popular food crops. Post-harvest losses constitute a significant portion of the overall losses for cereals, estimated to be around 19% [3]. A highly effective approach to enhance food security, alleviate hunger, minimize agricultural land requirements, promote rural development, and improve farmers' livelihoods is to mitigate grain losses throughout the supply chain. Storage is a critical component of the food supply chain, and multiple studies have identified it as the stage where the most substantial losses occur.

Grains are typically stored for consumption or as seeds for the subsequent planting season. Traditional storage structures, often crafted from locally available materials like grass and wood, lack the capacity to shield crops from pests over prolonged periods. Modern storage alternatives, including Polypropylene bags, have shown considerable loss rates, with maize grains experiencing losses of up to 59.48% after just 90 days of storage. According to [4], wheat incurs a post-harvest storage loss of 21.99%. Among the biotic factors, insect pests emerge as the most significant, causing losses ranging from 30 to 40% in grains [5]–[7].

Approximately 6,700 species of beetles and moths are responsible for causing extensive damage to food storage facilities worldwide [8]. The contamination of food products by insects and pathogens presents significant quality control hurdles for the food manufacturing industry, particularly in developed nations where such contamination is strictly regulated [9]. The effective management of pests in storage facilities demands prompt and precise pest identification and treatment. While various techniques are available for identifying pests in grain storage facilities, such as visual inspection, sifting, and the use of Berlese funnels, many of these methods are inefficient and time-consuming. Emerging alternatives such as CO2 and uric acid measurement, near-infrared spectroscopy, and soft X-ray imaging have demonstrated considerable potential in laboratory environments. Nonetheless, the majority of these devices are cost-prohibitive and require complex operational procedures and calibration [10].

One promising method for detecting insects within grain bulk relies on acoustic-based technology. Despite originating in the 1950s, this approach has only recently garnered widespread attention due to advancements in audio technology. The reliability and effectiveness of acoustic pest detection have seen notable enhancements in recent years, thanks to the development of new acoustic instruments and signal processing techniques [11]. Insects generate sounds while flying, feeding, laying eggs, or moving, which can be exploited for identification purposes. Various methodologies, such as bio acoustic signal processing, machine learning, wireless networks, microphone technology, and digital signature analysis, have been proposed for acoustic-based pest detection in the scientific literature. This article highlights the potential of noise filters in improving the acoustic signals captured from insects within wheat grains, a novel contribution to the field [12]–[18]. Subsequent sections of the paper will delve into the acoustic system in detail, alongside the experimental methodology.

II. Experimental Procedure

Rather of using a standard piezoelectric sensor, this one has been adapted to pick up low-level sounds like the insects buzzing. Having a robust boost circuit for sound pre-amplification was vital to the sensor's performance when it came to converting very low acoustic sound intensities into audible noises. Using a computer to store audio signals and reduce background noise from the surroundings is possible thanks to the amplifier circuit's architecture. There are two types of amplifiers (first floor transistor and second floor operational amplifier) included in the sensor's specs, as well as an output audio connection that may be connected to a computer system or speaker. The database that has been built into the device may then be used to identify the pest sounds. MATLAB software is used to store and analyse the majority of the data, as well as perform other data-related tasks (Figure 2.2). In order to reduce the influence of noise, many noise reduction methods were incorporated into the signal processing unit.

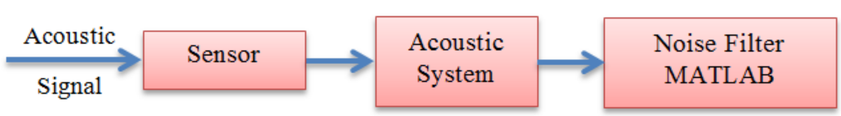

Figure-2.1: System for noise filtering of acoustic signal

To conduct this experiment, we used wheat that had a moisture content of 13 percent. Insect proliferation was carried out in a little dish of wheat seed in order to create a suitable number of adults and larvae. From 8 a.m. until 6 p.m., the trials were conducted. An adult insect was put in the test tube the day before the test, and it was coated with wheat grain so that the insects could get familiar with their new surroundings. Prior to opening the test tube, it was filled with pest-free wheat grain to a height of 10 centimetres. Before putting wheat grain into the test tube, a very thin veil was placed within the tube to prevent insects from reaching the upper layers. Grain mass surface and insect population were put 10 cm apart in order to begin the experiments. Digital signal processing software was used to capture the noises of adult beetles for 30 minutes, which were then relayed to a computer and an integrated signal processing circuit. The received sounds are saved in 30-second files by the sound recording software and played back later. Test tubes were filled with a thin coating of wheat grain and multiple wheat grains, each with several larvae, were put on top. The first step was to fill the test tube with wheat grain to a distance of 10 centimeters (no need to use separator veil, because the larvae is inside the kernel without any movement). After inserting the separator veil, a tiny layer of flour beetle-infested wheat (both larval and adult stages) was put in the test tube, and the test tube was then filled with insect-free wheat. Additionally, sound sensors were fitted at the correct heights. In the same way as the prior recordings, the sound recordings were made. All tests were carried out with the use of a temperature control system that kept the test rig's temperature at about 20°C. Figure 2.2 depicts the signal analysis architectural flow diagram.

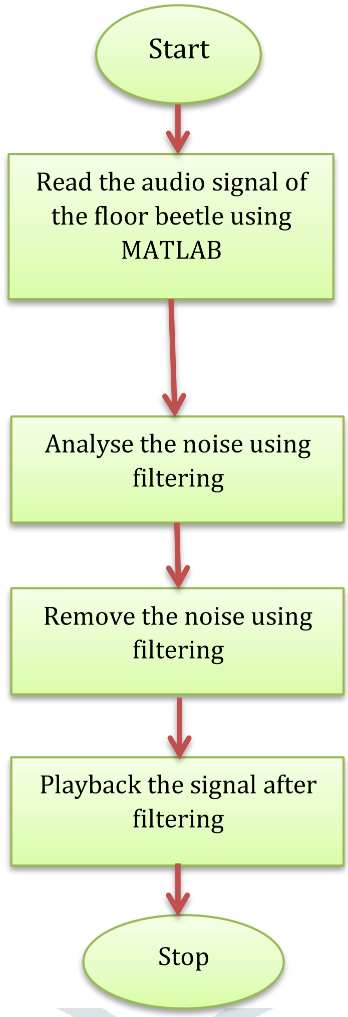

Figure-2.2: Architectural flow diagram of acoustic signal detection and signal analysis

III. Results and Discussions

When performing the larval stage test, MATLAB software was used to evaluate recorded acoustic frequencies. Some of the recorded noises exhibited multiple sound pressure peaks because to the rapid activity of numerous larvae. As seen in Figure 3.1, the larvae's peak intensity in the frequency domain may be seen. For the most part, larval sounds are found in the range of 1 to 7 kHz, with the most intense sound occurring at 0.3 kHz. This frequency range is almost identical to the range of frequencies that are audible to the human ear. A greater range of amplitude can be detected in the noise waveform compared to the original one. In the background, you may hear the sound of the surrounding area. As a consequence, the waveform is smoother and the audio stream clearer as a result of the filtering process. Figures 3.2 and 3.3 show the results of the FIR and IIR band pass filtering.

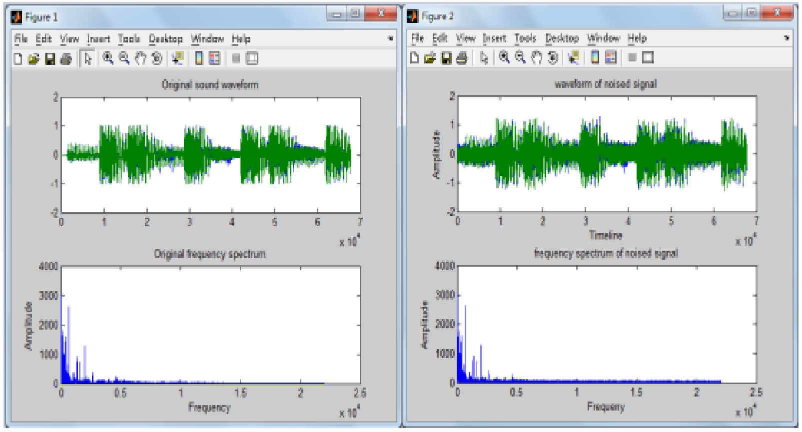

Figure-3.1: Spectral analysis of the acoustic noise

Spectral analysis of acoustic noise involves the examination of the frequency components present in a given sound signal. This process is essential for understanding the characteristics of the noise, identifying its sources, and assessing its impact. To conduct spectral analysis, the first step is typically to digitize the analog acoustic signal using an analog-to-digital converter (ADC).

Once digitized, the signal can be processed using various mathematical techniques to extract frequency information. By analysing the spectral content of acoustic noise, researchers can gain valuable information about its source and characteristics. Spectral analysis of acoustic noise is a fundamental tool for studying and understanding the frequency characteristics of sound signals. It enables insights into noise sources, variations, and potential mitigation strategies, contributing to the overall management of noise in various environments.

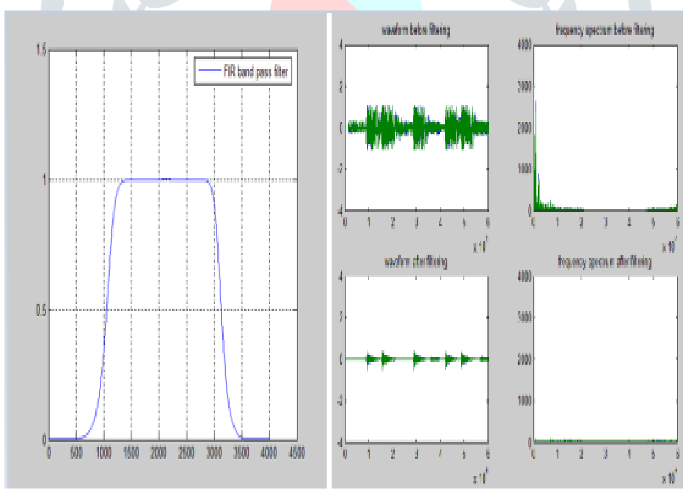

Figure-3.2: FIR band pass filter applied to remove noise

The Finite Impulse Response (FIR) filter stands as a fundamental component within digital signal processing setups, offering a steadfast linear phase frequency attribute coupled with any conceivable amplitude frequency characteristic. A distinguishing feature lies in its finite unit impulse response, ensuring stability within the system. FIR filters find extensive application across various domains including telecommunication and image processing, owing to their reliability and versatility.

The Infinite Impulse Response (IIR) filter is structured with recursion, featuring a feedback loop mechanism. Renowned for their exceptional precision in amplitude frequency characteristics, IIR filters diverge from linearity in phase.

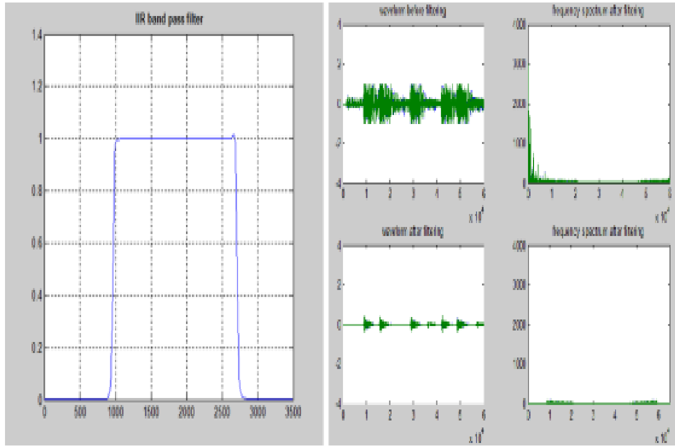

Figure-3.3: IIR band pass filter

First the sound of beetle is taken from stored .wave file and then it is loaded into the MATLAB. Then the spectrum (amplitude vs frequency) of the original beetle sound is displayed which shows more noise is present in the sound. It can be observed by looking into more disturbed signal. Then band pass filters of FIR and IIR types are applied to remove the environmental noise and obtain only desired noise of interest. The band pass plots of each filter are given in the plots. Now when these noise signals are passed through the band pass filters of each type the noise in the signal will be removed that is environmental noise. The resultant signal is smooth since it is free from such noise.

Table-1 shows the acoustic frequency characteristics of Triboium confusum larvae recorded from infected mass of wheat grain

Distance sensor (cm)	Sound level in dB	Frequency in kHz
10	-29 Ref[8]	1.9-7
10	-29 (After noise filtering)	1.9-7

IV CONCLUSION

In this study, a novel methodology is outlined to enhance the sound intensity of recorded acoustic emissions emitted by the beetle species Triboium confusum within wheat grains. The experimental setup involved capturing signals using sensors positioned at a distance of 10 cm from adult beetles. Through the application of both Infinite Impulse Response (IIR) and Finite Impulse Response (FIR) band pass filters to the received signals, a significant amplification in sound magnitude, approximately 10 decibels, was observed. This approach effectively boosts the perceptibility and clarity of the recorded audio signals, facilitating a more detailed analysis of beetle behavior and interaction within the wheat grain environment.

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