Objective

- Reduce the increasing number of accidents involving distracted pedestrians in urban areas
- Use modern techniques to develop a low-power low-cost wearable solution to detect and localize oncoming cars

System

- Microphones – 4 MEMS microphones are sampled synchronously
- Front-end hardware – Extracts spatiotemporal features from mics and transmits to smartphone app.
  - V1: MCU computes relative delay, zero-crossing rate, relative power
  - V2: custom ASIC replaces MCU to reduce power consumption
- Smartphone – Samples from a fifth microphone and uses data from the front-end hardware to detect and localize:
  - V1: runs machine learning algorithms to detect and localize
  - V2: runs machine learning algorithms for detection and runs our novel Angle via Polygonal Regression method to localize

PAWS: An Intelligent and Wearable System for Pedestrian Safety

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PAWS Headset + App

- Custom front-end hardware extracts, computes and transmits features to app
- App alerts users to the presence and location of oncoming cars

PAWS block diagram

- MIC1, MIC2, MIC3, MIC5
- Car Detection
- Smartphone
- Bluetooth LE

PAWS app data flowchart

- MIC1, MIC2, MIC3, MIC5
- Front-end hardware
- Smartphone

Car Detection

- Non-Uniform Binned Integral Periodogram
- MFCC, a common feature for sound classification, is unable to separate noise-like car tire sounds from environmental noise
- Non-Uniform Binned Integral Periodogram (NBIP):
  - Better separates car tire sounds from environment
  - Bins low frequencies into finer bins and high frequencies into coarser bins
- Random Forest classifier used to classify NBIP features as car or non-car sounds

Car Localization

- Direction Estimation: Angle via Polygonal Regression (AvPR)
- Classical direction estimation via TDOA has high error if position of mics are not stable
- ML classification requires more training classes/examples the finer the granularity
- Angle via Polygonal Regression (AvPR): perform direction regression over the polygon shape formed from relative delay features observed at different directions

Custom ASIC

- Custom application-specific integrated circuit replaces MCU for ultra-low power relative delay extraction from headset mics

Results

- ~20 hours of operation CR2032 using coin cell batteries
- Close to 100% detection rate and < 10 deg avg direction error

Acknowledgements

This work was partially supported by the National Science Foundation under Grant Numbers CNS-1704989 and CNS-1815274.