

Auditory Localization using Trilateration in Two Dimensions

Final Project in DT Signals & Systems

A. Seaborn¹ T. Lane²

¹Department of Electrical & Computer Engineering
Bradley University

ECE 301, FA18

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Problem Statement

" Use computer microphones from at least 3 laptops to record a 'gun shot' sound from a speaker."

- Develop an algorithm to determine the location of "gun shot"
- Vary the volume of gun shot, the distance of "gun shot" to study the robustness of your algorithm
- Add different background noise to the "gun shot" data, then analyze your performance of algorithm

Problem Approach

Use a microcontroller to sample three microphone sensors and use trilateration to find the source of the sound (in this case a buzzer triggered by an interrupt).

Two approaches:

Amplitude - find a predictable relationship between distance and amplitude, then run the trilateration.

Time Diff - detect the differences between arrival times and multiply by the speed of sound to find the distance.¹

Definition

Trilateration is a localization method which uses known points and their distances to an unknown point to find it.

¹343 m/1000 ms

Data Collection - Experiment Setup

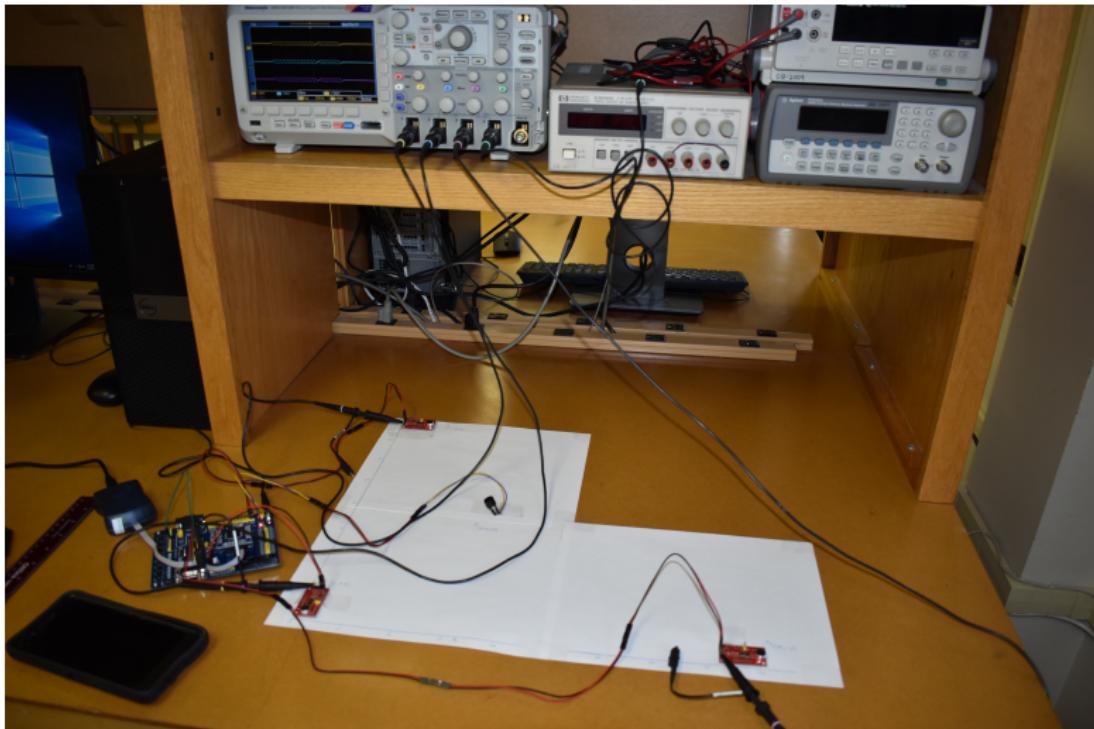


Figure: Sensor arrangement.

Data Collection - Experiment Setup

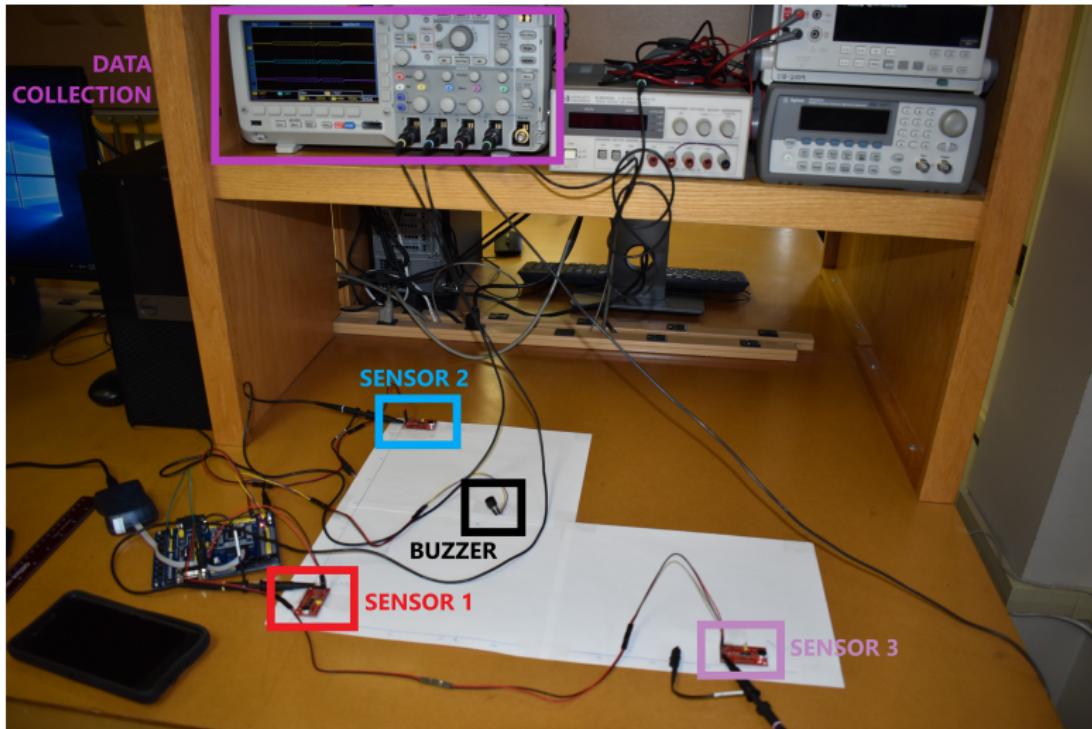


Figure: Sensor arrangement explained.

Data Collection - Experiment Setup

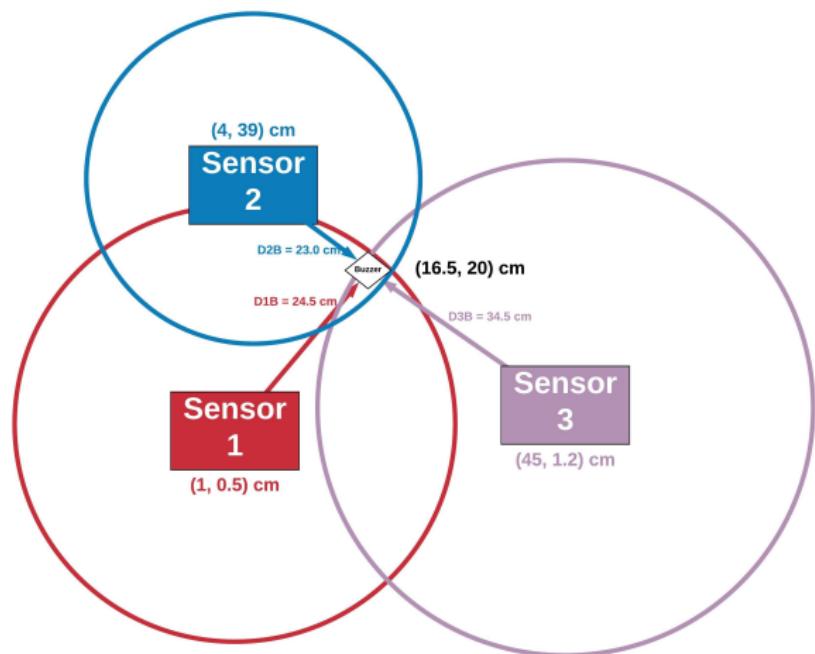


Figure: Experiment diagram.

Data Collection - Experiment Results

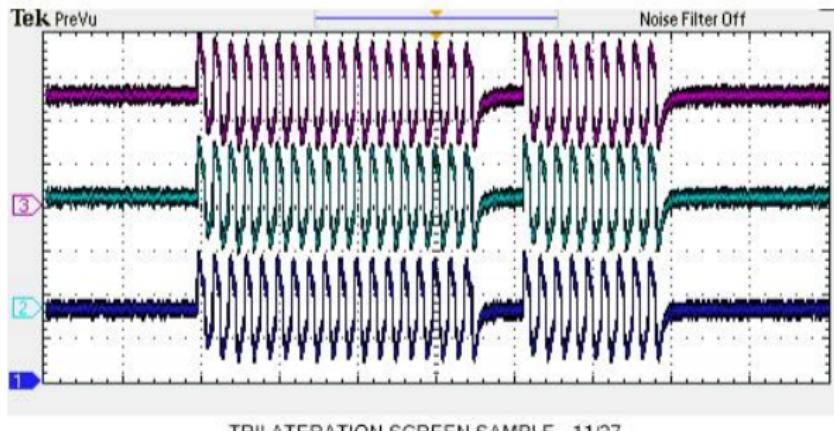


Figure: Data collection results².

²See this youtube video for a demonstration <https://youtu.be/WUPCAduKl10>

Data Collection - Experiment Results



Believe it or not, there is a delay in the arrival times of the audio samples, allowing us to apply the time difference approach.

Data Analysis - Data Preparation

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V | W | X | Y |
|----|--------------------|--------------------|-----------|------|---|--------------------|------------------|-----------|------|---|--------------------|--------------------|-----------|------|---|--------------|------------------|-----------|------|---|------------|---|---|---|---|
| 1 | Record Length | 325000 Points | -5.00E-01 | 2.52 | | Record Length | 325000 Points | -5.00E-01 | 2.6 | | Record Length | 125000 Points | -5.00E-01 | 2.42 | | Record Len | 125000 Points | -5.00E-01 | 2.5 | | Record Le | | | | |
| 2 | Sample Interval | 8.00E-06 s | -5.00E-01 | 2.76 | | Sample Interval | 8.00E-06 s | -5.00E-01 | 2.68 | | Sample Interval | 8.00E-06 s | -5.00E-01 | 2.62 | | Sample Intv | 8.00E-06 s | -5.00E-01 | 2.54 | | Sample In | | | | |
| 3 | Trigger Point | 6.25E+04 Samples | -5.00E-01 | 2.52 | | Trigger Point | 6.25E+04 Samples | -5.00E-01 | 2.68 | | Trigger Point | 6.25E+04 Samples | -5.00E-01 | 2.46 | | Trigger Poi | 6.25E+04 Samples | -5.00E-01 | 2.54 | | Trigger Pt | | | | |
| 4 | | | -5.00E-01 | 2.76 | | | | -5.00E-01 | 2.6 | | | -5.00E-01 | 2.63 | | | -5.00E-01 | 2.5 | | | | | | | | |
| 5 | | | -5.00E-01 | 2.52 | | | | -5.00E-01 | 2.6 | | | -5.00E-01 | 2.46 | | | -5.00E-01 | 2.5 | | | | | | | | |
| 6 | | | -5.00E-01 | 2.76 | | | | -5.00E-01 | 2.68 | | | -5.00E-01 | 2.62 | | | -5.00E-01 | 2.62 | | | | | | | | |
| 7 | Source | Glitch Capture CH1 | -5.00E-01 | 2.52 | | Source | Sample CH1 | -5.00E-01 | 2.6 | | Source | Glitch Capture CH2 | -5.00E-01 | 2.46 | | Source | Sample CH2 | -5.00E-01 | 2.5 | | Source | | | | |
| 8 | Vertical Units | V | -5.00E-01 | 2.68 | | Vertical Units | V | -5.00E-01 | 2.68 | | Vertical Units | V | -5.00E-01 | 2.66 | | Vertical UnV | | -5.00E-01 | 2.58 | | Vertical U | | | | |
| 9 | Vertical Scale | 2 | -5.00E-01 | 2.52 | | Vertical Scale | 2 | -5.00E-01 | 2.6 | | Vertical Scale | 1 | -5.00E-01 | 2.46 | | Vertical Sca | 1 | -5.00E-01 | 2.54 | | Vertical S | | | | |
| 10 | Vertical Offset | 0 | -5.00E-01 | 2.76 | | Vertical Offset | 0 | -5.00E-01 | 2.68 | | Vertical Offset | 0 | -5.00E-01 | 2.62 | | Vertical Off | 0 | -5.00E-01 | 2.54 | | Vertical G | | | | |
| 11 | Horizontal Units s | | -5.00E-01 | 2.44 | | Horizontal Units s | | -5.00E-01 | 2.68 | | Horizontal Units s | | -5.00E-01 | 2.46 | | Horizontal s | | -5.00E-01 | 2.54 | | Horizontal | | | | |
| 12 | Horizontal Scale | 1.00E-01 | -5.00E-01 | 2.76 | | Horizontal Scale | 1.00E-01 | -5.00E-01 | 2.6 | | Horizontal Scale | 1.00E-01 | -5.00E-01 | 2.66 | | Horizontal | 1.00E-01 | -5.00E-01 | 2.5 | | Horizontal | | | | |
| 13 | Pt Fmt | Y | -5.00E-01 | 2.52 | | Pt Fmt | Y | -5.00E-01 | 2.6 | | Pt Fmt | Y | -5.00E-01 | 2.42 | | Pt Fmt | Y | -5.00E-01 | 2.5 | | Pt Fmt | | | | |
| 14 | Yzero | -3.66 | -5.00E-01 | 2.68 | | Yzero | -3.66 | -5.00E-01 | 2.68 | | Yzero | -2.58 | -5.00E-01 | 2.62 | | Yzero | -2.58 | -5.00E-01 | 2.58 | | Yzero | | | | |
| 15 | Probe Atten | 10 | -5.00E-01 | 2.52 | | Probe Atten | 10 | -5.00E-01 | 2.6 | | Probe Atten | 10 | -5.00E-01 | 2.46 | | Probe Atten | 10 | -5.00E-01 | 2.54 | | Probe Att | | | | |
| 16 | | | -5.00E-01 | 2.76 | | | | -5.00E-01 | 2.6 | | | -5.00E-01 | 2.62 | | | -5.00E-01 | 2.5 | | | | | | | | |
| 17 | | | -5.00E-01 | 2.52 | | | | -5.00E-01 | 2.6 | | | -5.00E-01 | 2.46 | | | -5.00E-01 | 2.5 | | | | | | | | |
| 18 | | | -5.00E-01 | 2.76 | | | | -5.00E-01 | 2.6 | | | -5.00E-01 | 2.66 | | | -5.00E-01 | 2.5 | | | | | | | | |
| 19 | | | -5.00E-01 | 2.52 | | | | -5.00E-01 | 2.6 | | | -5.00E-01 | 2.46 | | | -5.00E-01 | 2.54 | | | | | | | | |
| 20 | | | -5.00E-01 | 2.76 | | | | -5.00E-01 | 2.68 | | | -5.00E-01 | 2.62 | | | -5.00E-01 | 2.58 | | | | | | | | |
| 21 | | | -5.00E-01 | 2.52 | | | | -5.00E-01 | 2.6 | | | -5.00E-01 | 2.46 | | | -5.00E-01 | 2.54 | | | | | | | | |
| 22 | | | -5.00E-01 | 2.76 | | | | -5.00E-01 | 2.6 | | | -5.00E-01 | 2.7 | | | -5.00E-01 | 2.5 | | | | | | | | |
| 23 | | | -5.00E-01 | 2.52 | | | | -5.00E-01 | 2.6 | | | -5.00E-01 | 2.46 | | | -5.00E-01 | 2.5 | | | | | | | | |
| 24 | | | -5.00E-01 | 2.76 | | | | -5.00E-01 | 2.68 | | | -5.00E-01 | 2.66 | | | -5.00E-01 | 2.58 | | | | | | | | |
| 25 | | | -5.00E-01 | 2.52 | | | | -5.00E-01 | 2.6 | | | -5.00E-01 | 2.46 | | | -5.00E-01 | 2.5 | | | | | | | | |
| 26 | | | -5.00E-01 | 2.76 | | | | -5.00E-01 | 2.68 | | | -5.00E-01 | 2.66 | | | -5.00E-01 | 2.58 | | | | | | | | |
| 27 | | | -5.00E-01 | 2.44 | | | | -5.00E-01 | 2.6 | | | -5.00E-01 | 2.42 | | | -5.00E-01 | 2.46 | | | | | | | | |
| 28 | | | -5.00E-01 | 2.68 | | | | -5.00E-01 | 2.62 | | | -5.00E-01 | 2.56 | | | -5.00E-01 | 2.46 | | | | | | | | |

Figure: Oscilloscope data export format.

Data Analysis - Data Preparation

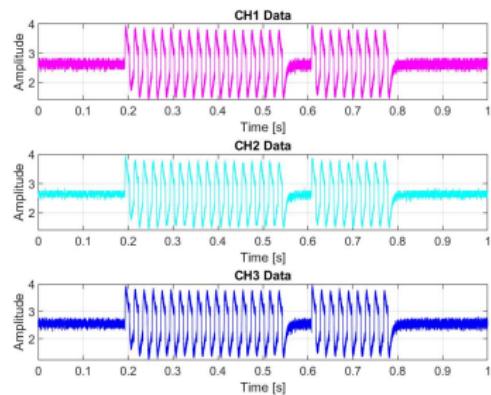
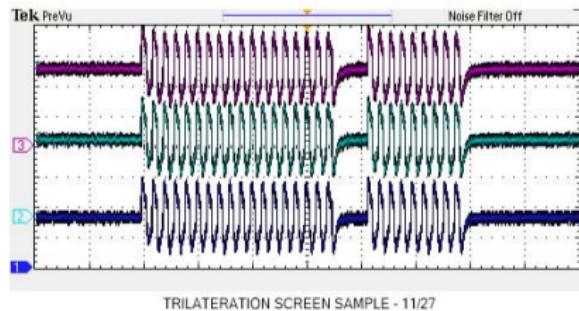
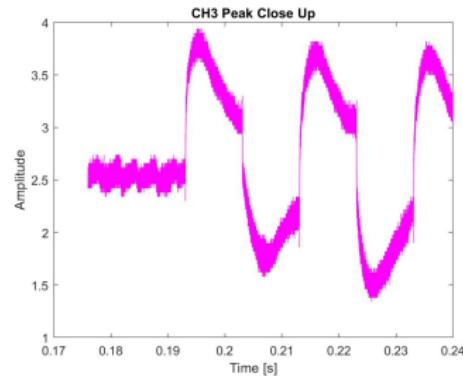


Figure: Comparison of data import.

Data Analysis - MATLAB Synthesis



We can use `findpeaks()` to locate extrema in the data.

Data Analysis - Results

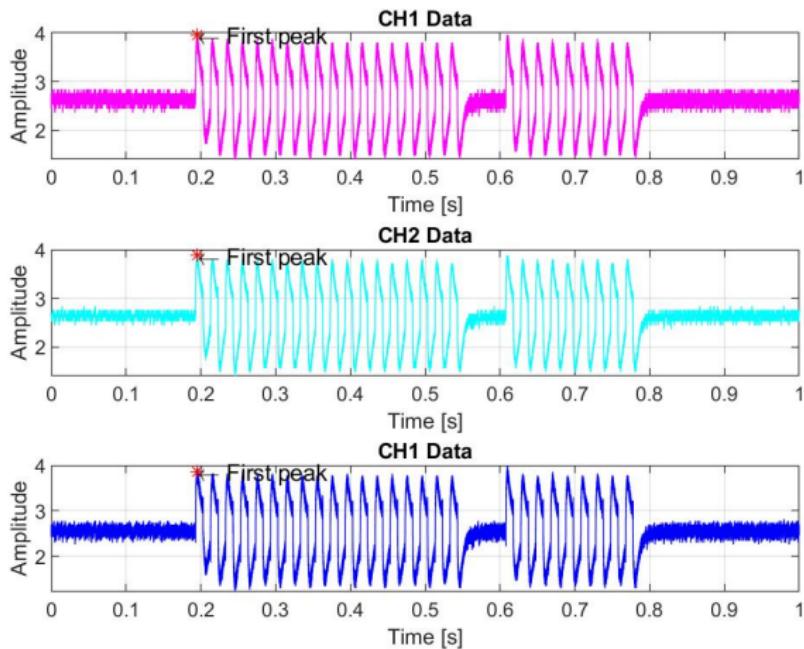


Figure: MATLAB peak search results.

Data Analysis - Results

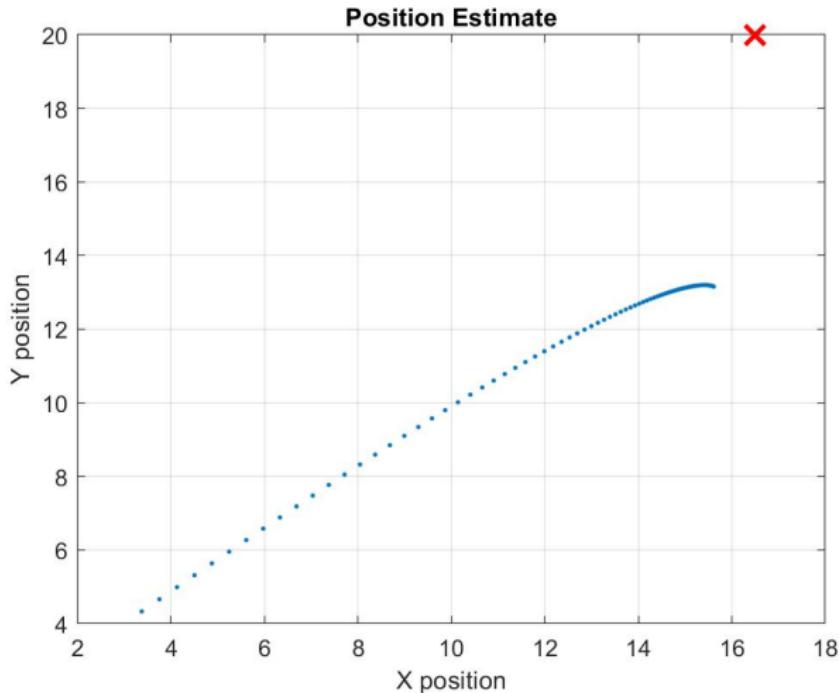


Figure: Trilateration results.

Going Further

There are several areas for further development:

- Use the envelope to utilize the amplitude approach.

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- ...

Questions

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