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# Evaluation of Auto Pilot Situational Awareness System Using Gunshot Detection Algorithm in a Localized Environment: Case Study Federal Polytechnic Offa, Mini Campus

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***Authors' contributions***

*This work was carried out in collaboration among all authors. Author OAA conceived of the presented idea. Author MKL developed the theory and performed the computations. Authors AAOO and ATA verified the analytical methods, then investigated the study site on Federal Polytechnic Offa for this study and supervised the findings of this work. All authors discussed the results and contributed to the final manuscript.*

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## ABSTRACT

Gunshot detection technologies are more applicable in many industries for the security enhancement of public places like the Federal Republic Territory FCT Abuja in Nigeria. Many factors affect the accuracy of the gun detection algorithm. This paper describes an audio-based video surveillance system in an auto pilot situational awareness to detect gunshots in Federal Polytechnic Offa. The Time Difference of Arrival (TDOA) of Shock Wave and Muzzle Blast is integrated to estimate the shooter location in the study are. The proposed design and algorithm was validated and shooter origin was resolute that was very close to theoretical values. The video camera is steering regarding the initial position to localize the acoustic source's position. Implementing an auto pilot situational awareness system is an experimental procedure with a gunshot detection algorithm in a localized environment. In the direction of the weapon, the distance

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between firearms, types of ammunition, types of study environment, and diffraction of audio, the standard feature for gunshot recognition are Mel frequency cepstral coefficients in terms of uniform gamma-tone filters linearly spaced over the whole frequency range from 0KHZ to 16KHZ. Experiments show that our system can detect gunshots with a precision of 93% at a false rejection rate of 5% when the SNR is 10db while proving the estimate of the source direction of the gunshot with an accuracy of one degree. The outcomes reveal that the data generated by the system can be leveraged by the firefighting department to quickly locate the whereabouts of the indoor fires, and the VR gamification scenarios can expedite the development of situational awareness for the trainees. The research recommends a real-time system implementation for protecting the Federal Polytechnic Offa against any form of treats.

*Keywords: Auto pilot awareness system; gunshot detection; algorithm; localized environment.*

## 1. INTRODUCTION

The threat to national security has been a significant concern for nations in recent years and has become unbearable for the local environment. The extent to which invaders encroach even on the so-called sacred places is alarming. Recently, Nigeria has been marked by turmoil ranging from kidnappings, political chaos, terrorism and bombings. Governments have tried various methods to contain these threats. Still, all have proved unsuccessful because there are too many roads and too few security guards to patrol all locations safely. Because of this, the lack of human power (security personnel) will introduce the autonomous operating system in public places to monitor events in a specific location.

In a diverse and active environment with low situational awareness, decision-making is influenced by many variables such as sudden sounds like gunshots or alarms. In such cases, the purpose of this or any other decision is essential, as well as the ability to understand and analyze the current situation quickly [1,2].

Situation awareness is vital in human information processing and pilots' decision-making processes. "Situational awareness" is formally defined as "a perception of the environment within a volume of time and space, the comprehension of their meaning and the projection of their status shortly" [3]. Situational awareness is a critical mental process affecting decision-making and performance [4]. Situational awareness is the leading paradigm in studying the human factor as the source of knowledge and investigating its effects on interacting with the environment. To improve situational awareness and secure the level of crime within Federal polytechnic Offa. Efforts must autonomously monitor the regions using an autopilot gunshot detection system, especially the public location [5-10]. A gunshot detection system is comprised of sensors to detect the sound of a gunshot, transmitters to send a message to the police dispatch centre or security point, and a computer to receive and display that message. When a signal arrives at the police station, the dispatcher decides whether or not to send a unit to respond to the signal [11-13].

The initial research into the effectiveness of gunshot detection systems is up-and-coming, particularly regarding the technology's usefulness in identifying and solving problems and detecting crime. As the technology develops and becomes more accurate and portable, these systems could prove to be highly effective tools for local police departments.

Gunshot detection systems use acoustic sensing technology to identify, discriminate, and report gunshots to the security personnel within seconds of the shot being fired [14-17]. As a problem-solving tool, gunshot detection reports can be used with police or security personnel data (e.g., citizen reports of gunfire) and physical features of a neighbourhood (e.g., parks or liquor stores) to identify neighbourhood hot spots. Suppose demographics (e.g., income level or gun ownership) are considered. In that case, the data can be used to analyze various dimensions of the problem and to evaluate the effectiveness of responses to the problem.

### 1.1 Campus Safety: Gunshot Detection Systems Benefit Measure

So far this year, the researcher has already equalled the number of deaths from school shootings conducted throughout 2021 [18]. Unfortunately, while school shootings are becoming a typical attitude in our country, implementing a gunshot detection solution could help prevent unnecessary casualties by being the first link in the chain of events to dispatch police and protect staff from imminent danger to warn our children.

Gunshot detection systems were originally developed for military use, but in recent years private companies have begun urging school systems to adopt the technology. Tragedies garnering national attention have left many parents questioning whether enough is being done to protect children in the classroom or school.

Several companies install and maintain gunshot detection systems, but generally, sensors are placed throughout the building that detects when and where a gun is fired. Information is relayed to police, administrators and other first responders in milliseconds. Alerts are also sent inside a building to notify those inside that there is an active shooter in the building [19-21].

Suppose an increasing number of gunshot detection systems are being installed in schools and other buildings across the country. Though few schools currently have the technology, advocates say the near-instantaneous gunshot detection could save lives in mass shootings.

Industry officials said gunshot detection systems are modernizing the way organizations respond to active shooter situations. Instead of relying on human behaviour in a chaotic situation, e.g., if a teacher or worker calls 112 to notify authorities, the system provides law enforcement with near real-time data on the threat and allows them to develop a plan to neutralize it quickly said.

Imagine in a second boom; in a second, you know it's a shot, and you know where they are. In the case of a mass shooting, every 18 seconds considering a victim dies, so every second counts. Earlier this year, one company, Shooter Detection Systems (SDS), received Safety Act certification from the Department of Homeland Security. The Safety Act certification offers companies protection against liability when using anti-terrorism technologies. SDS said its systems rely on acoustic and infrared sensors, and the company said its systems have never registered a false alarm.

## 2. LIMITATIONS

Extensive research into previous shot detection systems has proven that there are many approaches to existing shot detection systems with different algorithms;

- Host of complicated power-consuming algorithms: These detection algorithms can range from the Mel-frequency cepstral coefficients to the adaptive cancellation of background noise through multiple layers of notch and bandpass filters.

The triangulation (location) by TDOA (Time-Difference 4 on Arrival) of the shot must be calculated using the consistent sound velocity calculation and generalized cross-correlation phase transformations. Although these are computationally intensive tasks, this aspect can be handled by a computer receiving the data and not by the processors in the field, so they can only be used for detection.

While some systems rely solely on auditory information (and the reported false alarm rate is probably about right for the worst of them), the better systems use three sensor technologies and achieve false-positive rates of less than 1/10th of 1%. This is a much better accuracy when testing recordings than the video analytics systems. Cost is always a factor; The dedicated systems can require up to 70% less installation and maintenance and do not require live monitoring from a central station. In addition, these systems provide real-time updates directly to law enforcement, including the firearm type and the shooter's location, which is indicated on a building floor plan. Every facility is different, and needs vary. However, let's not rule out the dedicated systems just yet.

## 3. REVIEW TO EVALUATE GUNSHOT DETECTION SYSTEMS FOR SCHOOLS

According to [22], since 2010, an average of 15 people have died in mass shootings in our school system in Nigeria every year. The standard might have been higher, be it not for the COVID-19 pandemic that kept our kids and teachers out of school last year. According to the FBI, between 2000 and 2018, 74% of mass shootings in education took place in 12th grade or younger.

A few months passed, and the President of the Federal Government of Nigeria declared: Gun violence is an epidemic in this country. It's gotten so bad that more and more schools are starting to implement gunshot detection technology in their halls. The gunshot detectors will protect lives like a manual train station for fire alarm systems (train stations don't prevent fires from starting, but hopefully, they will be activated early enough to save as many lives as possible).

According to [23], the origins of many technological advances are often traced to innovations in various fields that were later made applicable through a simple redesign. Modern gunshot detection systems have similar roots.

The onset of World War I spawned a technique known as sound ranging, which provides information on the coordinates of artillery pieces. Developed by William Lawrence Bragg, a British military officer and physicist, initial sound removal techniques involved arrays of microphones carefully placed on the battlefield to detect sound events from the fired weapons and report them to a monitor at an operational base as shown in Fig. 1. The resulting information at times contained valuable information on the origin of sound events. Although the approaches' early effectiveness was less than ideal, the opposing sides of the conflict made changes to the procedure to achieve increasingly beneficial results.

By World War II, most major armies used ultrasonic rangefinders for mortar detection and counter-artillery operations. In particular, the British and US Marines used the range in defensive operations. Acoustic ranging equipment has become more sophisticated and cheaper over the years, but radar systems and aerial surveillance have taken over as the primary method of locating weapons in military operations. Radar operators can now identify heavy weapons more quickly. This is derived from more meaningful data in environments with extreme terrain or overgrown vegetation. The equipment could be placed on more mobile units for determining the location of aircraft and vehicles, and most importantly, the radar could work without waiting for shots to be fired. Sonic removal still had a place in combat, but it mainly acted as a backup for the rapidly growing radar capabilities. Across the United States, agencies have deployed gunshot detection and location systems in cities and other urban areas prone to firearm-related crimes and accidental gunfire. These systems are increasingly being considered as they make a significant contribution to community safety and law enforcement success, offering enhanced responsiveness capabilities and potential video evidence by incorporating video capture components into system designs. While some critics have raised concerns about cost, privacy issues, and accuracy, gunshot detection and localization systems used in American cities have had a significant impact on how agencies detect and respond to criminal activity. In the Federal Capital Territory in Abuja.

## 4. SYSTEM DESIGN

A sensor is used to listen for acoustic properties unique to the sound made when a gun is fired and then sets off an alarm that usually automatically dispatches the police. On most single-purpose devices, that's all the shot detector does. As soon as gunshots are detected, an alert is sent to the 112 dispatcher, and a text message is sent to the city police department and patrol officers. Most of this is done before someone even thinks to pick up the phone and dial the safety number due to a chaotic situation, improving response time.

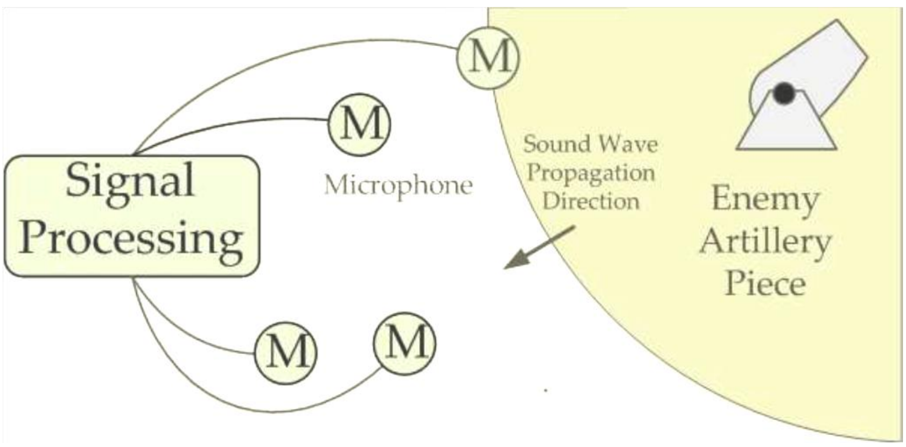


**Fig. 1. Sound ranging diagram**

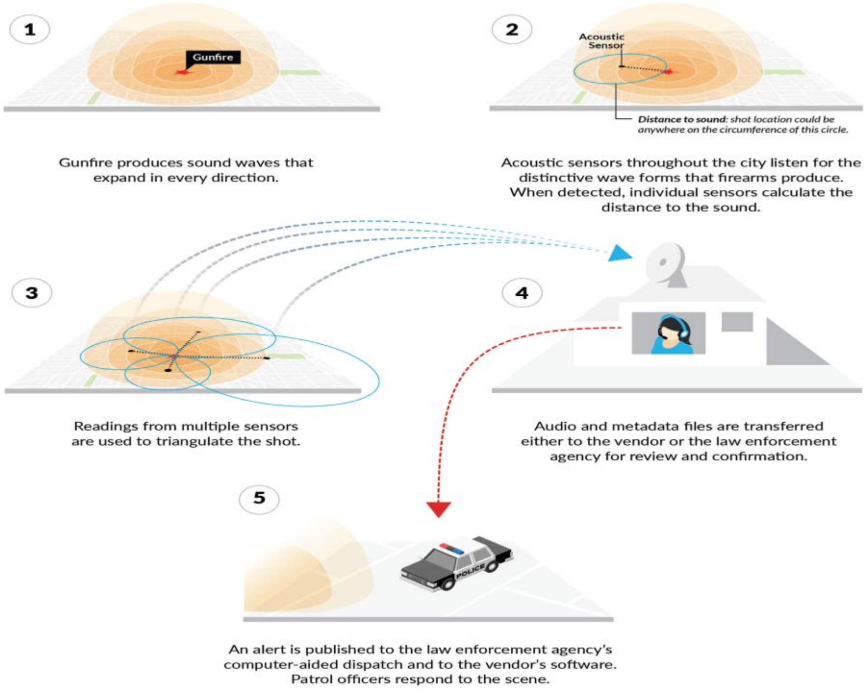


**Fig. 2. Gunshot detection technology data flow**

A particular shot detection system added benefits such as: B. Locating a shooter's location by triangulation. Adding cameras and gunshot detectors can be costly for any customer. While not capable of triangulation, a multipurpose camera can track a shooter's direction when installed on school campuses.

## 5. METHODOLOGICAL PROCESSES

### 5.1 Study Planning

Before assembling and testing a basic audio detection system, a general strategy must be outlined. The method to be designed in the following steps detects sounds with a specific set of properties, infers an origin direction of the sound source, and rotates a camera to point in the inferred direction. In a real-world setting, such a system would activate when triggered, automatically aiming a camera at the identified sound source in hopes of capturing potentially valuable video evidence to assist investigators.

With those expectations in mind, the system should have microphones to capture audio and a computer to process the incoming audio and send commands. The microcontroller receives the commands and sends the appropriate voltages, and a servo receives those voltages and rotates a platform. A camera is attached to the platform to quickly capture the scene on video. The camera can then be wired back to the computer to view or record the incoming video information. Hence, the servo only rotates the camera along the horizontal x-axis and has a rotation range of 180 degrees.

Establishing a system programming strategy along with device planning. The two main questions that need answers are: How does the system distinguish a gunshot-like sound from other sounds? And how does the system determine the direction of the source? Should characterize the sound of interest using measurable features. To the human ear, the most obvious characteristics are the perceived loudness and short duration of events. According to Michael and Lucien Haag, a gunshot measured from a meter away is often dB louder than a chainsaw, a jackhammer, or even an aeroplane taking off from 30 meters away.

Also, the rise time, the time from the start of the event to the first peak, is almost instantaneous. In particular, one study found that muzzle blasts, or explosive shockwaves and sonic energy emanating from gun barrels, often lasted less than three milliseconds. This means that one gunshot can be distinguished from another by the shape and relative strength of the gunshot waveform or by the visual representation of the audio signal or recording (to show changes in amplitude over time). The materials used in this project are limited by cost and time, but these audio properties can be leveraged with off-the-shelf components and intuitive programming.

The waveform in Fig. 3 shows the main characteristics of gunshot noise, high signal power, and a near-instantaneous first peak of relative silence. This shot in particular is said to have been taken at an outdoor shooting range. Note the distinct reflection recorded immediately after the initiation event. Most likely, the original sound event bounced off the back retaining wall or barrier used to stop incoming bullets. Finally, we have to deal with the means of determining the direction of the sound source. In a plane, if the object's velocity is constant, the time traveled a known distance gives the object's velocity. This is expressed as v = d/t. If the traveling wave maintains a constant velocity over a known distance, the elapsed time will also be constant. However, suppose the wave starts at his third point and travels with constant velocity along a trajectory that is not perpendicular to the midpoint of the two microphones. In this case the speed and distance are constant and the arrival time at each point may vary. Waves reach the nearest point first, then the farthest point. The delay between signals arriving at each channel can then be used to derive the source bearing. A source emanates from a point along an azimuth. These are the working principles behind sound cancellation, past and present, and are illustrated in Figs. 4 through 7.

For the sound source, in Fig. 4 S is closer to L than to R (SL < SR), so the sound propagates outward with a constant velocity (SL < SR), and the sound from S reaches L first., then R is reached. It also means that the radius is less than the radius b (ra < rb). Sound delay (ang) was measured from the midpoint between LandR. Similar to Fig. 4, the scenario in Fig. 5 shows how to derive from the differences in SLandSR. This time S is closer to R (or r is shorter than ra), so the corresponding angle is towards the R side from the center. Example 3.4 shows that the difference in SLandSR, orra, and b can be used to determine extreme angles. The angles obtained in these examples are independent of the distance from the sound source to the microphone. Since the derived angles are bearings, not endpoints, Fig. 7 leads to the same computational process for delays and subsequent angles, even though the furthest distance from the example microphone is included. Equipment and configuration.

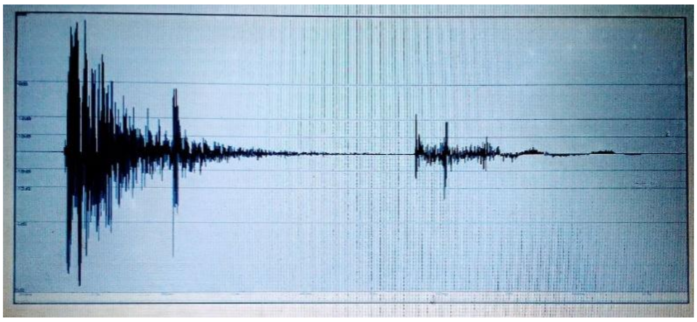

**Fig. 3. Waveform of a .22 caliber rifle shot with Reflection. (Audio courtesy of user gezortenplotzvia FreeSound.org recorded with Nady wireless microphone on minidisc)**

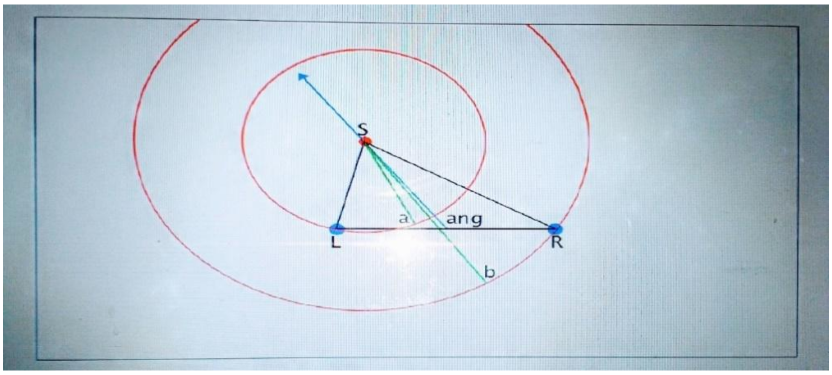


**Fig. 4. Angle determination from sound delay between two microphones**

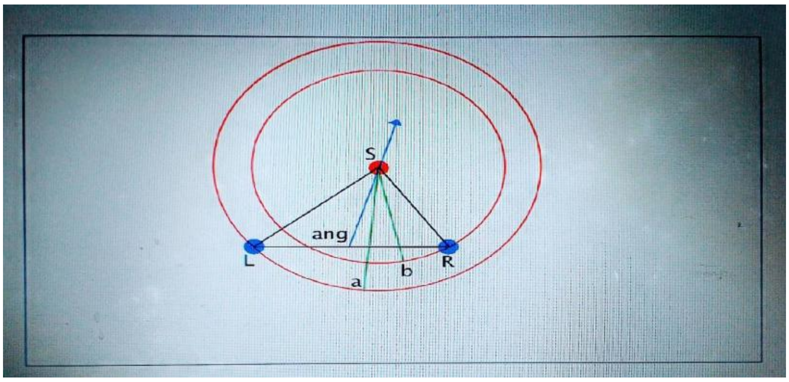


**Fig. 5. Angle determination from sound delay between two microphones (II)**

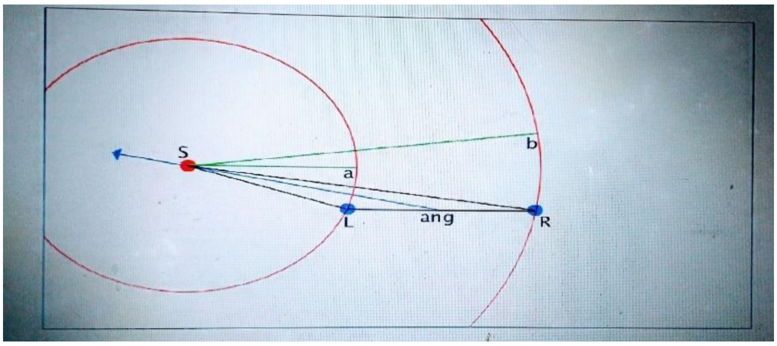


**Fig. 6. Wide angle determination from sound delay between two microphones**

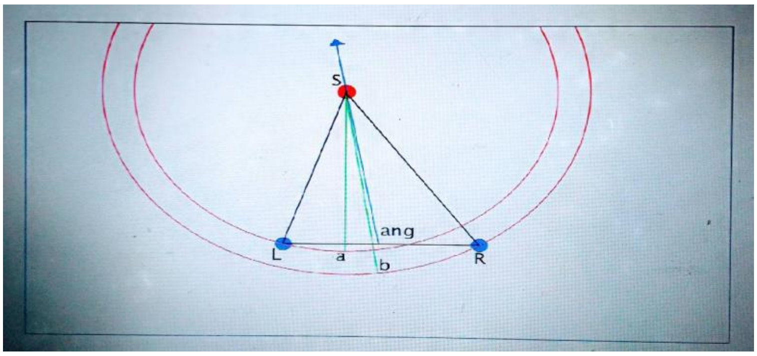


**Fig. 7 Distance angle determination of two-microphone audio delay**

A system starts with a pair of microphones. A microphone that is highly tolerant to significant impulses is ideal for a fully functional system used in real operation. Still, a pair of inexpensive small microphones is sufficient for this design. The microphones used in this test are a pair of Olympus ME-15 microphones. These are considered a stereo pair, both recording audio at the same time. Then connect your microphone to the laptop's stereo mic input using a stereo line-in cable. This computer is equipped with MatLab, general-purpose computing and programming software. MatLab handles both audio input and command output to the microcontroller. The actual programming scripts used by MatLab and the microcontroller are described later. The microcontroller is then connected to the computer via a serial interface. In this case, the connection is established via a USB cable. Our microcontroller of choice is the Arduino UNO due to its versatility and extensive open source support. The Arduino receives commands from the computer and sends the appropriate voltages to the servo motors that rotate the attached webcam. The servo motors are standard HS-422 servos, and the webcam is a 5-megapixel USB webcam that can be connected and viewed on a laptop.

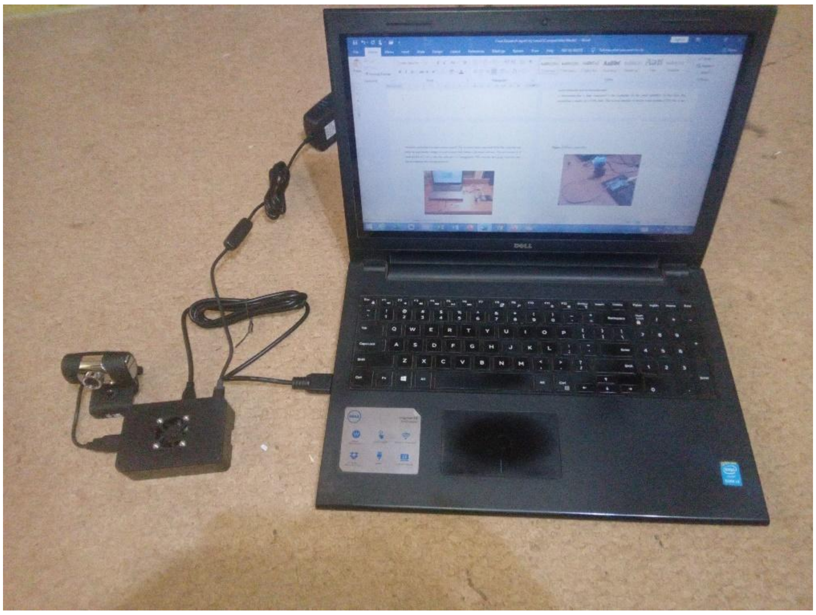

**Fig. 8.Shot detection and localization system, basic design overall**

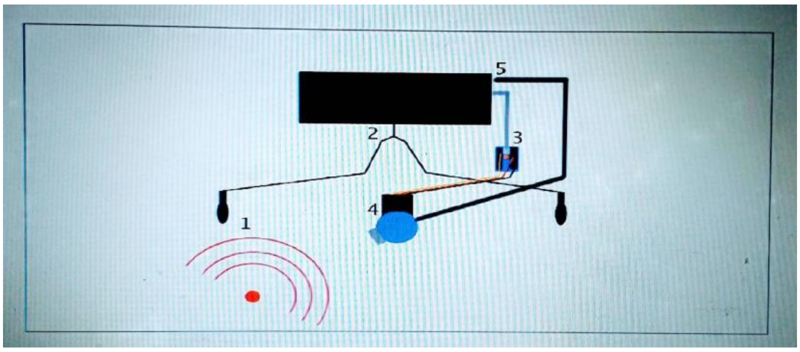


**Fig. 9. Basic system flow**

**Fig. 10. Gunshot detection and localization system, arduino and servo close-up of arduino and servo assembly**

Fig. 8 is an overview of the system designed, assembled and used for the tests outlined in this project. Mike captures the ringtone, and he sends it to MatLab for processing. MatLab will process the signal delay and compute the angle if the input signal meets the threshold requirement. The Arduino receives angle rotation commands via a serial connection (the white wire on the right side of the laptop) and communicates with the servo motors to which the camera is attached. Image information is sent from the camera to your computer via a separate USB connection for viewing and recording. This workflow is shown in Fig. 9.

1) The supply microphones, upon arrival, choose up sound
2) The Laptop gets and techniques incoming audio facts, determines feasible goal sign confirmation, puts off and ensuing angle
3) The Laptop sends a command to Arduino
4) Arduino sends voltage to the servo motor with digital digicam mount
5) Laptop gets ensuing picture facts from digital digicam figure.

Programming The machine is configured even as the Arduino and MatLab are programmed for the experiment. The Arduino platform turned included with MatLab to permit the microcontroller to be programmed and run continuously. The Arduino serial port maintains listening for MatLab serial instructions, executing the instructions, and returning outcomes on request. Next, a script was turned into written for MatLab to manner the incoming audio and ship suitable instructions automatically. Audio detection and picture reaction script This machine acquires audio indicators % 1, % 2. Based on described thresholds, this machine will discriminate unique obtained audio occasions from others.% 3. Using the perceived put-off of incoming audio indicators among the pair of recording channels, this machine will estimate the directional supply of the discriminated audio sign.% 4. This machine will command the servo motor to rotate the digital digicam array closer to the perceived supply of the discriminated audio sign.%% Materials Used:% (1) Arduino microcontroller with serial connection to pc and sign connected to the servo motor

*% (1) 5V rotational servo motor (180-degree range) connected to Arduino% (1) webcam attached to rotating mechanism of servo motor% (2) omnidirectional microphones arranged to acquire a stereo audio signal, connected to a computer via stereo microphone input, through Yadapter%% Notes% works with motor srv and add AFMotor.cpp and AFMotor.h to path: ...Arduino\libraries\Servo%%*
*Script%delete(a)%connect to the board*

```
a=arduino('COM13')
% define Pin#9 as output and attach the motor to it
a.pinMode(9,'output');
% Attach servo#2 to Pin#9
a.servoAttach(2);
a.servoWrite(2,90); %reset servo to center
% define the audio settings
% sampling frequency
fs=48000;
% resolution (bits)
nbits=16;
% no. of channels
ch=2;
% each “extraction” length in sec
t=0.5;
% signal power threshold
th=1200;
% window threshold size
win=200;
% define the audio object
recObj=audiorecorder(fs,nbits,ch); %begin recording
get(recObj) %collect/display values as they are recorded
disp '***BEGINNING ACQUISITION***' %status message
for k=1:2000
% aquire the audio signal
recordblocking(recObj,t); %record without on-the-fly control until recording is stopped
% Store data in double-precision array.
x=getaudiodata(recObj,'int16'); %signed integers mapped to set parameters (anything outside will be "rounded")
% find absolute value of incoming signal
xa=abs(x);
% extract L and R channels
L=double(x(:,1));
R=double(x(:,2));
[k max(L) max(R)] %query for maximum values during sampling "window"
if max(L)>th && max(R)>th %set power threshold
if xa(k:k+win)<win %set rise time threshold
% Plot the waveform (grid on, tight to L/R)
subplot(211),plot(L,'r'), grid on
axis([0 length(L) -2^15 2^15])
subplot(212),plot(R,'g'), grid on
axis([0 length(R) -2^15 2^15])
disp '***SYSTEM ARMED, DATA COLLECTED***' %status message
```

[c,lags]=xcorr(L,R); %cross-correlation between vectors
(automatically adjusts for length differences), returns a “lag vector”
[a1,b1]=max(L); %fs/time of max values
[a2,b2]=max(R);
[a3,b3]=max(c); %define c's maximum values as a3,b3
delay2=fs/2-b3 %delay is half of sampling frequency minus b3 (maximum value for c), in samples
s=delay2;
if s<-127 %round values outside degree parameters to furthest degree value left or right (to maintain 180 degree range)
s=-127;
elseif s>127
s=127;
end
% convert the delay s into degrees ang
ang=round((s+128).*179/256)
% rotate angle ang
a.servoWrite(2,ang);pause(0.01); c;
end
end
end
delete(a)

As usual in MatLab scripts, beginner's traces of textual content prefixed with per cent signs are used as recommendations and do not end in an actual programming language. Annotations guide each section of the script, utility and Th thresholds, and delay calculations and attitude transformation elements.

Thresholds in audio detection and image response script

% signal power threshold
th=1200;
% window threshold size
win=200;

According to the above script associated with the Threshold element of the script, the threshold is a relative signal power quantization level of 1200. This setting depends on several factors, including the microphone gain setting, the expected distance of the microphone from the sound source, and the expected background noise. Due to these many factors, the th setting should be carefully tuned for each use. 48 kHz corresponds to a threshold of 200 audio samples.

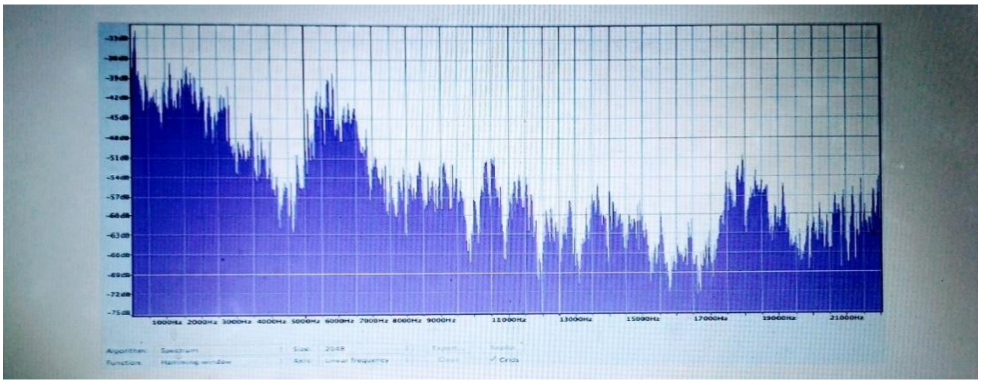

**Fig. 11. Output Plot the waveform (grid on, tight to L/R)**

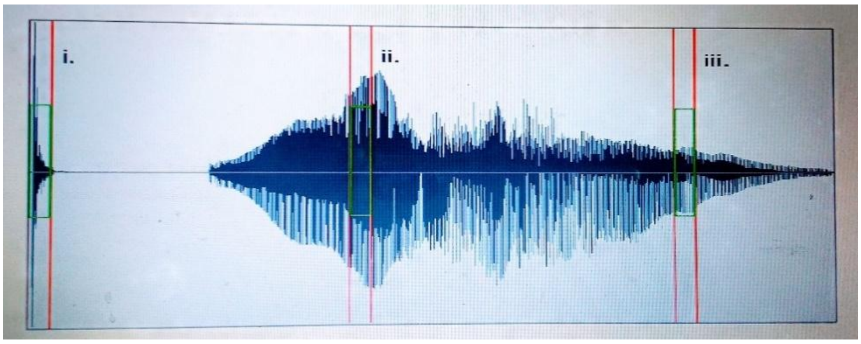


**Fig. 12. Discriminatory thresholds for excluding audio events**

Figs. 11 and 12 show how a series of thresholds work in identifying audio signals based on power and duration. At the window, the signal satisfies both the minimum power and maximum duration thresholds. ATII, the signal meets the minimum power threshold but is too long. Signal does not meet the power threshold. The script used in this project requires the signal to reach the power threshold and then the duration threshold to invoke the system response. Another important part of the project script is delay calculation and angle conversion (BelowScript). Computing Channel Delays and Angles in Detection and Response Scripts.

```
[c,lags]=xcorr(L,R); %cross-correlation between vectors (automatically adjusts for length differences), returns a “lag vector”
[a1,b1]=max(L); %fs/time of max values
[a2,b2]=max(R);
[a3,b3]=max(c); %define c's maximum values as a3,b3
delay2=fs/2-b3 %delay is half of sampling frequency minus b3 (maximum value for c), in samples
s=delay2;
if s<-127 %round values outside degree parameters to furthest degree value left or right (to maintain 180 degree range)
s=-127;
elseif s>127
s=127;
end
% convert the delay s into degrees ang
ang=round((s+128).*179/256)
```

At the bottom of the script, we determine the delay of the input audio event between channels and create the corresponding sample delay angle. The Arduino uses 0 degrees as a valid angle integer, so the range of 180 degrees is 0 and extends from 0 to 179. The delay and angle computation part of the script needs some explanation. The xcorr, max(L), and max(R) sections of the script mark the initial peak value of the incoming signal for each sampling window (previously defined as 0.5 seconds long). Each initial peak is marked with the numerical sample from which it was measured. The delay is then determined by the difference between these samples. If the value is outside the assigned range, it is rounded to the upper or lower bound depending on whether it is above or below those extremes. Assuming the speed of sound is about 350 meters per second, a sound wave travels 6 feet (or about 1.829 meters) in about 0.0053 seconds. Six feet is the specified distance between microphones used in the system and 0.0053 seconds is the maximum inter-channel delay. Since the sampling frequency defined above is 48 kHz or 48000 samples per second, the maximum inter-channel delay can also be measured as approximately 256 samples. Then the delay is added to 128, the reference to the R channel is considered instead of the L channel, and the sample to angle ratio is compared. The resulting value is rounded to the nearest integer and becomes the calculated rotation angle. So if the delay is 98 samples (signal faster than L he reaches R98 samples).

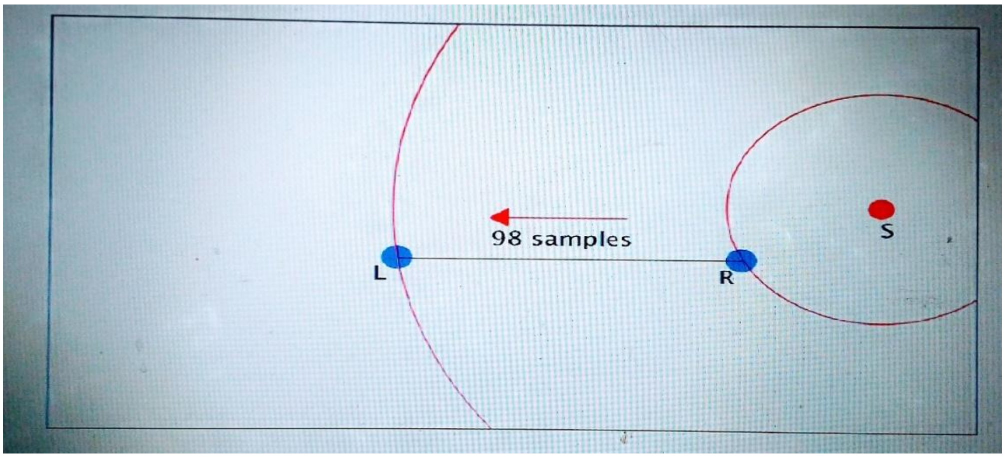


**Fig. 13. Delay and angle calculation example 1**

*ang = (98+128)*179/256*

*ang = (226)*179/256*

*ang = 158 degrees*

*On the other hand, a delay of -110 samples (signal reaches L 110 samples faster than R)*

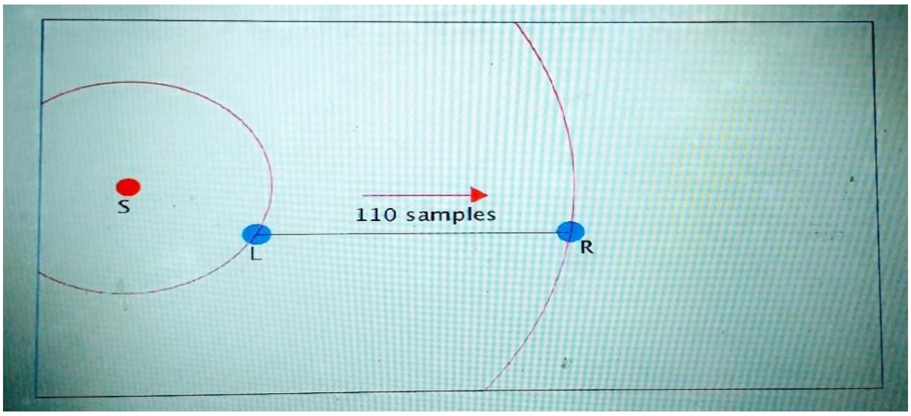


**Fig. 14. Delay and angle calculation example 2**

*ang = (-110+128)*179/256*
*ang = (18)*179/256*
*ang = 13 degrees*

The angles calculated from this script are measured left to right from the midpoint between the microphones. This means that angles from 0 to 88 degrees rotate the camera counterclockwise from the neutral position, and angles from 90 to 179 degrees rotate the camera clockwise to the L or R of the assigned reference. To do.

## 6. TEST AND RESULTS

A simple test was created and run to evaluate the system's functionality. The plan was set up in the surrounding administrative building, the mini-campus of the Swiss Federal Institute of Technology. This location was chosen to minimize potential disruptive effects and other variables introduced into the congested area of the main campus. This test was conducted at night to reduce the possibility of external noise interference from the wind and pedestrians. The temperature was about 37 degrees Fahrenheit. This is important because it is known that relatively small temperature changes do not significantly affect the speed of sound. Still, large changes in temperature can complicate calculations of the speed of sound.13.

1. As mentioned, the mics are elevated and about 72 inches apart. Spacing is designed towards the wide end of the spectrum to accentuate the delay between input audio channels. Grades were arranged at 5, 10, 15-. Step from midpoint between microphones, all distances at 10, 30, 50, and 70 degree angles in either direction from the same midpoint. A total of 24 markers were created. These marks indicated where the test tones were to occur. At the time of testing, a real firearm was not an available sound source. Instead, loud, sharp handclaps were used at each mark. The overall handclaps waveform is characterized by high intensity and short duration of both events, so it can simulate gunshots well. Applause was kept at a constant volume, but some variation in signal strength must be allowed. However, the deviations were considered acceptable due to the many factors that lead to sound deviations in real-life situations. Tests are designed to mimic a realistic environment while being controlled in the most rational aspects. At the time of testing, a real firearm was not an available sound source. Instead, loud, sharp handclaps were used at each mark. The overall handclaps waveform is characterized by high intensity and short duration of both events, so it can simulate gunshots well. Applause was kept at a constant volume, but some variation in signal strength must be allowed. However, the deviations were considered acceptable due to the many factors that lead to sound deviations in real-life situations. Tests are designed to mimic real-world environments while giving you control over the most practical aspects. 1. Point the camera towards the sound source and stop at the mark in the middle of the camera frame (see table below).
2. Aim the camera towards the sound source and stop at the mark in the frame, but not in the middle (represented by O in the table below).

3. Camera rotation, stopped with no sound source in the image (denoted by an X in the table below).
4. No camera movement in response (explained in the table below). Responses were determined after several camera movements in response to applause or after up to five marker attempts. Four. Each marker was tested in one trial, and the test consisted of three trials. The order of marker testing depends on the experiment. On his first two trials he described each class at one distance, followed by his remaining two distances, but on his last trial he progressed in a more staggered pattern. Table 1 through 1.3 show each experiment and set of results.

**Table 1. Test Trial 1 configuration and results**

| Trial 1 – Results | 5 feet | 10 feet | 15 feet |
|---|---|---|---|
| $70^0$ Stage Left(SL) | 1 | 1 | 1 |
| $50^0$ SL | - | - | 1 |
| $30^0$ SL | - | - | 0 |
| $10^0$ SL | 0 | X | 0 |
| $10^0$ Stage Left (SR) | 0 | X | 0 |
| $30^0$ SR | X | X | X |
| $50^0$ SR | - | - | 0 |
| $70^0$ SR | 1 | - | 0 |

**Table 2. Test Trial 2 configuration and results**

| Trial 2 – Results | 5 feet | 10 feet | 15 feet |
|---|---|---|---|
| $70^0$ Stage right(SR) | 1 | 1 | 1 |
| $50^0$ SR | - | - | 0 |
| $30^0$ SR | X | X | X |
| $10^0$ SR | 0 | 0 | - |
| $10^0$ Stage Left (SL) | 1 | 0 | 0 |
| $30^0$ SL | X | X | X |
| $50^0$ SL | X | - | 1 |
| $70^0$ SL | - | - | 1 |

**Table 3. Test Trial 3 configuration and results**

| Trial 3 – Results | 5 feet | 10 feet | 15 feet |
|---|---|---|---|
| $70^0$ Stage right(SR) | 1 | 1 | 1 |
| $10^0$ Stage right(SL) | 0 | 1 | 1 |
| $50^0$ SR | 0 | X | X |
| $30^0$ SR | 1 | X | X |
| $50^0$ SR | 1 | 0 | 0 |
| $10^0$ SR | 0 | 0 | 0 |
| $70^0$ SR | 1 | 1 | 1 |

Each test was passed through the first row, then the middle row, then the last row, and each row from top to bottom (stage orientation refers to the direction from the camera's point of view to the outer markers) . Each test passed through the first row, then the middle row, then the last row, and each row from top to bottom ("stage" direction refers to the outward direction from the camera's point of view to the marker ).

## 7. DISCUSSION

At first glance, the test results appear mixed and contradictory, with only trial 3 producing a response for each marker with camera movement. To make the results more meaningful and to really assess test results for inconsistent systemic responses, each study should be evaluated according to the amount of potentially useful evidence (or PUE) it generated. it was done. These are defined as the camera's response within the test area, ending at the sound source position somewhere in the frame (centre or off-centre). This is intended to simulate a real-world scenario where video recordings of incidents are presented as evidence. Potentially useful evidence in such scenarios requires that the event or its direct consequences be captured somewhere in the frame, centred or not. Within these parameters, the test resulted in Table 4.

Eight possible instances of the PUE response are associated with each marker in the specified range. This PUE results table helps clarify precisely the system's competing responses. The discrepancy is not necessarily from trial to trial but rather the variation between distances. The likelihood of useful evidence is higher in trial 3 than in the other trials, but trials 1 and 2 show that he increases in PUE with increasing space. Trial 3 yielded the opposite result, with PUE decreasing with distance and remaining the same. This is a counter-intuitive result. This is because we assume that events farther away in the camera's field of view are more likely to occur.

Common discrepancies in systems can be traced to several factors. First, the microphones used may not be optimal for identification tasks. Because most gunshots are short-lived, microphones are sensitive enough to define incoming audio information accurately, so instead of one long, loud burst, they emit a series of loud bursts of short duration. , you can record quickly and continuously.

The microphone used in this test was not specifically designed for this task, but it is necessary to complete our research objectives.

**Table 4. Potentially useful evidence results from test trials**

| PUE results | 5 feet | 10 feet | 15 feet |
|---|---|---|---|
| Trial 1 | 2 of possible 8 | 1 of possible 8 | 7 of possible 8 |
| Trial 2 | 3 of possible 8 | 3 of possible 8 | 5 of possible 8 |
| Trial 3 | 8 of possible 8 | 5 of possible 8 | 5 of possible 8 |

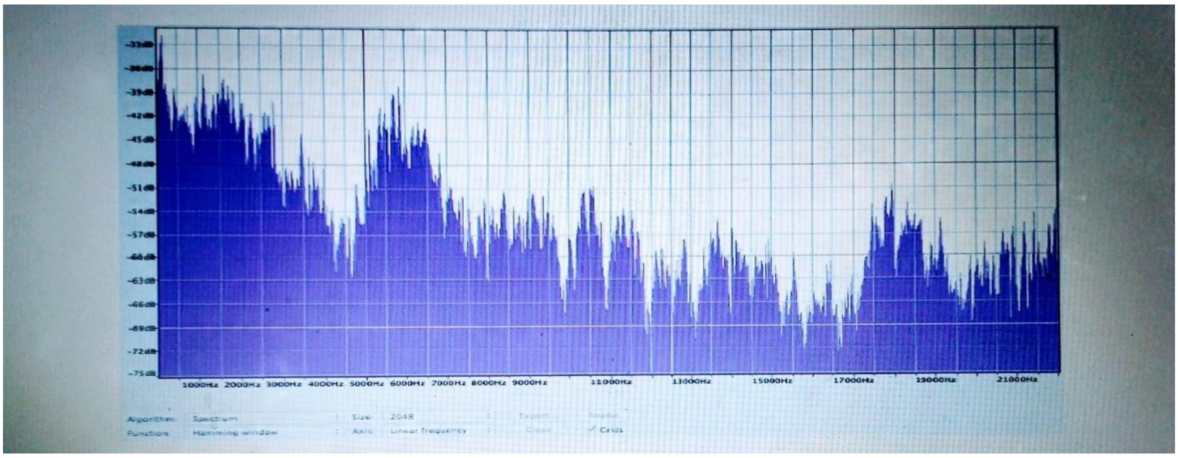


**Fig. 15. FFT of a .22 caliber rifle shot with reflection**

Second, the environment plays an important role in the effectiveness of these systems. Test locations and times were chosen to minimize uncontrolled variables, but not all are accountable, and slight changes in test conditions can lead to variability in the data. Finally, the programming language used in MatLab itself is available for review and possible updates. For sound effects, we will create sound effects with the correct threshold and conduct field research within the school. These settings determine the optimal combination that works best. If the system is designed to adapt automatically to changes in the noise floor, etc., be careful with the level of automation of the threshold. Real-time adaptive filters also help limit the amount of irrelevant and useless sound information that only slows progress.

These procedures, tests, and results help explain the essential detection and response process, but the design is fundamentally flawed. A short, large pulse causes camera movement, not necessarily a shot. This is because the sound must be filtered and analyzed at a higher level by programming to further distinguish other sounds of the same shape as the gunshot.

Unfortunately, junk tones usually peak around 630 Hz.

In Fig. 15, using the Fast Fourier Transform to transform the signal into the frequency domain, we can perform a frequency analysis of the sample trace shown earlier as the waveform in Fig. 3. The frequency range of highest intensity is from lowest to 2 kHz, with peaks below 500 Hz. An algorithmic learning strategy is the best current approach for correctly identifying other sounds. Algorithmic learning strategies are not used in this project but will be discussed later. Vendors such as ShotSpotter must provide scientists with data on product specifications and schematics for research purposes only to adequately simulate a product used in the field and attempt to replicate its functionality. This violates a vendor's right to withhold proprietary information but, most importantly, encourages unbiased review and testing in scientific, peer-reviewed forums. These steps, as noted above, help dispel doubts about the functionality of these systems and improve the overall public wealth. At the time of this test, ShotSpotter representatives and researchers chose not to answer questions regarding specific elements of the design, functionality, and test data of their respective Federal Institute of Technology offer security systems. Researchers provide online quantitative analysis of the quality of collected audio samples. As a measure of quality, consider the signal-to-noise ratio (SNR) calculated from real blasts throughout 400 ms for each muzzle blast. Researchers believe each audio sample has a defined reference noise pattern consisting of random representatives of amplitude 0.1. H.

One-tenth of the maximum signal amplitude picked up by the microphone. Six microphones were proposed in the final setup, but one was used during the experiment. The proposed plan has six microphones spaced at 60-degree intervals. The previous sound pressure corresponds to the classical background noise that can be sampled from an outdoor environment compared to a school campus area characterized by a gentle breeze. Fig. 15 shows the probability distribution function associated with the calculated SNR. The muzzle blast is + and ranges more than 20dB over the reference noise pattern, and the audio quality is very high. Finally, note that even echoes can be easily identified using the noise criteria produced by the sound output.

System testing is an important phase of implementation. System testing includes hardware devices (Cameral, Pi-Board, and Arduino UNO) and computer program debugging using MATLAB, test data acquisition and processing procedures. Experimental work is done with text data trying to stimulate all conditions that may arise during processing. Suppose structured programming was employed during coding, using an algorithmic approach. In this case, testing proceeds step-by-step from higher to lower levels of the program module being tested until the entire program is tested as a unit. The testing methods adopted during the testing of the system were unit testing and integrated testing.

## 8. CONCLUSION

Unfortunately, while Federal Polytechnic Offa school shootings are becoming a worry in Offa Community, implementing a gunshot detection solution could help prevent unnecessary casualties from the unforeseen situation on campus. The first link in the chain of events is to dispatch police and protect staff from imminent danger by warning students about Several gunshot detection systems being installed in schools and other buildings across the country; instantly detecting gunshots in mass shootings could save lives. While the shot analysis is not perfect, a car backfires or a book slammed on the ground could set off a false alarm. The idea is to use these alerts and has a human immediately review the video to detect a threat or the absence of one. As with using a central station for video verification of intruders, instead of automatically dispatching the police, integrators can work with their critical stations as facilitators to dispatch only when video assists in escalating the situation for an immediate response. Cost is always a factor when testing recordings. Dedicated systems can reduce installation and maintenance costs by up to 70% and require live monitoring from a central campus station. In addition, these systems provide real-time updates directly to law enforcement, such as the types of firearms shown on building floor plans and the location of shooters. Each facility is different and has different needs.

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## COMPETING INTERsESTS

Authors have declared that no competing interests exist.

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