THE ANDREW & ERNA VITERBI FACULTY OF ELECTRICAL ENGINEERING
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Acoustic Vehicle Localization

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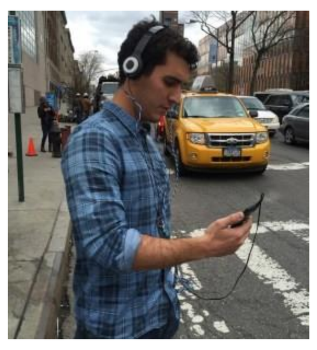
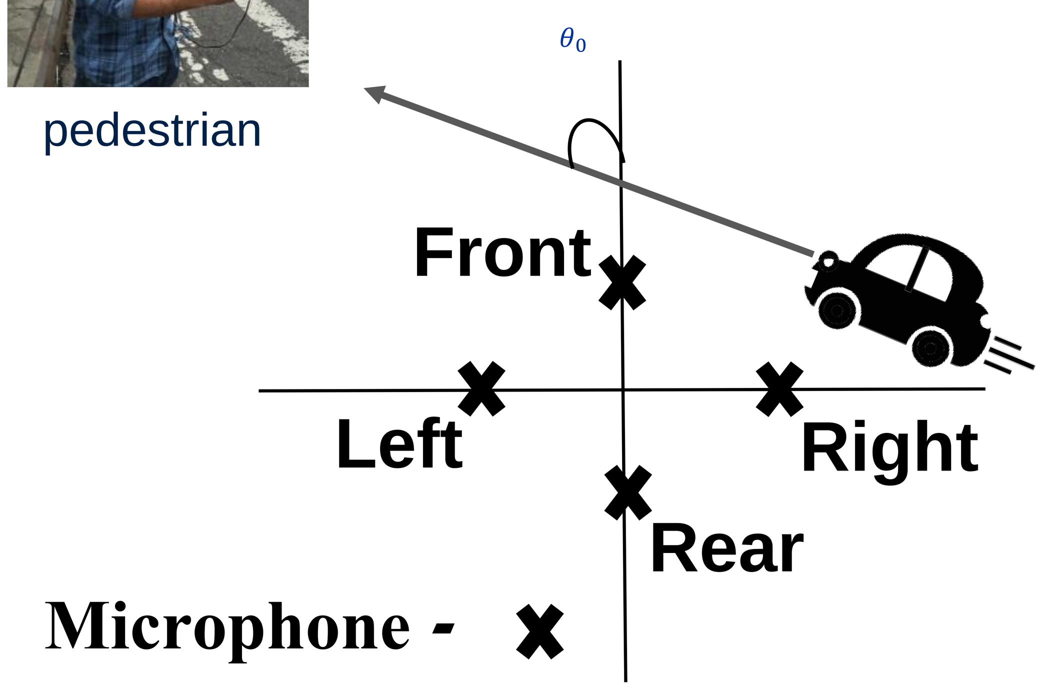
Introduction

- Nowadays pedestrians who use headphones regularly and people who suffer from hearing disability are exposed to the risk of being hit by passing traffic.



pedestrian



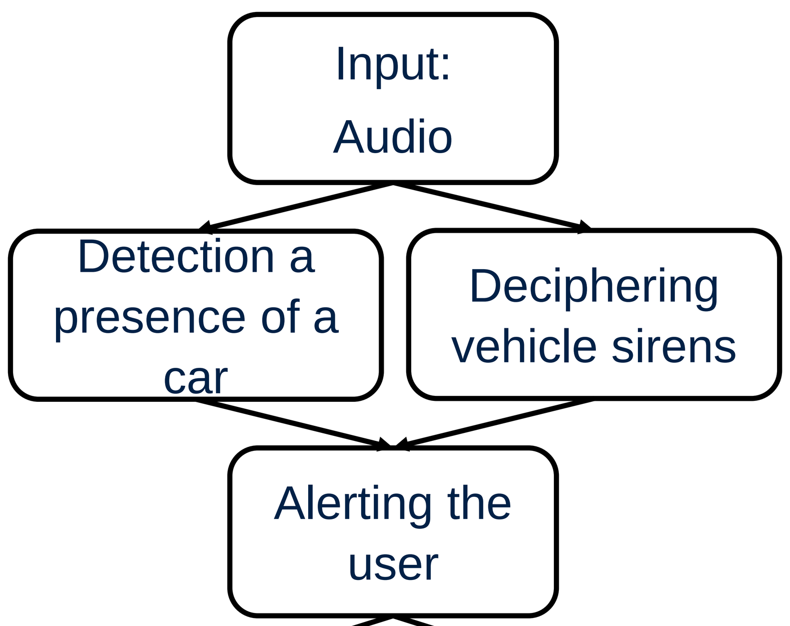
Goals

- Designing an algorithm which can alert the user when an endangering vehicle is present:
  - Determine the direction of the endangering vehicle.
  - Estimate its distance.
  - Alert the user.

Challenges

- Data base wasn't documented enough.
- Not enough variety of recorded scenarios.

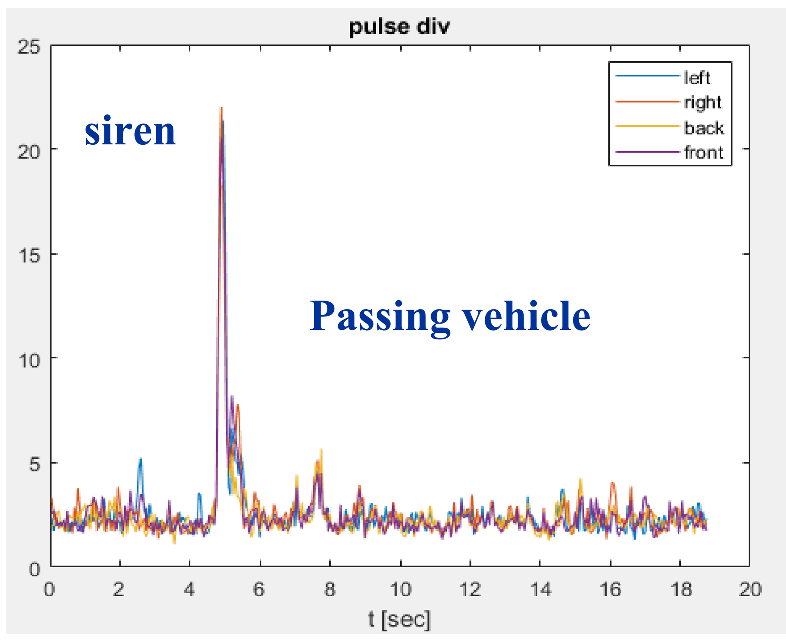
Selected Solution



- The system works with data segments:
  - Each segment is 100 mili seconds worth of samples
  - 50% overlap between consecutive segments.
  - The sample frequency used was 30 KHz.
- The sirens are detected by analyzing the spectrum energy.
- The distance of the vehicle is estimated using regression.
- The direction is calculated with Time Difference of Arrival and geometry (TDoA).

Detecting vehicle sirens

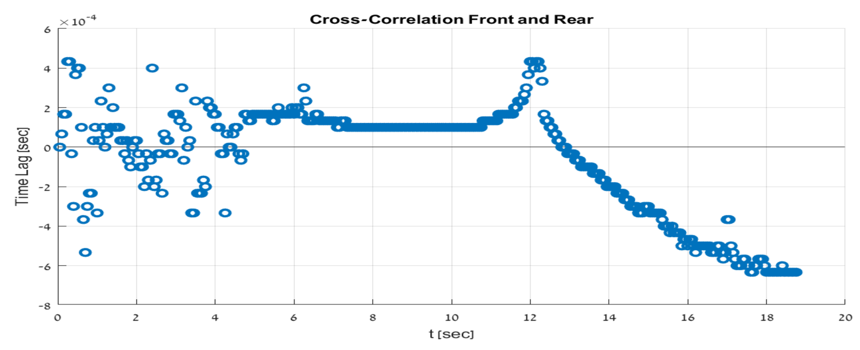
- In order to determine if a data segment contains siren, we calculated the ratio between the maximal energy along the band 340 - 600 Hz and the averaged energy along 200 - 750 Hz.
- Segments with sirens are not used for direction and distance estimation.

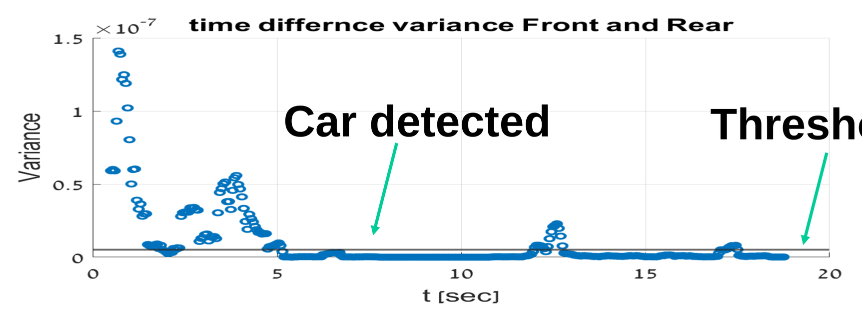


Energy ratio of a full recording

Vehicle Detection

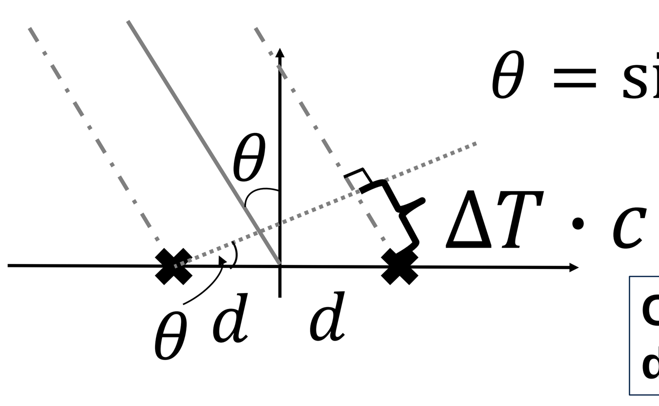
- After checking for sirens, the algorithm calculates the TDoA for the data window of the left-right channels and front-rear channels.
- If the variance of the TDoAs for the last 10 data windows is lower than a selected threshold, then the algorithm suspects a vehicle.
- If the variance stays lower than the threshold for 7 data windows, the algorithm will detect a vehicle





Direction Estimation

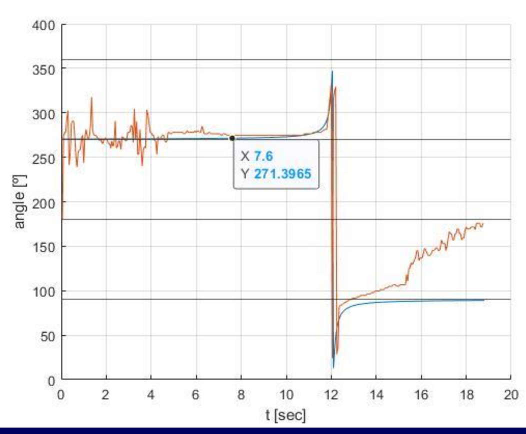
- From the TDoA the algorithm can calculate the direction of the sound source:



$$\theta = \sin^{-1}\left(\frac{\Delta T \cdot c}{2 \cdot d}\right)$$

C – sound speed
d – distance of mic

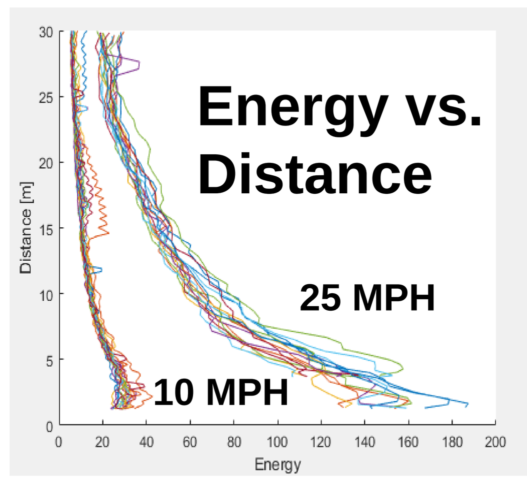
- From Cross-referencing the angle from the left-right channels and the front-rear channels the algorithm can determine the azimuth angle.

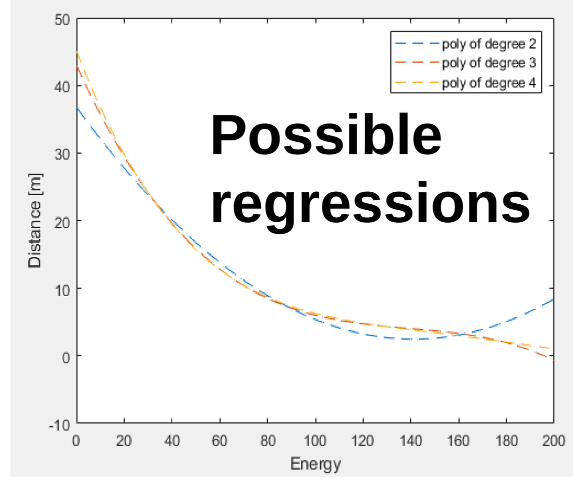


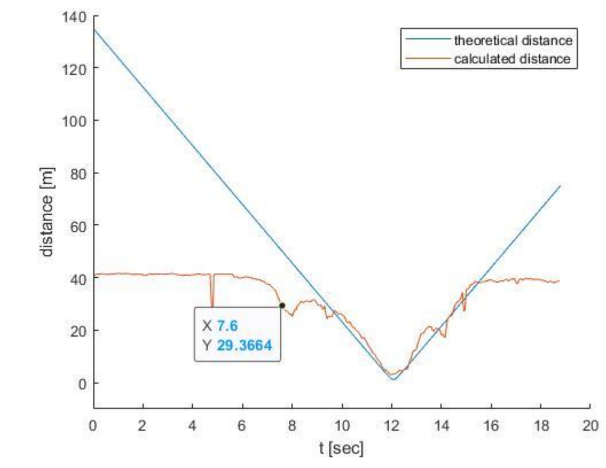
Angle: theory vs. calculation

Distance Estimation

- In order to estimate the distance of the vehicle, the algorithm makes use of the relation between the energy of the sound signal and the known distances of past samples:







Regression with Fourth degree polynomial

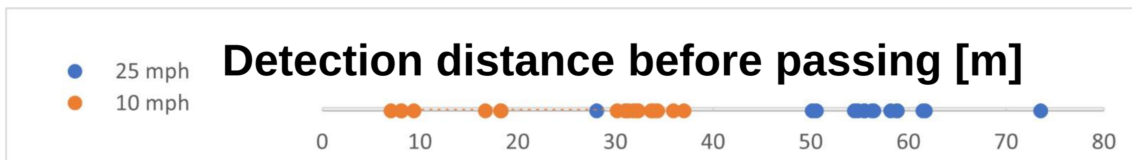
Demonstration

https://www.youtube.com/watch?v=8F5EW0iE0F0

Results

- The algorithm was tested with 34 different samples of a single vehicle passing the system.

- The algorithm provides an average detection time of 5.2 seconds before the vehicle passes the system.



- The algorithm detects the approaching car in an average estimated distance of 38 meters from the system.

Conclusions

- Distance estimation would be done better using advanced machine learning tools.
- Its easier to detect a faster moving vehicle because of the high signal noise ratio.
- Given that the human reaction time is less then a second, the algorithm provides sufficient time for the user to react to a passing vehicle.

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