Identification of dangerous domestic events through their acoustical fingerprint.

Professor: Dr. Rodrigo Sarlo

Student: Lucas Spies

Tuesday May 11th, 2021
(CEE 5440: Final project presentation)

VIRGINIA TECH™

Outline

- Problem statement
- Methodology
- Implementation and results
- Future work

Outline

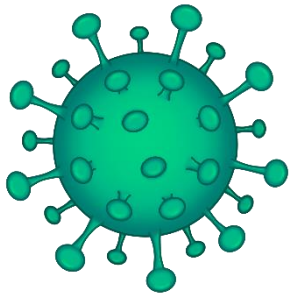
- Problem statement
- Methodology
- Implementation and results
- Future work

Problem statement: Background

- Security of the person represents a basic entitlement which is guaranteed by the Universal Declaration of Human Rights (United Nations, 1948) [1].
- Governments guarantee this right through laws and law enforcement services such as the police and emergency services.
- However, these services tend to act in a reactive way (i.e., someone calling 911, the triggering of an alarm, the activation of a panic button, etc.)
- There is multiple possible threating situations inside our living place. Still, one of the most common ones is **Domestic Violence (DV)** or **Domestic Abuse (DA)**. These situations are defined as violence or other type of abuse in a domestic setting.

Problem statement: DV during COVID-19 pandemic

- There were multiple studies in 2020 on how the pandemic affected DV cases and DV reporting [2,3]:
  - Reports in France have increased 30% since they initiated a March 17th lockdown.
  - DV calls in Argentina have increased 25% since their March 20th lockdown.
- Xue et. al. [4] shows an unconventional approach where they claim that family violence (FV) situations can be identified by providing surveillance via tweets.
- COVID-19 pandemic has **highlighted the flaws of a reporting system**, which is not capable of ensuring that people who experience abuse can continue to obtain access to support.



Problem to tackle in this project

Problem statement: Possible solution or mitigation approach

- Microphones are being integrated to our living places in an increasing way:
  - Amazon Echo
  - Google Home
  - Apple HomePod
  - Microsoft Invoke

- Can we take advantage of the microphones in electronic devices already present inside a house?
- Could these microphones provide the means to **passively sense and detect** any potential DV situation?

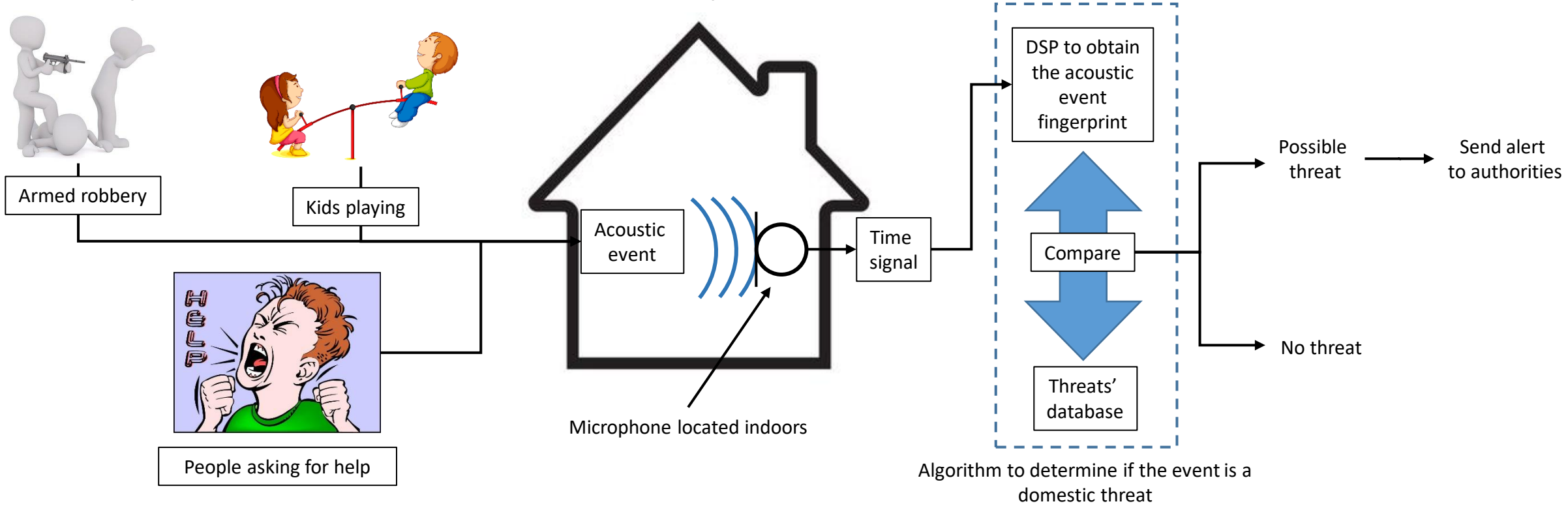
Objective of the project

Outline

- Problem statement
- Methodology
- Implementation and results
- Future work

Methodology: Proposed approach

- Indoor acoustic event recording, signal processing and classification (i.e., is there is a threat or not):



Methodology: DSP strategies considered

- Let's consider a reference signal x[n] and a recorded signal y[n]
  - **Time domain comparison**: Run a correlation analysis between x[n] and y[n].

$$R_{xy}[m] = \sum_{n=-\infty}^{\infty} x[n]y[n-m]$$

  - **Frequency domain "correlation":** Compare reference and recorded signal PSDs frequency line by frequency line.

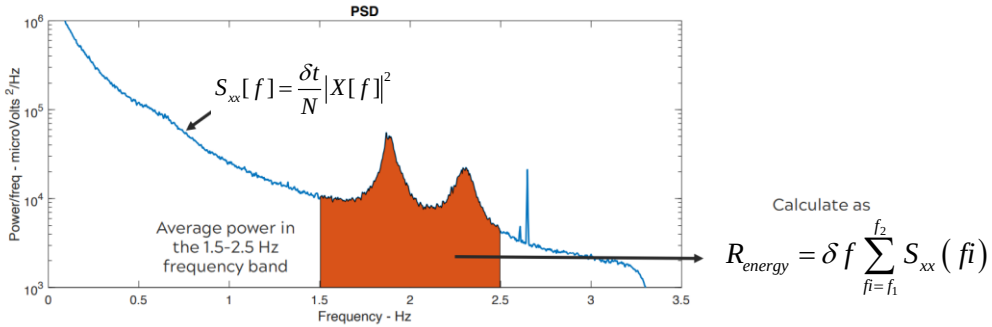
$$S_{xx}[f] = \frac{\delta t}{N}|X[f]|^2 \quad \Longleftrightarrow \quad S_{yy}[f] = \frac{\delta t}{N}|Y[f]|^2$$

  - **Spectral energy event detection (SEED)**: Compare reference and recorded signal spectral energy content within specific frequency ranges.

$$R_{energy} = \delta f \sum_{fi=f_1}^{f_2} S_{xx}(fi) \quad \Longleftrightarrow \quad C_{energy} = \delta f \sum_{fi=f_1}^{f_2} S_{yy}(fi)$$

Methodology: Spectral energy event detection (SEED)

- Spectral energy computation
  - Reference event energy: $R_{energy} = \delta f \sum_{fi=f_1}^{f_2} S_{xx}(fi)$
  - Current event energy: $C_{energy} = \delta f \sum_{fi=f_1}^{f_2} S_{yy}(fi)$



CEE 5440: Lecture Slide 6.1 Power Spectral Density. Sarlo (2021)

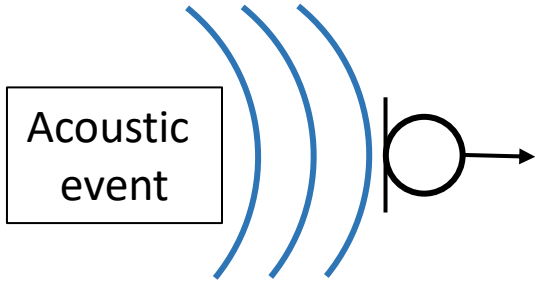
- Pros:
  - Time-independent
  - Energy calculation and comparison are computationally inexpensive
- Cons:
  - It is assumed that S_{xx} (PSD for the reference event) is unique
  - The method could result in false positives

Outline

- Problem statement
- Methodology
- Implementation and results
- Future work

Implementation: Proposed setup

- Raspberry Pi and ReSpeaker 2-Mics Pi HAT board



Example events obtained online

ReSpeaker 2-Mics Pi HAT

Raspberry Pi 3 Model B

Call 911

Call/text a relative

Ask for a safe word/phrase

Different in-house acoustic events

Data acquisition (acoustic pressure)

Signal processing (database comparison)

Action for possible dangerous domestic event

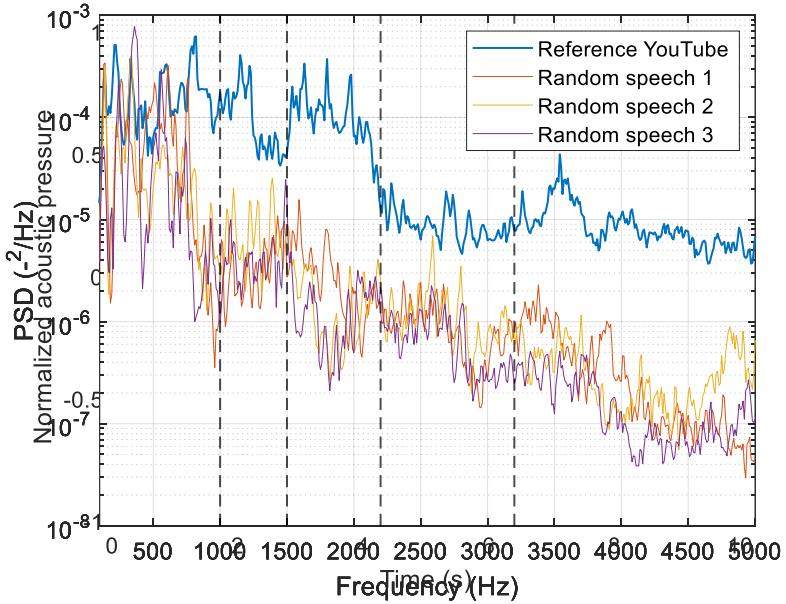
Initial scope for the project

Implementation: Case of study

- Reference event: Someone screaming for help.
  1. Recorded multiple audio signals of people asking for help using YouTube recordings
  2. Computed the reference PSD from these recordings
     1. Welch's method for PSD computation: sampling frequency of 44.1 kHz, Hanning window, 50 % overlap between windows, 4410 points for FFT computation (freq. resolution of 10 Hz)
  3. Computed PSD for other random speech signals
     1. Specified the frequency range for energy computation (i.e., 1.0 to 1.5 kHz and 2.2 to 3.2 kHz)

$$R_{energy} = \delta f \sum_{fi=f_1}^{f_2} S_{xx}(fi) \qquad C_{energy} = \delta f \sum_{fi=f_1}^{f_2} S_{yy}(fi)$$

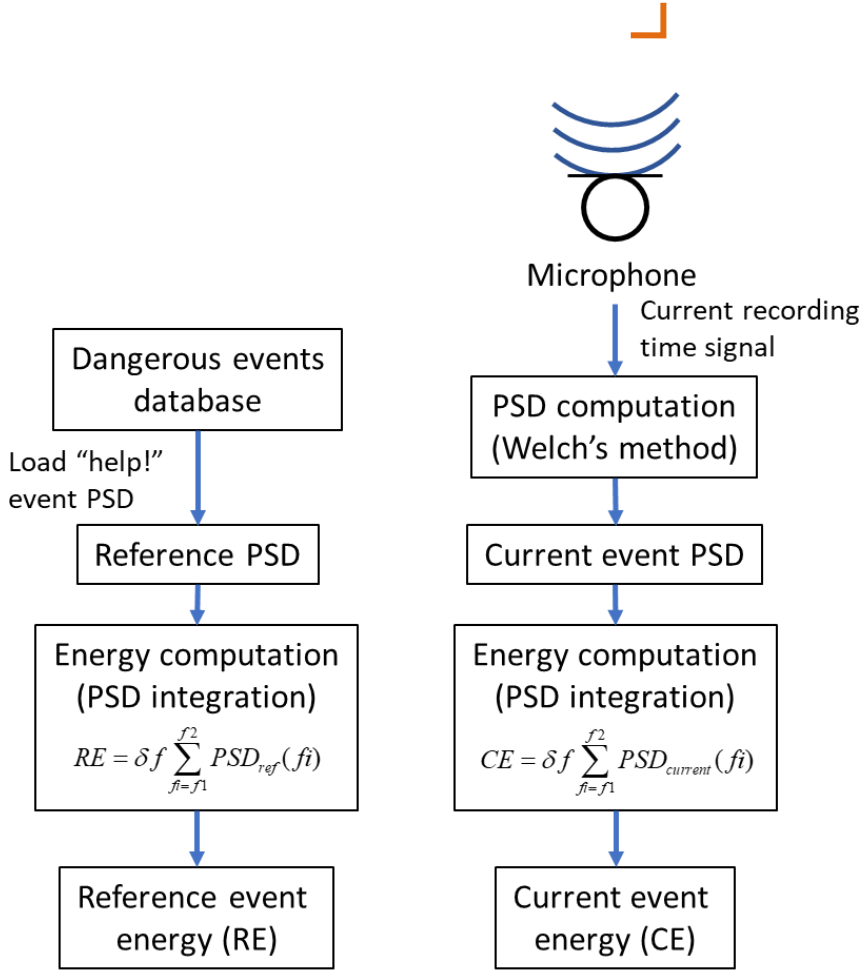
ProSoundEffects



Implementation: SEED steps

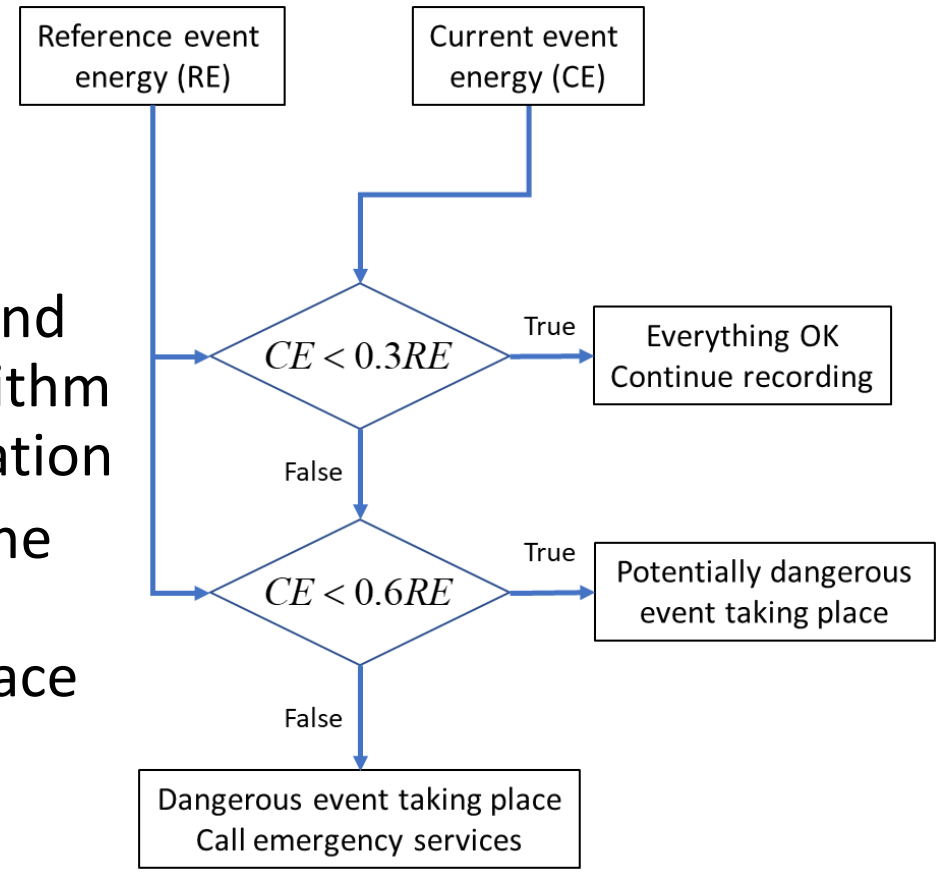
- Data acquisition and signal processing
  1. Reference energy computation
     1. Load reference event PSD
     2. Compute reference event spectral energy
  2. Current energy computation
     1. Record current audio signal
     2. Compute event PSD
     3. Compute current event spectral energy

Main outputs: Reference event and current event energy within the frequency ranges specified



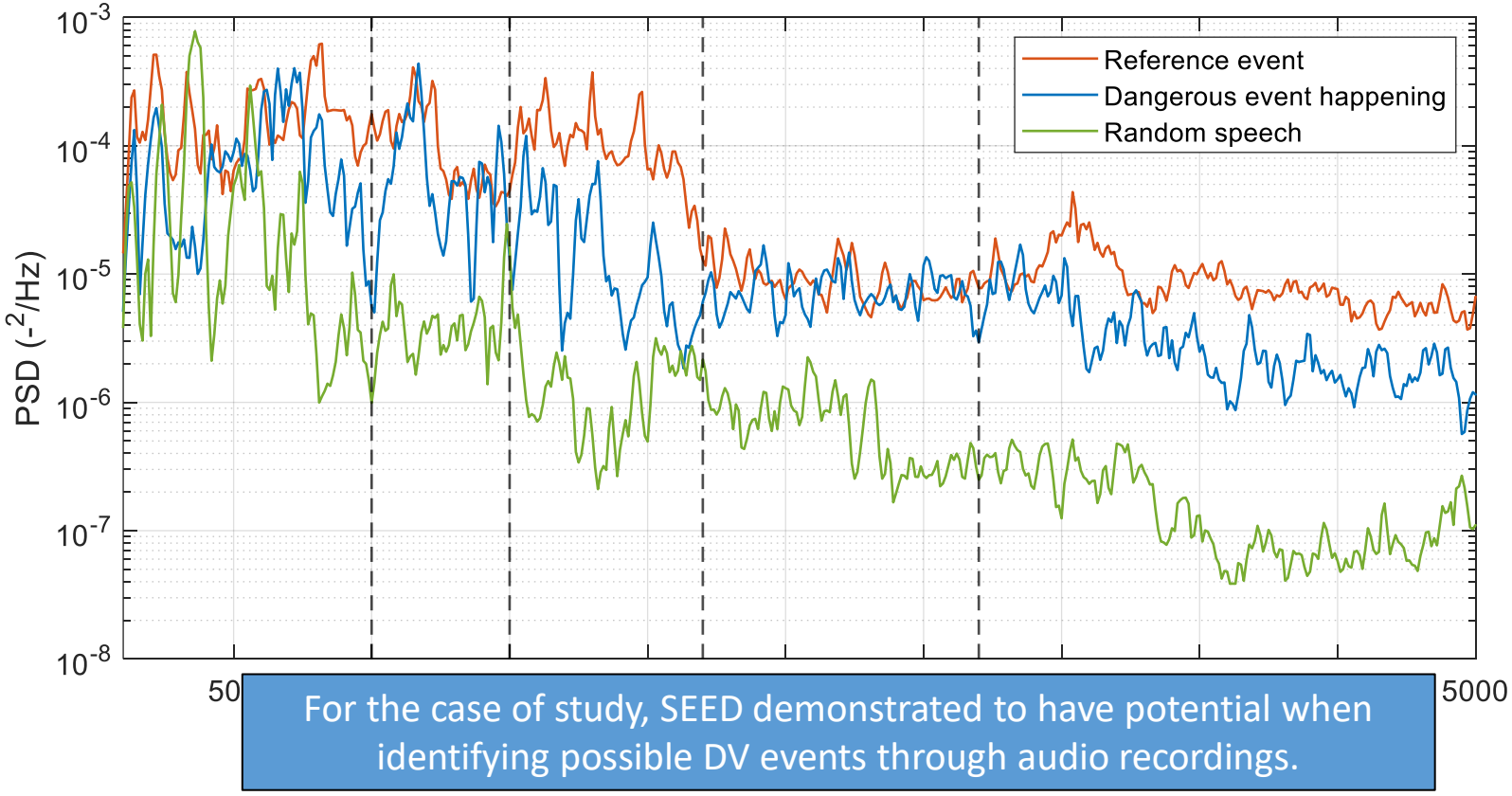
Implementation: SEED steps

- Spectral energy comparison and decision
  1. If the current energy is below 30% of the reference event energy then the board will continue recording
  2. If the current event energy is between 30% and 60% of the reference event energy, the algorithm will consider this as a potentially violent situation
  3. If the current event energy is above 60% of the reference event energy, then the algorithm considers this as a dangerous event taking place



Results: Preliminary PSDs

- PSD for: reference event, dangerous event and random speech



For the case of study, SEED demonstrated to have potential when identifying possible DV events through audio recordings.

Implementation: Raspberry Pi demonstration

(Check the time – Raspberry Pi – demonstration)

Outline

- Problem statement
- Methodology
- Implementation and results
- Future work

Future work

- Study how SEED performs for other DV or DA events (increase the number of events in the database).
- Increase the number of events used to compute the reference PSD.
- Determine better frequency ranges for energy computation. This can be done through the study of false positive cases (events with similar acoustic fingerprint).
- Compare SEED with off-the-shelf speech recognition libraries.
- Increase capability of SEED by adding a word recognition algorithm (change in mean test by squaring the acoustic signal).

References

- [1] Wikipedia Contributors. Security of person, Feb 2021.
- [2] McKenney M. Elkbuli A. Boserup, B. Alarming trends in US domestic violence during the covid-19 pandemic. The American journal of emergency medicine, 38(12):2753–2755, 2020. PMID: 32937063.
- [3] Megan L. Evans, Margo Lindauer, and Maureen E. Farrell. A pandemic within a pandemic — intimate partner violence during covid-19. New England Journal of Medicine, 383(24):2302–2304, 2020. PMID:32937063.
- [4] Jia Xue, Junxiang Chen, Chen Chen, Ran Hu, and Tingshao Zhu. The hidden pandemic of familyviolence during covid-19: Unsupervised learning of tweets.J Med Internet Res, 22(11):e24361, Nov2020

Questions? Comments? Suggestions?