Artificial Neural Network Classification for Gunshot Detection and Localization System

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Abstract:- At present, better situational awareness is undeniably paramount for a soldier in the field, whether he is dismounted or on board a vehicle. Quick determination of where the enemy fire comes from could save life in a very deadly situation. In military setting, there is a long-felt need for a system and a method to identify acoustic events such as gunshots and to locate the shooter's location as quickly as possible. We envisioned a system to detect gunshots and to locate the shooter's location. Also, friendly boots on the ground near the sensor carrier can receive enemy position data through WiFi or Bluetooth connectivity with their smart devices (e.g., smartphones). With this, soldiers will have the technology that will assist them in knowing what happened and where the shooting came from. The study employed the adaptive capability of an Artificial Neural network in the detection and localization process. Microphones were used as primary sensors. The implemented system was subdivided into two modules: the classification and localization module. Sound signal properties were used to identify or differentiate gunshot from background noise and other explosive acoustics; difference in time of arrival and signal strengths were used to locate the origin of the gunshot sound. Around thousand rounds of 5.56mm where used to qualify the performance of the system. To test the 360 degrees performance, the sensor set up was gradually rotated while the position of the shooter was incrementally increased by 10 meters starting from a distance of 50 meters up to 100 meters. A success rate of around 99 percent is guaranteed in distinguishing sound from M-16 rifle from that of background noise or fire crackers. On the other hand, test result for localization showed that the system is capable of providing more than 90 percent accuracy for the source orientation, i.e., assuming +/- 15 degrees precision. Distance accuracy of more than 90 percent was also observed during the test (assuming +/- 5m precision).

***Keywords**:- Artificial neural network, classification, localization, acoustic, gunshot detection.*

I. INTRODUCTION

At present, better situational awareness is undeniably paramount for a soldier in the field, whether he is dismounted or on board a vehicle. Quick determination of where the enemy fire comes from could save life in a very deadly situation as shown in Figure 1. In military setting, there is a long-felt need for a system and a method to identify acoustic events such as gunshots and to locate the shooter's location as quickly as possible.

Fig 1:- Situational awareness is life-saving in combat scenario.

We envisioned a system to detect gunshots and to locate the shooter's location. Also, friendly boots on the ground near the sensor carrier can receive enemy position data through WiFi or Bluetooth connectivity with their smart devices (e.g., smartphones) as shown in Figure 2. With this, soldiers will have the technology that will assist them in knowing what happened and where the shooting came from.

Having this system, it will help the military in reducing casualties during operations. Gunshot detection systems are defined as technologically advanced acoustic sensing systems capable of identifying, discriminating and reporting gunshots (Mazerolle, et.al, 2012).

They provide information for law enforcers in two regards: first, it identifies possible gunshot events based on audio information, and second, it provides the perceived location of the sound source.

II. OBJECTIVE

The study was geared to accomplish the implementation of a system capable of identifying or differentiating gunshot from background noise and other explosive acoustics and locate the origin of the gunshot sound by utilizing the capability of Artificial Neural Network.

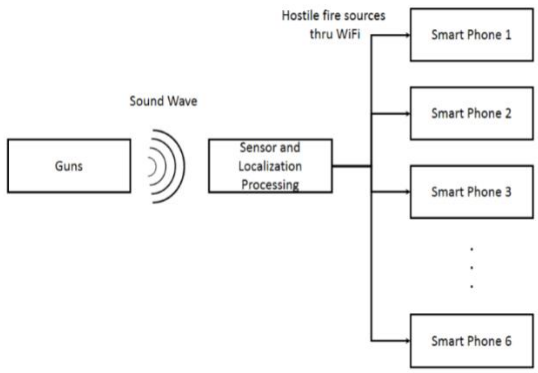

Fig 2:- Client smartphones can receive shooters position.

III. MATERIALS AND METHODS

In the system, the adaptive capability of an Artificial Neural network in the localization process was employed. The system demonstrator is shown in Figure 3.

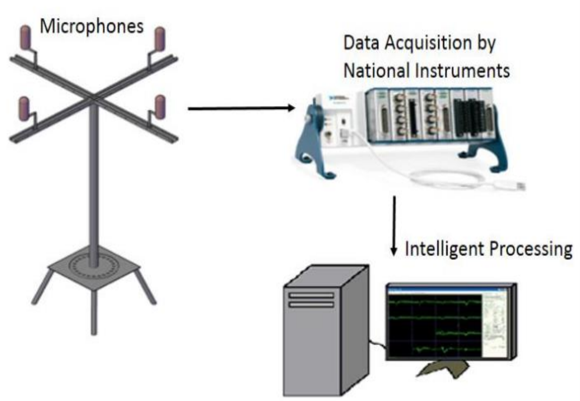

Fig 3:- Experimental set-up for recording M16 gunshot

Microphones were used as primary sensors. Sound signal properties were used to identify or differentiate gunshot from background noise and other explosive acoustics; difference in time of arrival and signal strengths were used to locate the origin of the gunshot sound. The implemented system was subdivided into two modules: the classification and localization module. Figure 4 and 5 shows the classification and localization module respectively.

In Figure 4, the recorded signals from the microphone have undergone a filtering process. A band-pass filter was used to remove unwanted frequencies in the recorded gunshot sound. The filtered signals are fed to the feature extraction function. There are two sets of feature extracted from the filtered signal: spatial and features from the frequency domain.

In extracting spatial features, a spatial coordinates to the possible occurrence of the shock wave and muzzle blast is determined, and spatial elements are collected using this coordinates. For the calculation of features in the frequency domain, a window function of finite length is place on the window on top of the signal at time zero and truncates the signal within the window. After this, the SFFT of the truncated signal is computed and the process is continually repeated by incrementally sliding the window to the right until the window reaches the end of the signal. The two sets of features are fed as inputs for training and testing the ANN classifier for gunshot classification.

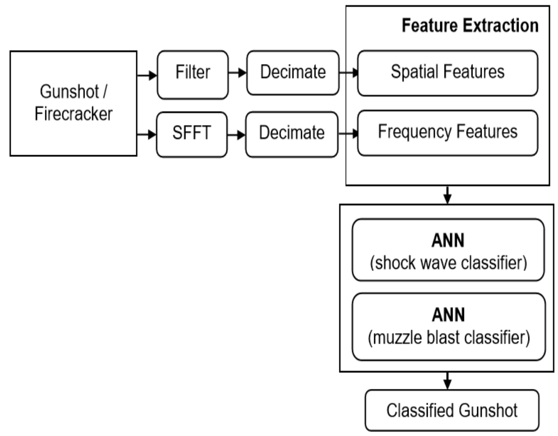

Fig 4:- The classification module.

As shown in Figure 5, the classified gunshot passed through the two filters implemented in the system. A band-pass filter was designed to remove unwanted signals. After the filtering process, the time of arrival of the muzzle blast and the shockwave of the signal is calculated.

The difference of the time of arrival between the muzzle blasts of the four microphones is used as input to the ANN localizer for the determination of angle orientation of the source while the shockwave time of arrival is used as inputs to derive the distance of the source.

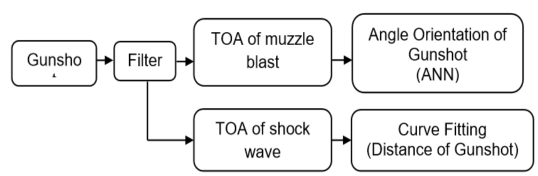

Fig 5:- The localization module.

IV. RESULT AND DISCUSSION

For testing the system, around thousand rounds of 5.56mm where used to qualify the performance of the system demonstrator. In testing the 360 degrees performance, the sensor set up was gradually rotated while the position of the shooter was incrementally increased by 10 meters starting from a distance of 50 meters up to 100 meters (see figure 6 for illustration).

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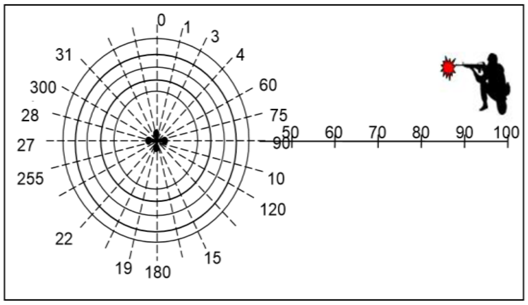

Fig 6:- Angle and distance orientation

Accuracy results of the testing turned out to be excellent. A success rate of around 99 percent is guaranteed in distinguishing sound from M-16 rifle from that of background noise or fire crackers as shown in Table 1.

Angle	Distance (meter)					
(degrees)	50	60	70	80	90	100
0	✓	✓	✓	✓	✓	✓
15	✓	✓	✓	✓	✓	✓
30	✓	✓	✓	✓	✓	✓
45	✓	✓	✓	✓	✓	✓
60	✓	✓	✓	✓	✓	✓
75	✓	✓	✓	✓	✓	✓
90	✓	✓	✓	✓	✓	✓
105	✓	✓	✓	✓	✓	✓
120	✓	✓	✓	✓	✓	✓
135	✓	✓	✓	✓	✓	✓
150	✓	✓	✓	✓	✓	✓
165	✓	✓	✓	✓	✓	✓
180	✓	✓	✓	✓	✓	✓
195	✓	✓	✓	✓	✓	✓
210	✓	✓	✓	✓	✓	✗
225	✓	✓	✓	✓	✓	✓
240	✓	✓	✓	✓	✓	✓
255	✓	✓	✓	✓	✓	✓
270	✓	✓	✓	✓	✓	✓
285	✓	✓	✓	✓	✓	✓
300	✓	✓	✓	✓	✓	✓
315	✓	✓	✓	✓	✓	✓
330	✓	✓	✓	✓	✓	✓
345	✓	✓	✓	✓	✓	✓

Table 1. Gunshot Classification Results

On the other hand, test result for localization showed that the system is capable of providing more than 90 percent accuracy for the source orientation, i.e., assuming +/- 15 degrees precision as shown in Table 2.

Angle	Efficiency (%)
0	97.42
15	69.53
30	99.74
45	97.84
60	98.31
75	98.85
90	96.47
105	92.31
120	98.53
135	99.07
150	97.21
165	97.63
180	96.13
195	99.54
210	69.93
225	99.70
240	98.07
255	99.97
270	99.27
285	99.67
300	99.99
315	99.89
330	99.02
345	99.07
360	99.97

Table 2. Gunshot Angle Orientation Results

Efficiency (%)	Distance (meter)					
	50	60	70	80	90	100
	97.5	97.2	97.0	97.3	96.8	97.5

Table 3. Gunshot Distance Orientation Results

Distance accuracy of more than 90 percent was also observed during the test as reflected in Table 3(assuming +/- 5m precision).

V. RECOMMENDATION

The following recommendations are offered.

- Miniaturize the system such that the form and weight factor can be easily integrated into a combat vehicle (e.g., APC).
- Take into account the effects of the motion of the platform where the system is to be attached, since the

testing of the system is assumed to be stationary and it should be able to work on top of a moving vehicle.

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