Proposal for Microphones Intelligent System Technology

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Abstract

When was the last time you thought about your safety? Often overlooked, Safety is an integral part of survival that most neglect because it is “unlikely” to happen. Truth be told, not everyone follows laws and some do break it. This is an evident truth that many do not truly understand until they themselves get hit with an intruder in their house or a schooler shooter. To make sure your safety is guaranteed to the highest degree, this project creates a microphone security system that is usable in a wide area and it gives you important information if there is an intruder. The system tells you when your home or facility is broken into with an outside system that triggers the inside system using a self training alarm system to derive dangerous noises to the safety of the home: glass break, shouting, screaming, etc. The outside system uses dynamic time warping to determine compare real time audio with dangerous noises for any similarity and if it catches any the system will trigger the inner system plus add it to the database. The inside system activates with at least 3 microphones in each open space, allowing for accurate detection of people's position in a given space. This will be helpful when one is hidden from a burglar, but does not know when or how to escape. Microphones systems as a new form of security are definitely the new frontier of security systems to give homeowners a stealthy way to assess the situation with all the information they need.

Introduction

In 2023, 250.7 burglaries were committed per 100,00 people. Although that number is not large given a year, depending on your area or seasons the chances can fluctuate. This means that safety is still a top priority in day life. For those trying to secure their homes or private areas to keep safe, many people usually use some form of security cameras or some detection system.(Vigderman & Turner, 2024). However, the average cost of a security camera is $100-$300 with added monthly cost of around $10-$30 and even maintenance cost for electricity (Vigderman & Turner, 2024). Unfortunately, security cameras are affected by their environment which leads to accuracy reductions of 20-35% depending on the material and density of obstacles in the way(Gu et al., 2009). Furthermore, on average blind spots cover up to 20-40% of areas in single-camera setups, particularly in homes with multiple rooms or outdoor surveillance (Gu et al., 2009). This is concerning based on the fact that blindspots may lead to potential targeting. To put light on the situation though, it is predicted based on information before 2025 that compound annual interest rate will be at 15.2% for 2025-2030 (Grand View Research, 2024). This means that there is a lot of potential to profit from improving the downsides of security cameras.

Microphones are devices that have a lot of potential as a better form of security. Compared to the average security camera defense which houses a microphone as well, it might seem questionable to just use microphones, but just using a microphone has benefits in stealth and cost. This sounds very counterintuitive because having an open camera reduces robbery by 13% (Ratcliffe, Taniguchi, & Taylor, 2009). However a reduction in robbery does not mean the security system is good. Once an intruder enters your facility, a camera can only be used after the crime, not during for any sort of safety or reassurance.

My project is a security system that uses a self training alarm system to trigger an innie microphones system to find the position of the source of noise . For context, Using microphones as a method to find the source of sound is a fairly old idea dating back to 1995. In their project, they used 16 microphones placed equidistant from each other relying on fourier transformation to figure time delay and used angles to calculate the source of sound(Michael, Brandstein, John, Adcock, and Silverman, 1995). They showed the possibility of determining the location to a high degree using a microphone array with accuracy less than 0.02 meters from the source (Michael, Brandstein, John, Adcock, and Silverman, 1995). However upon further analysis of the methods used, it is not very practical as a mass production product. Consumers need a more versatile, quick product that leverages any position of the microphones to determine location. My idea uses geometry to figure the source of the sound, meaning it would not bug if the angles are sharp, and also allows for scalability and customizability in real life environments with a delay system to detect for crimes. The inside system will have customizability with a grid(scalable in meters) determined by the user, allowing for personalized placement of 3 or more microphones in a given inside area and allow for more than one grid for each open space/room. This will allow the program to be used dynamically. For outside detection, dynamic time warping can be used to check for a list of sounds that match the current audio from the outside microphones, thereby creating an alarm system that can go hand in hand with the microphone position system(Müller, 2007; Senin, 2008). When detected the alarm audio can go back into the list, creating a self training alarm system that can activate the inside microphone system.

Approach to my novel Security System

The external microphone system requires a server-side database of alarm sounds, which can be hosted locally or through a third-party service to offload computations and deliver

seamless outputs to the user. For internal microphones, a user-friendly graphical interface is needed to configure microphone positions accurately. This interface should feature a scalable grid with adjustable units, allowing users to map real-world locations with precision. To maximize flexibility, the system should support multiple grids and configurations with more than three microphones, enabling custom setups for diverse spatial arrangements.

The outside part of the security system uses a self-training alarm system that requires microphones to go around certain areas: a house, a school, or a private area. The outside detection system can be stealthy on the lawn or the side of the house for maximum hearing capacity. After the microphone starts recording, an algorithm will look through a list of noises(glass break, footsteps, shouting, etc.) to discern whether the alarm should be triggered (Fig. 1). This is possible using dynamic time warping, which is highly used in speech recognition, allowing for accurate detection of any sound using a confidence threshold, not just words (Müller, 2007; Senin, 2008). This allows for similar audio to be detected and taken out of the recorded audio into the list of dangerous audio, allowing for a self-training alarm system.

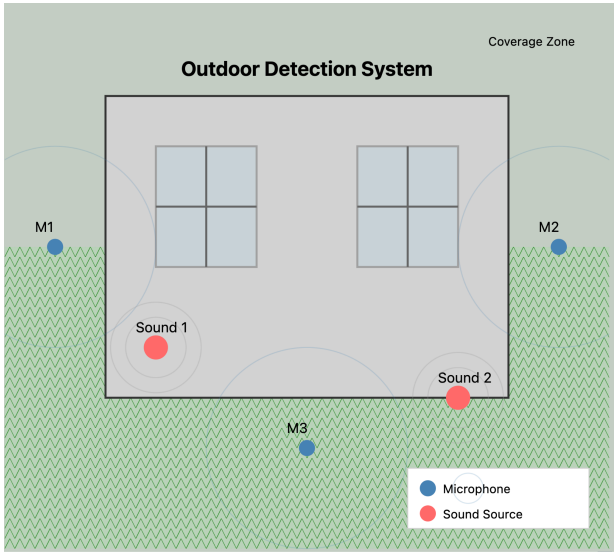

Figure 1. *Outdoor Detection System*(author generated, December 2024)

Note. This describes the layout of a home with 3 microphones and shows how a layout of the microphones could be.

The inside security system requires at least 3 microphones per room or open space(Fig. 2). This allows the accurate detection of a person who is burglarizing your home and when you are safe to escape. To do so, all microphones must be at the same height, so putting them on the ceiling would be the optimal position. Using the 3 microphones, whatever inside the triangle is formed will be detected on the grid. However, more microphones are needed to allow for a bigger range(4 for a rectangle or square).

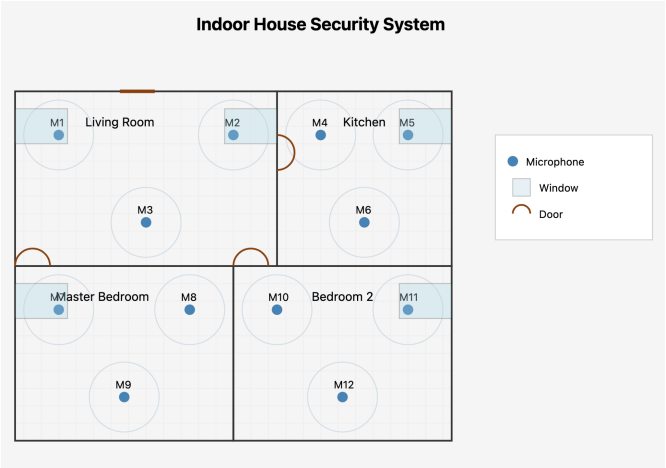

Figure 2. *indoor Detection System*(author generated, December 2024)

Note. This describes the layout of a home with 3 microphones per room

To calculate the delay of each microphone from the other, a fast Fourier transformation is needed to determine the delay for each microphone relative to each other. The Fourier transformation converts a position time graph into a magnitude frequency graph, allowing for sound to be easily analyzed/compared(Cochran, 1967). This is a common algorithm used to detect sound at a precise level, even using it to find a photon's velocity going through ultra-transparent material(Kraft & Leiperiz, 1993). After transforming the audio into a frequency graph and using Fourier transformation, we can derive the delay between the two graphs(microphones), recording the delay between microphones.

After determining the delay between microphones, we take the microphone with the lowest in comparison to the other microphone. This microphone will be one of the radii from the source of sound projects. After that we find a radius that has the delay of the microphones compared to the closest microphone, determining the point in the process. The method to do so is to find the lowest error given all the locations of the microphones and the delay based on the closest microphone(Fig 3). We also know the speed of sound is 343m/s, so we can use time to determine distance.

$p(x,\ y)\ =\ arbitrary\ point$

$i(x,\ y)\ =\ microphone\ location$

$D_{\ i}\ =\ delay\ compared\ to\ closest\ microphone$

$n\ =\ sides$

$$Error\ =\ \sum_{i\,=\,0}^{n}\left(\sqrt{(X_{\ p}-X_{\ i})^{\ 2}+(Y_{\ p}-Y_{\ i})^{\ 2}}-D_{\ i}\right)$$

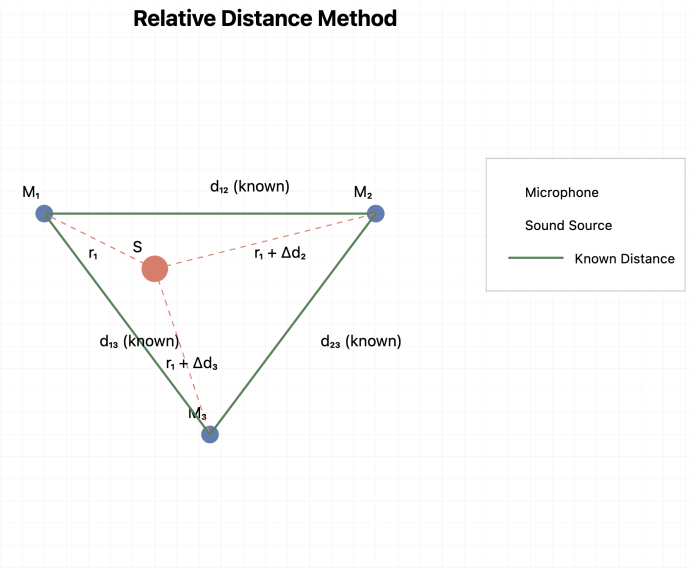

Figure 3. *Geometry Calculations System*(author generated, December 2024)

Note. This describes the calculations involved to determine the source of sound.

This project will demonstrate the feasibility of microphones in the security industry and explore a more helpful way to defend your personal space. I will engineer an application with Python to demonstrate the inside and outside of the microphone security system. Though my improvements are simple in retrospect, the potential for the safety of everyday citizens is of great importance. I look forward to getting potential guidance on the analytics and funding to bring a new security system forward.

Main Milestones

1. **All microphones working, derive a database for hosting, and audio files of dangerous noises** - When I know the microphone works, I have a database, and I have audio files for breaking glass, I will know the system is prepared.
2. **Dynamic time warping algorithm working the database** - When the algorithm worked as intended and I confirmed that it ran through every audio file in the database and checked if the current audio sounded like the audio in the database, I knew I would be ready for the next step.
3. **Gui for outside microphone system and Fourier transformation working** - When the Gui is working as intended with a scalable grid system, scalable microphone count, and a working time delay system with the Fourier transformation, I know I can proceed.
4. **Source of sound calculations and alarm system** - The end goal of the project is to have the outside microphones trigger the inside microphones and to have this all work swiftly and accurately, creating an efficient security system that keeps your safe space… SAFE.

Solution to potential risks

1. If the microphones do not pick up enough sound, I will amplify the sound of the microphones to produce better results.
2. If the Fourier transformation does not work, I can always rely on dynamic time warping to determine the delay in frequency.
3. If the source of sound is inaccurate, I will adjust the amount of microphones to improve the accuracy of the source of sound.

Future Timeline

1. 2/7/25: initiate tinkering around with locally hosting my own database for the audio files and finding a database that has glass break sounds, footsteps, etc…
2. 2/15/25: Get the microphones(5-6) & check the usability of each.
3. 2/25/25: Preparing the algorithm setup so that when the confidence level reaches a certain threshold the audio clip is sent into the database and creates an alarm to make a notification on the computer.
4. 3/5/25: Create a GUI with a scalable grid system and a method to add more microphones
5. 3/25/25: Use the Gui system to derive the delays/distances using the Fourier transformation with the speed of sound.
6. 4/10/25: Use the least square geometry equation to derive the most accurate point.
7. 4/25/25: The rest of the time before the presentation should be finding any errors with the code or usability and testing out all possibilities of microphone orientation and number usage in combination with testing for user feasibility and a flawless alarm system that works well.

I have tested out whether 3 microphones can be used to triangulate the source. Using some cheap microphones I got off a 3rd party website, I only found the direction of the source of

sound outside of the triangle, which is all I could get using dynamic time warping. I had a lot of fun creating the small project and am honored by this opportunity to create something more advanced. The guidance and funding for this project would be indispensable in creating a usable microphone security system. The microphones needed are not cheap by any standards, but their benefit through their range is not short sold. Most importantly, guidance can help me confirm whether I am going on the right path based on the results I produce in a given period. I am hopeful to explore this topic further and contribute to the field of science.

Item	Amount	Cost	Link
Bluetooth microphone speakers	7	$20	https://amzn.to/4fGt1ux

Personal Interest

Research is so fun! If I never signed up for research my sophomore year and met my teacher, Dr. Tu, I would probably be in robotics wondering whether it is worth it getting home at 9 pm just to build the same robot with similar code each year. During my sophomore year, I started pursuing action recognition models and discovered that research does not mean biology, physics, and chemistry. The field is so wide and advanced, allowing all who pursue it to enjoy their things. Every day, I feel so grateful I chose to pursue research and love that I am allowed to further the field in my special way.

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