Police Assistant Shot Spotter System

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1 Introduction/Motivation

Illegal gunfire activity in public places causes fear in public as well as the loss of innocent lives. The police(primary stakeholder) get notified about such an event if someone from near shot area calls the police or informs them through patrolling PCR van but at that time there is a lot of chaos in public which results in delay of rescue operation(as revealed in survey). Therefore, the information only gets to the cops until they feel safe enough. This delay in the response causes usually the culprits to escape and destruction of shreds of evidence. This causes the apprehending criminals to be a challenging task as well as creates public distrust in police department. A system that provides the pinpoint position of the fired shot will greatly reduce the reporting time of such cases. This should allow the faster response, assisting the cops to arrive at the location faster and at least saving the evidence (bullets shells, etc.) that might give information about the shooters as well as illegal use of shooting weapons. The data will be analyzed manually first at the server by a supervisor to confirm a gunshot case. Then the data will be provided to all nearby PCR vans. The calibrated position will be shown through an android application. This will allow a faster response and securing forensic evidence after the gunshot incident.

2 Market Research/Literature Survey

Research paper [1] extends gunshot detection evaluation to a noisy environment and assess its performance, comparing it to other more complex methods. Gunshot sounds are made up of distinct components, namely, the muzzle blast, lasting about 3 milliseconds caused by the explosion of the charge that propels the bullet and the other sounds related to mechanical actions on the gun. Features are extracted from the impulsive sound and then correlated with the signals detected. The threshold was set in a noisy environment (low SNR ratio). Also with the knowledge of the direction exclusively the camera can focus the speakers [2]. Other applications that require only the calculation of the direction are the audio surveillance systems and detecting the gunshots by poachers in forests [6]. This kind of systems, used for intrusion detection [3] or gunfire location [4]

3 Hardware Implementation

The following are the hardware required for the project. For Shot detection circuit

1) Microphones
2) 10k potentiometer
3) Copper circuit board
4) OP-Amplifier IC (Lm358)
5) Resistors (as per filter design)
6) Capacitor (as per filter design)
7) LEDs
8) Diode
9) Male female headers

For the calibration of direction

1) Microcontroller
2) Stepper motor(Indication of direction)
3) ESP8266(For transmitting information to the server)

For the physical structure

1) 5mm Acrylic sheet
2) Tripod
3) Aluminum L
4) Screw nuts
5) 1 inch (bore) PVC pipe

For connections wires as per requirement

4 Software requirements

The following are the software required for the project

1) Arduino IDE
2) ExpressPCB
3) Multisim
4) HTML, Java for developing the app/webpage to upload necessary data.

5 Implementation

The system process can be classified into 2 parts.

1. Detection of gunshot[8]
2. Calibration of the direction of the shot.[8]

For the detection of a particular sound, the frequency of the source is analyzed and studied. And according to which a bandpass filter is designed. For instance, the central frequency of a finger-snap lies at nearly 3 kilohertz so a bandpass filter with cut off frequencies fL =2.5kH and fH=3.5kH can be designed for detecting snap sound. The circuit is shown in figure 1.

The following stages consist of in the detection circuit:

1) 2nd order low pass filter

2) 2nd order high pass filter
3) Non-Inverting Amplifier with a gain of 100
4) Non-Inverting Amplifier with a gain of between 2.5 to 5
5) Peak detector
6) Comparator circuit with 1.5V offset

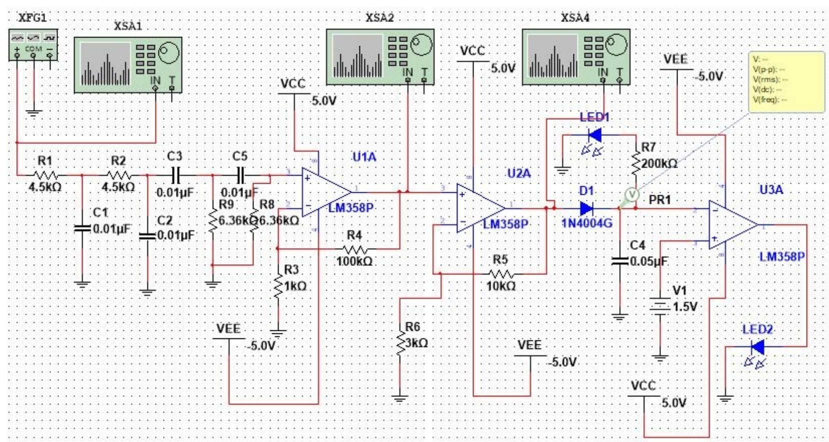
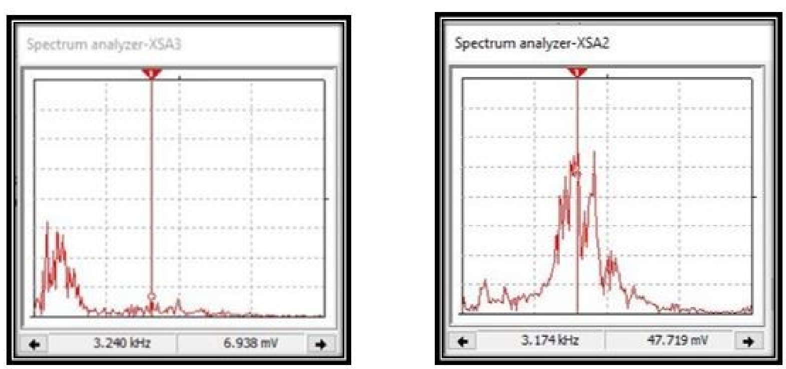


Figure 1: Finger Snap Detection Circuit

The frequency spectrum of the finger-snap and gunshot is shown in the figure below



Frequency spectrum of 9mm pistol

Frequency spectrum of finger-snap

Figure 2: Frequency Spectrum

The circuit gives response better for sounds with impulse nature i.e., sound having high amplitude for a short duration of time. For instance finger-snap, gunshot, and firecrackers, etc.

For the calibration of direction, it can be assumed that the sound source is very far away in comparison to the distance between microphones. Then simple trigonometry can be used to determine the angle of from the center of the microphone pair. This is described below.

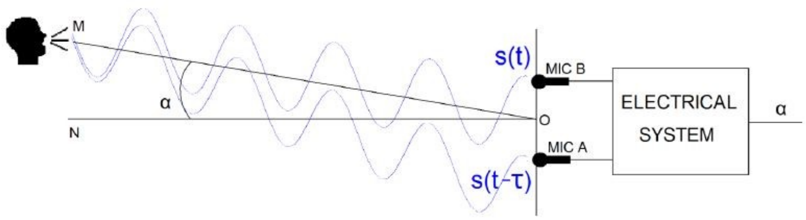


Figure 3: Arrangement of microphones and the sound source[5]

Calculation

Speed of sound, v = 331.3 + (0.606*T) metre per second

Here 'T' is the temperature in Celsius

Consider the figure 3

$$\sin\theta = (\text{delay}*\text{sound speed})/\text{mic distance}$$

$$\theta = \sin^{-1}(\text{delay} *\text{speed of sound})/ \text{mic distance}$$

$$\theta = \sin^{-1} ((\tau * v)/d)$$

After that, the angle from the center of microphones can be calculated as $\pi - \theta$ in radians.

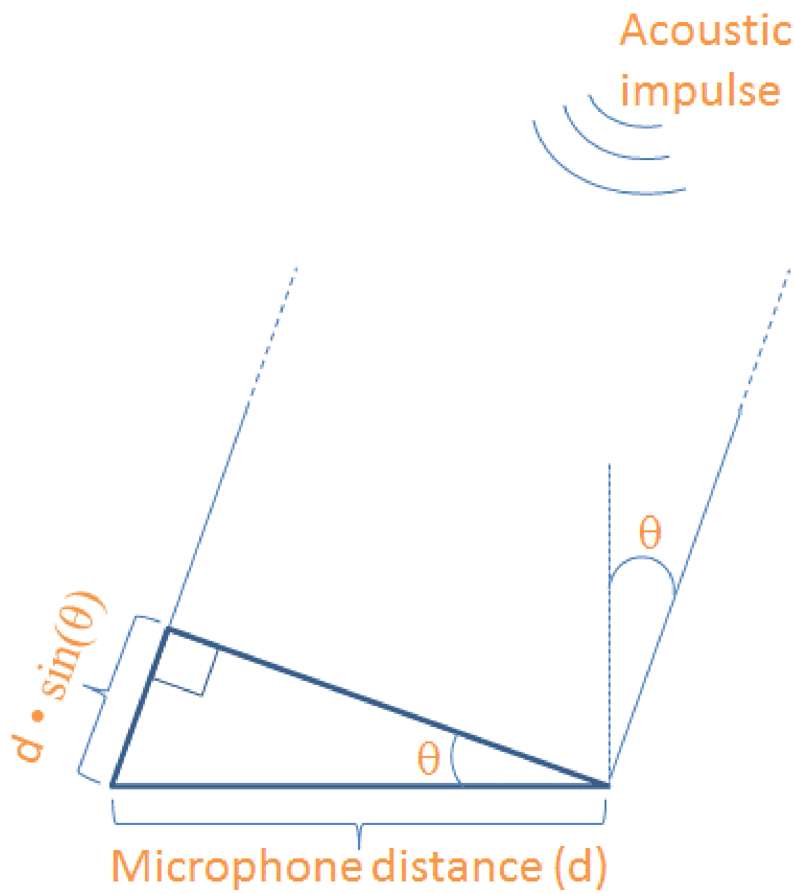


Figure 4: Two microphone angle model [8]

The delay between the time of arrival (TOA) of the acoustic signal at two microphones can be calculated with the help of the timers of the microcontroller. This is described above.

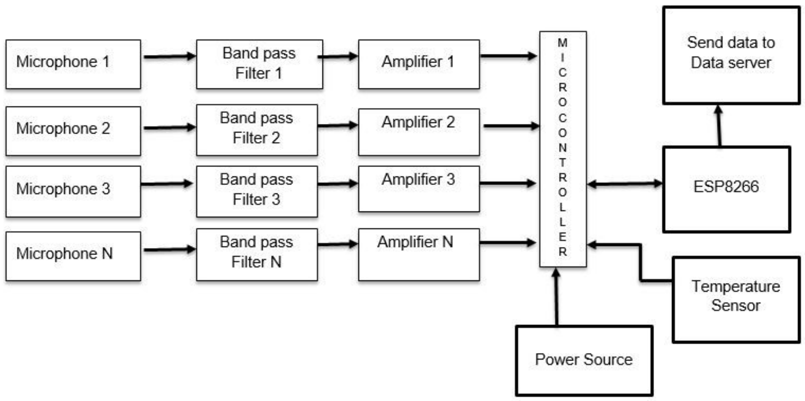


Figure 5: Block diagram

The data from the device will be uploaded to the cloud for analyzation. This is required because sometimes noise may also lie in the frequency bandwidth and trigger false alarm causing a waste of resources and time. The data will be analyzed first by the server. If the server gets agree that the sound detected is indeed gunshot then it then will be analyzed by the admin. After confirmation from the admin, the shot area will be shown in an android application.

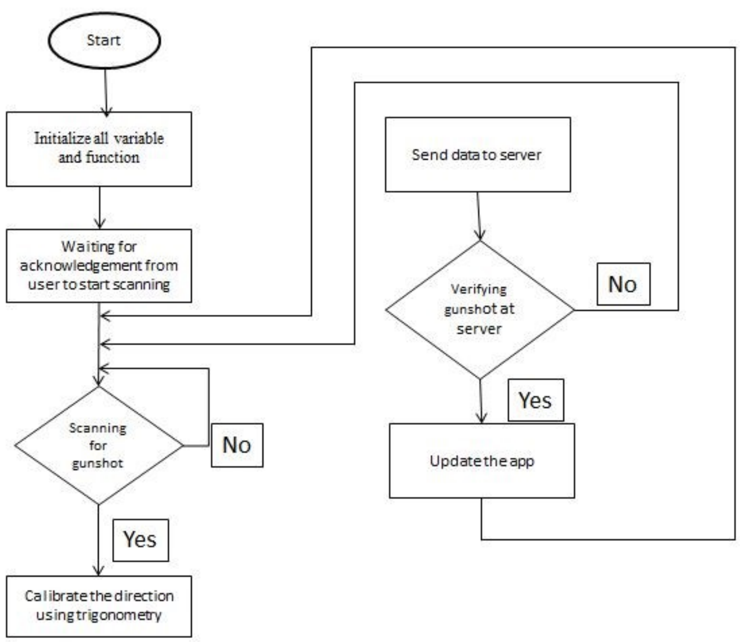


Figure 6: Flow chart

The 3D model of the project is shown in figure 4. The "green spheres" are the microphones and filter circuit, preamplifier circuit, microcontroller is shown protected inside a square block of grey color. The height of the device is given with the help of a tripod.

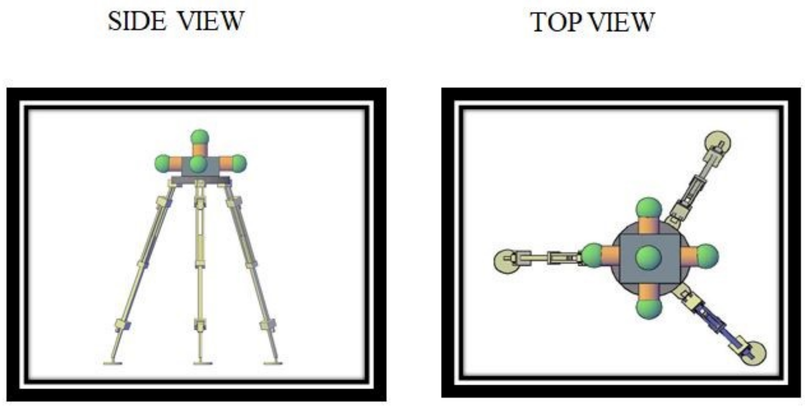


Figure 7: 3D Model of the device

6 Feasibility

Globally many organizations and institutions have been working on the above problem statement and a lot of effort has been spent in research and development to overcome challenges like noise prone environment, coherent sources, simultaneous gunshots, reverberations, etc. Since system applications involve the use of a searchlight, or a wide-angle camera, which covers a wide area in their field of view, the system does not require angle determination with very high accuracy.India has been working on such a rugged and reliable system for many years. Such a system can prove to be of great aid in hostile areas such as disturbed and volatile border regions and can play a vital role to counter infiltrations along the country's territorial borders. The present challenge is to improve the accuracy of direction estimation and source ranging.

References

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[5] Carlos Fernandez Scola; Maria Dolores Bolanos Ortega. " Direction of arrival estimation – A two microphones approach". Thesis presented as part of Degree of Master of Science in Electrical Engineering, Blekinge Institude of Technology; September 2010.

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[8] http://people.ece.cornell.edu/land/courses/ece4760/FinalProjects/f2013/agw39-mag338/agw39-mag338/agw39-mag338/agw39-mag338.html