SafeDetect Product Documentation

1st Charles Andre
Ming Hsieh Department of Electrical Engineering
University of Southern California
Los Angeles, USA
candre@usc.edu

2nd Yutong Gu
Ming Hsieh Department of Electrical Engineering
University of Southern California
Los Angeles, USA
yutonggu@usc.edu

3rd Sharon Guo
Ming Hsieh Department of Electrical Engineering
University of Southern California
Los Angeles, USA
guox@usc.edu

4th Sufyan Shaikh
Ming Hsieh Department of Electrical Engineering
University of Southern California
Los Angeles, USA
sufyansh@usc.edu

***Abstract*—SafeDetect is a product developed over the course of the University of Southern California's Internet and Cloud Computing course. By utilizing an audio detector, multitech xdot, raspberry pi, AWS and a machine learning model we are able to detect gunshots and triangulate their location. This paper will go over motivation, implementation, and results.**

I. Introduction

Gun violence, specifically death from gun violence, has been steadily increasing over the past few decades. When a person is shot they must receive urgent medical treatment in order to mazimize their chances of survival. In the past pedestrians are often relied on to report cases of gun violence and only then are police and medical professionals alerted to report to the scene. This delay and reliance on human intervention can lead to delay in medical help. In the worst case a treatable wound may turn fatal.

In this paper we propose SafeDetect as an alternative that will rely on audio detection rather than human intervention. By removing the human component our system will have faster response time and will be able to avoid situations where a person is shot and no one is aware. Our product works as a network system where multiple units collaborate to both detect gunshots and use their locations to triangulate the location of the shooting.

A. Current Market

Smart gunshot detection systems are becoming increasingly common in urban cities. Large cities like Los Angeles have a policing budget of over four million and currently employees a gun detection system with a high false positive rate and a 40 second delay. Cities are willing to pay and have been paying for smart gunshot systems.

Durham, North Carolina received a proposal from a competitor to install gunshot detection technology in a three mile radius. Twenty to twenty-five sensors would be instaled per square mile. Initial annual cost was estimate to be $235,000 and then $195,000 annually thereafter. If we had submitted our product in the same proposal we would be able to place two-hundred nodes and remain significantly cheaper with an approximate initial annual setup of $50,000 and approximately $2,000 annually thereafter. This is with no return profit butwe have enough leeway to scale up our pricing for profit and still remain below our competitor

II. Target Problem

In order to implement successful and useful gunshot detection our system will focus on acheving two main goals.

1) Detecting when a gunshot has occured.
2) Tracing the location of the gunshot.

III. System Overiview

Here we will discuss the technical implementation of our product. It is a network of several individual nodes centered around a receiving Mulitech Conduit.

A. Individual Module Overview

Each node will have a unique identifier and three main physical components.

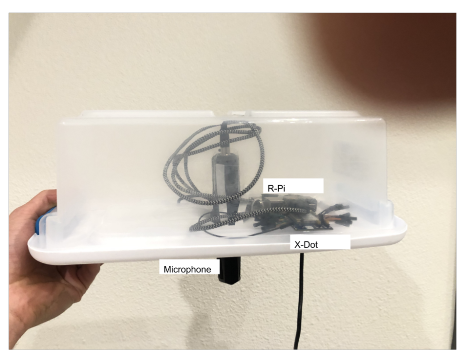

Fig. 1. Physical components assembled attached to lid of a box.

1) Microphone Audio Sensor
2) Raspberry pi
3) Multitech xDot

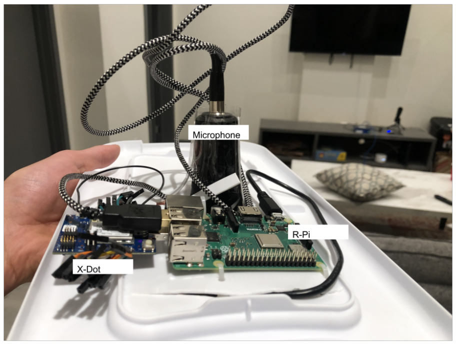

Fig. 2. Physical components assembled attached to lid of a box.

The microphone is constantly recording audio and storing it in the Raspberry pi. Once the audio reaches the raspberry pi, the pi will constantly be scanning for if audio amplitute exceeds a certain threshold. This threshold is determined from extensive trial and error. It is high enough that normal, everyday activity does not trigger it but not so high that it can not detect gunshots from afar. Once the threshold is surpassed the current audio stored in the raspberry pi will be processed and sent through our machine learning model to see if a gunshot is detected. The pi will containing storing audio in the background so that there are no audio gaps.

If a gunshot was indeed heard than that information is sent to the xDot over a USB serial port. The xDot will then send the information over to the multitech conduit over lora.

B. Network Overview

A single network consists of serveral individual nodes around a multitech conduit pre-loaded with Node-red. The conduit receives two main pieces of information from the xDots over lora radio: whether or not a gunshot was detected and the pi's local timestamp. By sending data over lora radio instead of another method like wifi we get two main benefits.

- Higher Range
  Lora signals have a range of 10 km if there is direct line of sight. We would be able to acheive that line of sight because our product will be placed high up out of the way of everyday life. In more suburban areas where less units may be required we are able to space out our nodes more while staying in range of the conduit.
- Lower Costs
  Other competing systems often utilizes wifi to send their data. This leads to a higher recurring cost.

On node-red the data is converted to a json object and then sent to the cloud. The only requirement to connect to the cloud is to create a HTTP request node with the URL being the endpoint from the AWS account

IV. AWS Cloud Overview

Our project makes use of a handful of AWS applications, primarily IoT Core, Lambda, and S3. IoT Core is an application that receives messages from IoTs and publishes those messages to an MQTT topic. Lambda is an event-driven, serverless computing platform provided by Amazon as a part of Amazon Web Services. It is a computing service that runs code in response to events and automatically manages the computing resources required by that code. S3, or Simple Storage Service, is a service offered by AWS that provides object storage through a web interface.

Data from the conduit is passed over to IoT Core. In the IoT Core all messages sent by the xDot are available in the topic in JSON format. The object contains the device's embedded unique ID (EUI), timestamp, gun-shot confidence and the volume. However, these messages are not saved by default and need to be saved into S3. To save messages into S3, we invoke a rule, that saves a given message to S3. It is possible to save the files such that the files are named [Device EUI].json. By doing this, all messages stored in the S3 Bucket are current JSON objects and this allows us to iteratively search through the bucket. Searching through all the JSON files allows us to find the three nodes that heard the gunshots first to pinpoint the location of the gunshot.

A. Multilateration

To pinpoint the location of the gunshot, we need to run a function. Lambda is perfect for this because it can be set to only activate based on a trigger. The trigger is a condition that, if met, calls the function, giving us our desired output. The trigger we set is that if a gunshot message is heard on IoT Core, activate the lambda function. Our function iteratively finds the three nodes that heard it the soonest and grabs the timestamp and EUI of the nodes. The location of the nodes is saved in a lookup table referenced by the EUI. By using the EUIs, we can find the GPS location of the nodes that heard the gunshot. The GPS location is in standard WGS84 format and is then converted to Cartesian coordinates. After converting the coordinates, we run a multilateration algorithm based on Bancroft's Algorithm [] . This algorithm makes use of differences in Times of Arrival (TOA) of a signal and locations of base stations (our nodes) to pinpoint the location of the sender of the signal. In our case, the signal is a sound wave and the velocity of a sound wave is 343 m/s. By using this, we can accurately obtain the Cartesian coordinates of where the sound originated and convert it back to GPS coordinates.

V. Time Synchronization

Initially, we were going to use the built in time stamps that go along with the LoRaWAN protocol. However, we soon realized that there could be inaccuracies on the order of seconds due to where the gunshot lies in the sliding window. If by chance, the gunshot is at the start of the window on one node and the end of a window on another node, we would detect a multiple second time difference, which is incorrect.

To fix this, we normalize the clock on the Raspberry Pi to the Master clock running on AWS. To do this, we send the Raspberry pi time almost instantaneously, and at least with equal delay at every node, to the conduit. There we calculate the time difference between that node's time and the master time. We store this conversion factor in a lookup table, which allows for easy conversion to real time whenever we receive a Raspberry Pi time stamped message. The Raspberry Pi stamps a window with the time at which the peak sound (assumed to be the gunshot) was detected.

VI. Results

A. Figures and Tables

a) Positioning Figures and Tables: Place figures and tables at the top and bottom of columns. Avoid placing them in the middle of columns. Large figures and tables may span across both columns. Figure captions should be below the figures; table heads should appear above the tables. Insert figures and tables after they are cited in the text. Use the abbreviation "Fig. 2", even at the beginning of a sentence.

TABLE I
TABLE TYPE STYLES

Table Head	**Table Column Head**		
	Table column subhead	***Subhead***	***Subhead***
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[a]Sample of a Table footnote.

Figure Labels: Use 8 point Times New Roman for Figure labels. Use words rather than symbols or abbreviations when writing Figure axis labels to avoid confusing the reader. As an example, write the quantity "Magnetization", or "Magnetization, M", not just "M". If including units in the label, present them within parentheses. Do not label axes only with units. In the example, write "Magnetization (A/m)" or "Magnetization {A[m(1)]}", not just "A/m". Do not label axes with a ratio of quantities and units. For example, write "Temperature (K)", not "Temperature/K".

Acknowledgment

We would like to acknowledge our Internet and Cloud Computiong Professor, Dr. Young Cho and our Internet and Cloud Computing Teaching Assistant Arthur Win.

References

Please number citations consecutively within brackets [1]. The sentence punctuation follows the bracket [2]. Refer simply to the reference number, as in [3]—do not use "Ref. [3]" or "reference [3]" except at the beginning of a sentence: "Reference [3] was the first . . ."

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