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Gunfire Directions Finder System (GDFS) for Law Enforcers

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Abstract
Aim: This study aimed to develop a gunfire detection device that can identify and locate the source of the gunshot in any circumstance.
Methodology: The proponent aimed to make a descriptive as well as accurate study. The study employed qualitative and quantitative approaches to collect and analyze the data. To develop the planned project known as the Gunfire Direction Finder System (GDFS) into a gadget that would be beneficial to the proponent, it is the proponent's intention to collect data from a few officers and individuals working for the AFP. The proponent's goal is to create a device that is not only useful but also simple to operate.
Results: The study conducted shows the completion of the device development and the successful calibration and testing of the functionality of the device. The output is equal to the expected output.
Conclusion: The Gunfire Direction Finder System produced some encouraging results in terms of detecting gunshots and determining the estimated direction in which they came from. The system was successful in achieving a high degree of detection accuracy while simultaneously maintaining a low percentage to capture reverberated sound that caused negative results. The direction estimation method generated accurate estimations of the direction in which the gunfire was fired, which enabled law enforcement officials to react quickly and take the proper actions. Distance estimation accuracy varied dependent on ambient conditions and sensor setups. To increase the system's capability of reliably estimating distances across a variety of ranges, further development and enhancements are required. The response speed of the system was satisfactory, allowing law enforcement personnel to get alerts and notifications at the appropriate times.

Keywords: *Arduino, Gunfire Direction, Raspberry Pi, Sound sensor*

INTRODUCTION

Law enforcement services encounter a wide variety of obstacles when it comes to preserving law and order and safeguarding the public's safety. It is essential for law enforcement to make use of technological support systems if they are going to be successful in properly addressing these difficulties. This focuses on the necessity for law enforcement agencies to use technology systems to increase the effectiveness of their operations and expand their capabilities. The use of technological systems can provide law enforcement authorities with several benefits. To begin, they facilitate the effective collection and examination of data, which in turn gives officers the vital insights necessary to make educated judgments. A technology solution that is meant to detect and localize the sound of gunfire is referred to as a gunfire detection system. It does this by employing a system of audio sensors that are strategically placed throughout an area to identify the unique auditory signature that is produced by gunfire. To precisely identify and determine the source of shooting occurrences, the system records and analyzes the audio data in real-time being captured, using Sound sensor, Raspberry pi and Arduino. The system was evaluated as acceptable using the ISO/IEC 25010:2011 standard.

In an era characterized by accelerated technological progress, law enforcement agencies are confronted with new challenges posed by increasingly sophisticated adversaries. Criminal organizations and other illicit entities

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have adapted to the digital age, utilizing technology to engage in illicit activities while evading traditional detection and capture techniques. Therefore, it has become imperative for law enforcement to incorporate technological advancements to combat these evolving threats effectively.

The intent of this study is to examine the pressing need for law enforcement agencies to enhance their capabilities by leveraging the power of technology. By doing so, they can gain a significant advantage over their opponents and can assure the safety and security of their respective jurisdictions. Technological advances have the potential to revolutionize the field of law enforcement by providing a variety of tools and strategies to combat the expanding influence of criminals and to enhance overall operational efficiency.

This study examined the evolving nature of illicit activities and the difficulties they present for traditional law enforcement methods. Ranging from ambuscade, harassment by sniping military detachment, criminal organizations have become increasingly adept at leveraging technology for illicit operations. Faced with these contemporary threats, the limitations of conventional investigative methods have become strikingly apparent, necessitating a paradigm shift in law enforcement strategies.

Moreover, this study explored the prospective advantages that technology can provide to law enforcement agencies. By adopting sophisticated tools and systems, such as artificial intelligence, machine learning, and data analytics, law enforcement agencies can enhance their capabilities in several domains. These technological advancements can expedite and improve criminal identification, enhance surveillance and monitoring capabilities, facilitate intelligence collection, and streamline overall operational processes.

In addition, the study addressed potential concerns and ethical considerations regarding the incorporation of advanced technologies in law enforcement. Examining and addressing aggression of the enemy to military detachment by gun firing. The study concluded with an exhaustive overview of successful case studies from around the globe, demonstrating how law enforcement agencies have already utilized technology to gain an advantage over their adversaries. These examples illustrated the tangible benefits and quantifiable outcomes accomplished through the strategic implementation of innovative technological solutions.

The ever-changing landscape of illicit activities necessitates a proactive approach from law enforcement. This study demonstrated that incorporating technological advancements is not only essential for law enforcement, but also advantageous. By enhancing their capabilities, they can harness the power of technology to obtain a decisive advantage over their adversaries and make society safer and more secure.

Snipers pose a significant hazard to the safety of personnel and civilians in several military and law enforcement operations. Snipers are trained marksmen who can eliminate distant targets with extreme accuracy and precision. Detecting and preventing snipers from causing damage can be difficult, particularly in urban environments where snipers can easily blend in with their surroundings.

To combat this issue, it is possible to create a Gunfire Direction Finder system (GDFS) that uses a variety of technologies, including acoustic sensors to detect and monitor snipers. The device can be designed to provide personnel on the ground with real-time alerts, allowing them to take the necessary steps to neutralize the threat.

The development of a Gunfire Direction Finder system (GDFS) device can provide the military and law enforcement agencies with numerous benefits. It can enhance personnel and civilian safety and security by detecting and preventing sniper attacks. In addition, it can provide valuable intelligence by monitoring snipers' movements and locations.

The device for the Gunfire Direction Finder system can be created using cutting-edge technologies such as machine learning, artificial intelligence, and computer vision. In addition, it can be integrated with existing military and law enforcement systems to provide an all-encompassing Gunfire Direction Finder solution.

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Overall, the development of a Gunfire Direction Finder system device can have a substantial effect on the protection and security of military and law enforcement personnel and civilians. It can provide a potent instrument for detecting and averting sniper attacks and ensuring the success of vital operations.

The Gunfire Direction Finder System (GDFS) is designed to detect and monitor snipers during military and law enforcement operations specially in detachment camps, as well as provide real-time alerts to ground personnel. The device can be designed to use acoustic sensors, to detect snipers and provide accurate location data.

Multiple sensors on the device can detect a variety of signals, such as the sound of gunfire or the thermal signature of a sniper's rifle. The sensors can be strategically arranged to provide maximum coverage over a large area. The device can also use advanced algorithms and machine learning techniques to precisely identify sniper locations by analyzing sensor data.

The device can provide personnel on the ground with real-time notifications, such as a visual display or an audible alarm, when a sniper is detected. The device can also provide information on the type of weapon, range, and direction of the sniper, allowing personnel to take the necessary steps to neutralize the threat.

The Gunfire Direction Finder system device can be designed to be portable and durable, with extended battery life. In addition, it can be integrated with existing military and law enforcement systems, including command and control systems, to provide a comprehensive Gunfire Direction Finder solution.

The advanced observer is responsible for ensuring that artillery fire is transmitted with precision and maximum effect on enemy targets. They must be able to work effectively under duress, maintain composure and concentration in high-stress situations, and adapt to changing battlefield conditions.

Objectives

This study aimed to develop a gunfire detection device that can identify and locate the source of the gunshot in any circumstance.

Specifically, it sought to:

1. design and develop a gunfire detection device system that can utilize detect sounds and calculate the data received from the sound sensor;
2. design a system that can convert analog data into digital for the best interpretation of data; and
3. test the functionality, accuracy, and acceptability of the system to provide a reading in the sound direction and approximate distance of the gunfire. .

METHODS

Research Design

The proponent aimed to make a descriptive as well as accurate study. The study employed qualitative and quantitative approaches to collect and analyze the data. To develop the planned project known as the Gunfire Direction Finder System (GDFS) into a gadget that would be beneficial to the proponent, it is the proponent's intention to collect data from a few officers and individuals working for the AFP. The proponent's goal is to create a device that is not only useful but also simple to operate.

Data and Process Modeling

To achieve the goals of the study, the process of developing the system was carried out in tandem with the utilization of a tool or model that acted as a guide. The tools and models include methods which are organized step by step for resolving requirements across each phase of the model. The prototyping Development Model was selected as the instrument to offer the needed outcome after going through a process of rigorous review and analysis beginning with the gathering of data and continuing all the way up to the development of a solution. It outlines the several processes that must be completed to produce the intended product.

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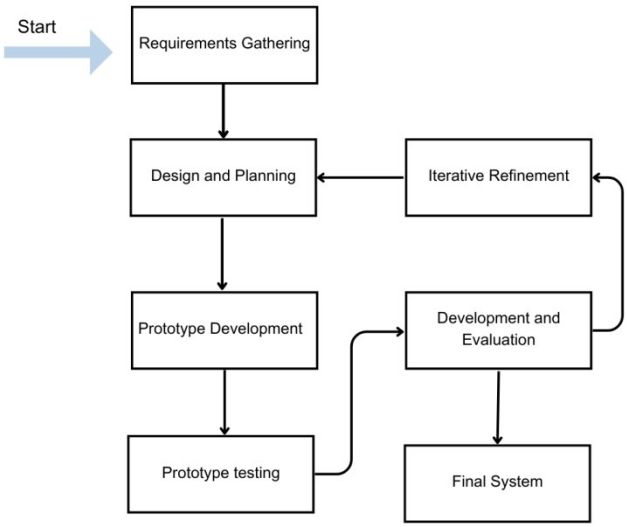

Figure 1. Prototyping Development Life Cycle

Materials

Materials such as software and hardware were considered for building the prototype of the system. They were properly selected to ensure that the requirements result would be accomplished. See Tables 1-2.

Table 1. Software in the Study

Software	Version
Raspbian Buster	Version 10
Arduino IDE	Version 1.8.19
Python	Version 3.11
MariaDB	Version 10.3
Apache	Version 2.2
PHPMyAdmin	Version 7.3

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Table 2. Hardware in the Study

Qty	Unit	Description		Unit Price	Total
1	Pc	Arduino Nano	CH340 USB	600	600.00
1	Pc	Raspberry Pi	Raspberry Pi 4 Model B Dev Board	7,595	7,595.00
1	Pc	LCD	7-inch HDMI LCD (B) for Raspberry Pi	2,748	2,748.00
1	Pc	Micro SD Card	Class 10	610	610.00
10	Pcs	LED Light	Wired 5mm LED Light	67	670.00
2	M	Foam	2 meters speaker foam	311	622.00
8	Pcs	Sound Sensor		385	3,080.00
10	Pcs	Speaker Damper	189MM x 10MM	99	990.00
6	Pc	Jumper Wires	Male to Male, Female to Female, Male to Female	60	360.00
1	Pc	Bread Board	Solderless Breadboard 400 Tie Points Circuit Bread Board Half Size	80	80.00
4	kg	PLA	PLA+ 3D Printer Filament Dimensional Accuracy +/-	800	3,200.00

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			0.03 mm 1 KG Spool 1.75 mm ESUN Matte PLA		
1	Pc	Tripod	Tripod Stand Foldable	489	489.00
1	Pc	Projector Tray	Projector Tray for the device	964	964.00
				Total	**22,008.00**

Statistical Tool

The statistical tool used in the interpretation of data is percentage. The formula to get the percentage is as follows:

$$X-dB=20\log_{10} \quad \text{(Distance)}$$

Where Distance = 10^((X-dB)/20
X = Estimated Maximum Decibel to be Read
dB = Decibel Reading

Participants in the Study

Because there is a requirement for absolute confidentiality, the sample includes a single unit for data collection. Only a certain number of army officers enlisted troops from the same company, and some developers from within the Armed Forces of the Philippines had their data collected.

Table 3. Participants in the Study

Respondents	Frequency	Percentage
Army Officers	3	7.5%
Enlisted Personnel	34	85%
AFP Developers	3	7.5%
Total	40	100%

RESULTS and DISCUSSION

The problem encountered by Law Enforcers in detachment camp is to identify the direction of gunfire for them to decide where to retaliate fire, with this the proponent came out with this system to develop, The Gunfire Direction Finder System (GDFS) was developed to reliably identify and estimate the direction of gunfire. This information is essential for law enforcement and security purposes, as it helps to pinpoint the location of potential threats. For the system to accomplish its goals, it makes use of sound sensors, several algorithms for processing signals, and various methodologies for estimating directions and can visually get the output information through '7 LCD and successive blink of directional LED lights, this Gunfire Direction Finder System (GDFS) device is acceptable by the Law Enforcers to help them in their decision making.

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Table 4. Summary of Results of Prototype Testing

Test Item	Item Name	Test Result: Passed / Failed
1	Sound Sensor Device Prototype	Successful
2	Calculation of Device Prototype	Successful
3	Main Prototype	Successful

Table 4 shows the completion of the device development and successful calibration and testing of the functionality of the device. The output is also equal to the expected output.

Accuracy in Detection. The analysis of the results includes a determination of how well the device can detect the sound of gunfire. Metrics such as true positives, false positives, true negatives, and false negatives were utilized to get an accurate picture of this. The performance of the system and any factors that may have influenced the accuracy, such as ambient conditions or noise interference, are going to be the primary topics of discussion during the stakeholder meeting.

Estimation of the Direction Accuracy: Based on the findings, an evaluation of how accurately the direction estimate algorithm determined the position or direction of the gunshot was performed. This evaluation considered a variety of elements, such as the estimation of the angle of arrival, the processing of microphone arrays, or the computation of the time difference between arrivals. During the discussion, the benefits and drawbacks of the algorithm, as well as prospective areas for improvement, were brought to everyone's attention.

Accuracy of Distance Estimation: The findings evaluated the system's ability to estimate the distance approximately between the sensors and the location where the gunshot was fired. For this evaluation, you may need to compare the estimated distance to the actual distance while under controlled environments. The precision of the distance estimation as well as any potential sources of error or ambiguity in the measurement were the primary topics of conversation.

System Response Time: The evaluation of the system's response time was included in the results. This refers to the amount of time that passes between the detection of a gunshot and the creation of an alarm or the notification of law enforcement. During this conversation, the effectiveness of the system in delivering timely information was discussed in order to provide a speedy response, as well as possible solutions to speed up the response.

Analysis of False Positives and Negatives: The results and discussions analyzed the occurrences of false positives (mistakenly recognizing non-gunshot sounds as gunshots) and false negatives (missing actual gunshots). Incorrectly identifying non-gunshot noises as gunshots is an example of a false positive. During this analysis, the various causes of these errors as well as potential ways to reduce them, such as improving the signal processing algorithms or lowering the threshold settings, were investigated.

System Limitations: The discussion highlighted any limitations or constraints of the Gunfire Direction Finder System (GDFS), such as its performance in severe weather conditions, signal attenuation over long distances, or its dependence on specific sensor configurations. For example, its performance in adverse weather circumstances. This was helpful in gaining insights into areas where additional research or development is required.

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Future Enhancements based on the results and the conversations: It may be possible to identify prospective paths leading to future enhancements. This may involve improving the accuracy of the algorithms used to detect gunfire, refining the methods used to estimate direction and distance, or introducing extra features such as Gunfire Direction Finder System (GDFS) with artificial intelligence that can identify gunfire.

Conclusion

The Gunfire Direction Finder System produced some encouraging results in terms of detecting gunshots and determining the estimated direction in which they came from. The system was successful in achieving a high degree of detection accuracy while simultaneously maintaining a low percentage to capture reverberated sound that caused negative results.

The direction estimation method generated accurate estimations of the direction in which the gunfire was fired, which enabled law enforcement officials to react quickly and take the proper actions.

Distance estimation accuracy varied dependent on ambient conditions and sensor setups. To increase the system's capability of reliably estimating distances across a variety of ranges, further development and enhancements are required.

The response speed of the system was satisfactory, allowing law enforcement personnel to get alerts and notifications at the appropriate times.

Recommendations

Improving the accuracy with which distances are estimated should be the primary focus of future research and development. This could involve adjusting the calibration process, adding more sensor data, or researching more complex distance estimate techniques.

It is recommended to execute regular recalibration and continuous monitoring of the system to guarantee that its performance remains stable over time. Degradation of sensors shifts in the surrounding environment, and algorithm drift should be monitored and remedied as soon as possible.

In further iterations, researchers might incorporate artificial intelligence to the device so that it can recognize the sound of gunshots from different types of firearms.

Implementing weatherproofing measures, such as protective enclosures or noise reduction techniques, is one way to increase the system's resistance to the effects of unfavorable weather conditions.

It is recommended that user feedback and usability studies be carried out to further enhance the user interface of the system, hence making it more instinctive and user-friendly.

It is encouraged to work together with various law enforcement agencies and security professionals to collect data from the actual world, validate the operation of the system, and get insights for the purpose of continuously improving the situation.

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