Chainsaw location finding based on travelling of sound wave in air and ground

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Abstract. Deforestation is a major problem in the world because it affects to temperature and increasing carbon dioxide. In this research, it is therefore proposed that the sound signal inspection of chainsaw which take place from deforest activity and localize the position of deforesting by using the sound signal detection of chainsaw that travels in two mediums are in the air and soil and find the time difference which two waves in both medium travel to the observer or the detector. The correlation operation is used to determine the time difference to calculate the distance between the sound source and the observer and find the direction of the sound source by rotating the microphone to get the most magnitude of sound and take the direction and distance to specify the location of the loggers. Which the proposed system is low complexity and energy-saving and can move easily. From the system test, it was found that the accuracy was 95%.

1. Introduction
The greenhouse effect and global warming are important problems of the world. The main cause of these problems is the production of large amounts of CO2 beyond the capacity that nature can dispose of. The natural mechanism for eliminating CO2 is the photosynthesis of plants. Therefore, forest resources are very important. However, nowadays the number of forest areas in the world is decreasing rapidly. One of the major causes is illegal logging, without reforestation. For this reason, it is essential to stop. One important step is to detect illegal logging especially in remote areas. In general, detection of logging can be divided into passive and active manner. The passive process is a process of detecting when the actions are completed, such as using current satellite images and past satellite images for comparison [1] [2] or using drones to take pictures and compare which is costly and both of them need high technology. As for the active method, it is a process of detecting while the activity occurs and still active, such as using thermal imaging images from drones or satellites to detect humans in the forest without permission by detecting smoke [3][4] or detecting sounds caused by logging activities with a focus on the detection of the chainsaw sound. This method is less costly and does not require advanced technology. Thus, it is a method that is popular and it is continuously developed. From investigating many studies, it was found that there are various methods for detecting deforestation by sounds. In 2011 M. Babis [5] and his research team has presented logger detection and specify the position by sound with wireless measurement networks in the desired target
Later in 2015, Valentin [6] and his research team has presented intruder detection by detecting sound of chainsaws along with several methods of locating with wireless detection networks. Later in 2016, Juan G. Golonna [7] have presented the chainsaw sound detection system for logging in the Amazon rainforest, with a focus on building centre nodes with embedded and use MFCC Mel-Frequency Cepstral Coefficients cooperate with one class kennel to recognize the saw sound.

In 2017, Laszlo and his team presented the use of sound characteristics in the time domain for chainsaw sound detection in order to reduce the amount of calculation. Reduce Cost Computational. In 2018, Dir Chandra Prasetyo, [9] has presented the saw noise detection from logging along with the vibration detector in order to estimate the falling tree and send the data via GSM Module and in 2019, Sheikh Fahad Ahmad [10] with his team presented an algorithm that uses distance vector parameters in combination with k-mean clustering for automatic logging detection. From investigation mentioned above it is noticeable all of the tools mentioned used wireless detection which is costly, requires algorithmic complexity, have problems about energy distribution and inconvenient to install and maintain. Mind of these disadvantage, this study aims to develop the deforestation detectors by using the concept of detection and localize the position of illegal deforest. The sound of a chainsaw on the air with microphone and sound of a chainsaw on the ground with geophone were detected based on travelling of sound wave in air and ground. Moreover, the deforestation detector has been designed to give the high accuracy and uncomplicated.

2. The principle of sound detection of chainsaws

In general, sound detection of a chainsaw from unauthorized logging activities will consist of signal processing procedures and characterization for determining the saw blade sound pattern. To enable detection and management with the goal being fast to reduce the loss of forest resources. Therefore, the location of the sound source is important. In general, systems that presented are usually used multiple sound sources detector to find the location of the sound source. The system is shown in Figure 1.

![Figure 1. System for locating targets using multiple detectors](image-url)

Each sensor will find the direction of the highest magnitude of sound waves and then bring the data to find the intersection points of vector, and which will get a position of sound source. Which must use many detectors for accuracy, but in this research presented a method that detecting sound and locating sound sources based on the travelling of sound wave from the same sound source on the two mediums are air and ground as shown in Figure 2.
Figure 2. The system components are presented.

By the speed of sound in the two mediums have not the same velocity. Therefore, we can calculate the distance between the sound source and the observer with the coordinates shown as in Figure 3.

**Figure 3.** The calculation of the distance between the sound source and the observer.

From Figure 3, the sound source is a distance away from the observer (S) and $V_A$ is the sound velocity in the air, $V_G$ is the sound velocity in the soil. Since the sound traveling in both mediums are the same distance (S), therefore

$$S = V_A t_A = V_G t_G$$

(1)

Where $t_A$ and $t_G$ are traveling times of sound wave in air and soil respectively. And if we assume that $\Delta T$ is the time difference that both waves use to travel by

$$t_A - t_G = \Delta T$$

Or

$$t_A = t_G + \Delta T$$

(2)

By substitute $t_A = t_G + \Delta T$ into Equation (1), will get

$$V_A (t_G + \Delta T) = V_G t_G$$

(3)

If rearranged the Equation (3) would get

$$t_G = \frac{V_A \Delta T}{V_G - V_A}$$

(4)
When substitute Equation (4) in to the Equation (1) will get \( S \) as follows.

\[
S = \frac{V_G V_A \Delta T}{V_G - V_A}
\]  (5)

By Equation(5), it found that the distance was found by time difference in waves travel to the observers multiply by velocity of waves in the air and divide by a difference of speed between the speed of sound in ground and air. If the direction of waves was found by rotate condensers microphone the direction of the sound source to the observer was got and take the distance and direction to create a vector. Then it will get the location of the sound source as shown in Figure 4.

![Figure 4. The location of the sound source.](image)

To determine the correlation between sound wave signals that travel in air and ground are operated and find the time that gives the maximum output which is the \( \Delta T \).

3. The proposed system

From the experiment, the sound of a chainsaw motor from microphone and geophone will be amplified by a gain of 100 and 2000 times with a Non-inverting amplifier and both of these signals will be forwarded to the bandpass filter with a centre frequency of 200 Hz. The audio amplifier and bandpass filter circuit for microphone and geophone are shown in Figure 5a and 5b, respectively.

![Figure 5a.](image)  ![Figure 5b.](image)

**Figure 5.** The audio amplifier and bandpass filter.

A signal from both filters will be taken to a computer by sound card with steps of software as a flowchart in Figure 6.

By audio signal received from microphone and geophone will be compared with reference level number. If one of two signals has over reference level of them. Both signals will be recorded for 1 minute. Then both signals will be led to correlation to find the time difference that both signals delay and bring that time to find the distance between sound source and observer by using MATLAB.
4. **Experimental and result**

Figure 7 shows the bandpass frequency responded form the audio amplifier and bandpass filter. The result displays the highest frequency peak of the chainsaw at around 200 Hz. This indicated that the initial wood was cutting. Then, this range was used to calculate in MATLAB programme.

In order to get the $\Delta T$ value, the recorded version of the chainsaw was used as an initial source of audio signal and the result is shown in Figure 8. Then, the others audio signals was created another copy of this signal for simulate the signal form geophone with time shift occurring. Afterward bring the both signals to correlate each other in order to find the time difference. Finally, the obtained time difference value was employed to calculate the distance by specifying that the sound velocity in the air...
is 340 m/s and in the ground equal to 600 m/s. The cross correlation between s1 and s2 was corresponds to the position of the delay time which both signals are overlapping.

**Figure 8.** The test results distance 782 meters.

**Figure 9.** The real results distance 593 meters.

The top line signal is the chainsaw audio signal that has been amplified and filtered by the bandpass filter. The middle line signal is a duplicated signal of the upper line but has a 1.1-second delay and the bottom signal is the correlation result between the upper line and the middle line signal. When using the time difference to calculate distance will get an estimate distance of 782 m. Figure 9 demonstrates the real experiment, s1 and s2 are geophone and microphone signals respectively. Finally, the experimental result of distance measurement is shown in Figure 10. The experimental result agrees well with prediction because of the tendency of graphs which obtained from experiments and theories tend to be in the same direction. There is only 5% error which is calculated from each point in both graphs at the same time. From this graphs comparison, it indicated that the deforestation detector has high accuracy interpretation.

**Figure 10.** The various distance calculated results versus distance that compute from theory.
5. Conclusions
In conclusion, the deforestation detector was successfully developed. The sound wave source from chainsaw was identified by using geophone sensor, microphone sensor and MATLAB programme. From the practical used, it suggested that the system can work 95\% accuracy. The developed detector was convenient, consume less energy and can be easily moved around. It is also possible to install the system on a moving vehicle. The maximum distance detected was 1 km approximately due to the sensitivity of the geophone is still low. In further development, the high quality sensors which have seismic exploration with long range bandwidth should be used. These would allow the system to operate at a greater range.

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