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The Fu Foundation School of Engineering and Applied Science

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

PAWS: An Intelligent and Wearable System for Pedestrian Safety

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Objective

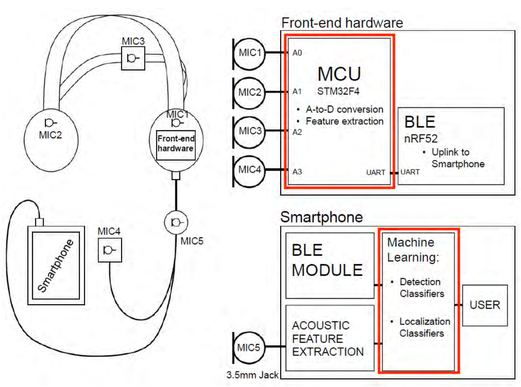
System

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

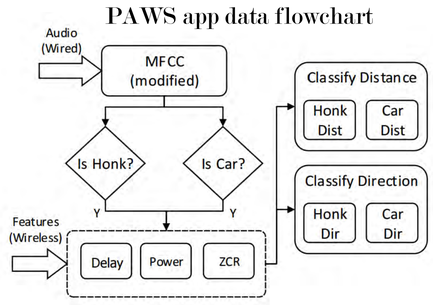
PAWS block diagram



Smartphone –Samples from a fifth microphone and uses data from the front-end hardware to detect and localize:

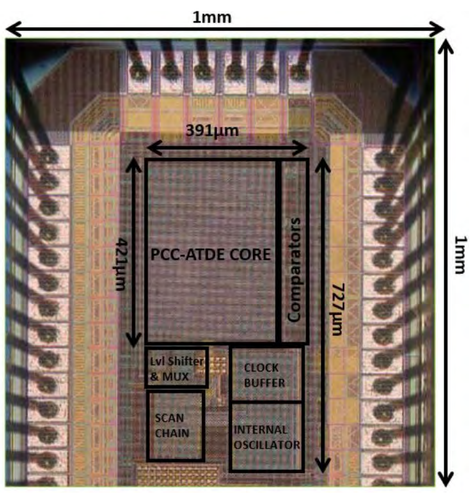
- V1: runs machine learning algorithms to detect and localize
- V2: runs machine learning algorithms for detection and runs our novel Angle via Polygonal Regression method to localize

PAWS app data flowchart



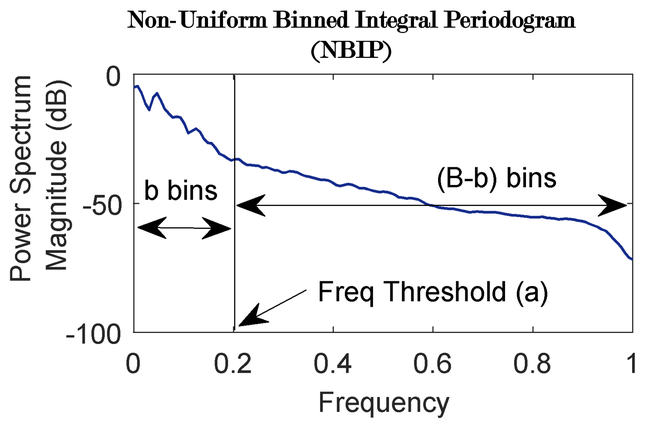
Custom ASIC

PERFORMANCE SUMARY	
Technology	180nm CMOS
Sampling Frequency	50KS/s
Range	[-2.52ms,2.52ms]
T_{LSB}	20µs
Peak INL	-1.57/1.33 LSB
Peak DNL	-0.85/0.97 LSB
TDE ENOB	6.06bits
Number of TDE Channels	3
Comparator Power (Unit)	3.1nW
PCC-ATDE Core Power	65.9nW
Total Power	78.2nW
TDE Energy per Conversion Step per Channel	7.84fJ/Conv.-Step
Active Area	0.28mm²
Die Area	1mm²



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

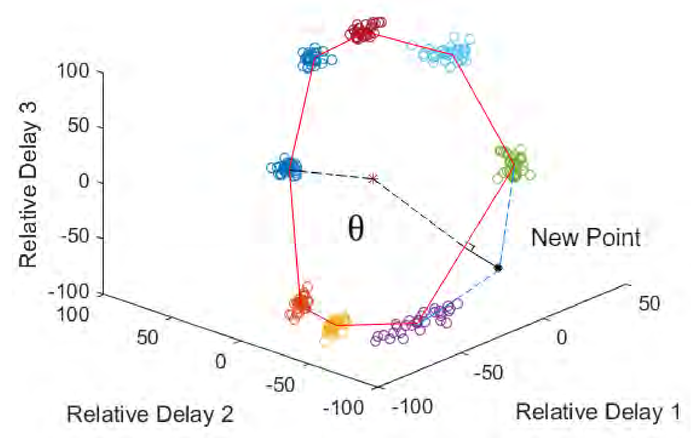
Car Detection



- 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

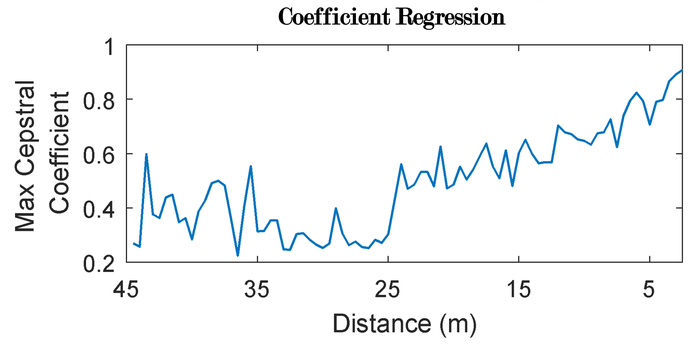
Car Localization

Direction Estimation: Angle via Polygonal Regression (AvPR)



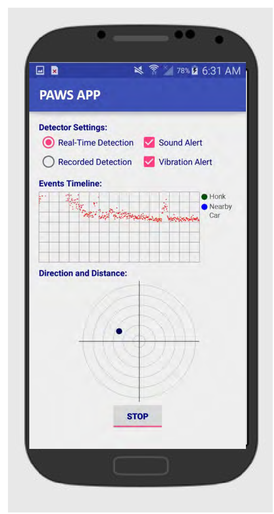
- Classical direction estimation via TDOA has high error if position of mics are not stable
- ML classification requires more training classes/examples the finer the granularity
- Angle via Polygonal Regression (AvPR): perform direction regression over the polygon shape formed from relative delay features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

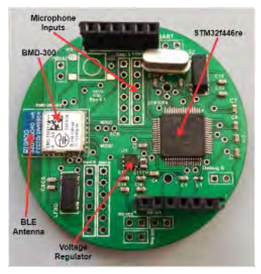
Distance Estimation: Maximal Cepstral Coefficient Regression



- Fine-grained distance estimation by performing regression over the maximal cepstral coefficients
- Beyond ~30m the coefficients show no noticeable pattern, resulting in two coarse distance classes (< 30m, > 30m)

PAWS Headset + App

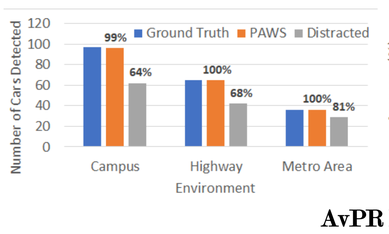


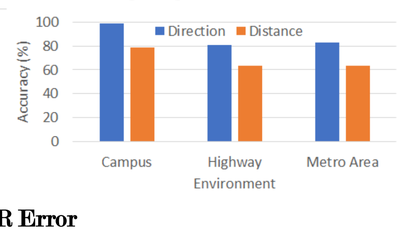


- Custom front-end hardware extracts, computes and transmits features to app
- App alerts users to the presence and location of oncoming cars

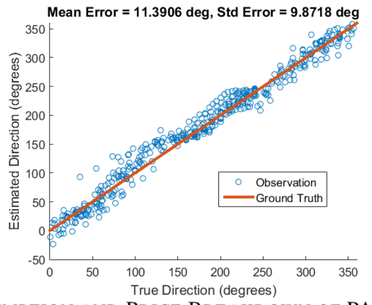
Results

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





AvPR Error



POWER CONSUMPTION AND PRICE BREAKDOWN OF PAWS AND PAWS LOW-ENERGY (**PAWS LOW-ENERGY TOTAL IN BOLD**)

	Idle [mA]	Active [mA]	Unit Price [U$]
MCU (STM32f4)/ASIC	4.37/∼0	50/∼0	3.20
BLE Transciever (nRF52)	0.46	7	6.40
MEMS Mics × 4	0.48 × 4	0.48 × 4	0.40 × 4
Amplifiers × 4	2.34 × 4	2.34 × 4	1.60 × 4
Regulators	0.1/0.6	0.1/0.6	0.50/3.00
Total	16.21/**11.84**	68.4/**18.9**	18.10/**20.60**

Acknowledgements

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