Authors
Lewis Girod
Andreas Ali
Mani Srivastava
et al.

Center for Embedded Networked Sensing

Cooperative Acoustic Vehicle Localization

Lewis Girod, Andreas Ali, Kung Yao, Mani Srivastava
CENS - http://research.cens.ucla.edu/

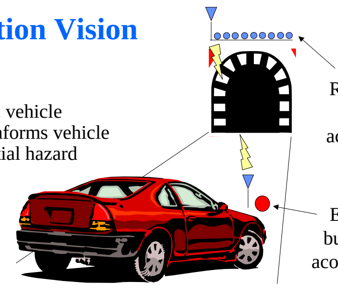
Introduction: Improving vehicle safety by position tracking in GPS-denied area.

Project Goal

- **Assess use of audible acoustic ranging for vehicle safety applications in GPS-denied areas**
- **Develop a testing platform to enable experimentation**
- **Perform some initial experiments to test signaling waveforms**

Application Vision

- **Cooperative system**
  System coordinates acoustic vehicle tracking via RF signaling, informs vehicle of position relative to potential hazard



Problem Description: Develop a system to acoustically track vehicle location and speed

Receiver Setup

- **Linear array of 14 microphones**
- **Sampled at 48KHz**
- **Suspended over the roadway**
- **Wirelessly synchronized to vehicle**

Emitter Setup

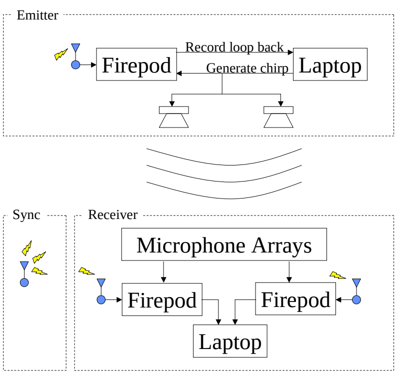
- **Two emitters: one on each side of the front bumper**

- **Driven from laptop inside the vehicle**
- **Connection to OBD-II port to record reported vehicle speed**

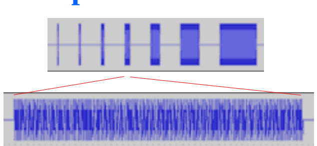
- **Connection to 433 MHz radio logs synchronization and break beam events**

Proposed Solution: Localization based on time of arrival using pseudo-noise sequence

System Architecture

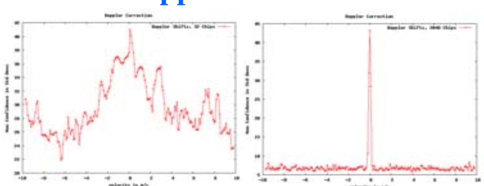


Chirp Code Selection



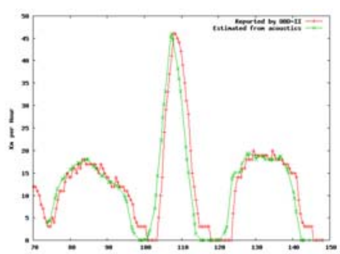
- Pseudo-noise repeating sequence of varying length
- Because these codes are very sensitive to Doppler shift, we needed to correct for Doppler shift in the detection process
- Chirp lengths of 512 chips and above had very few detection errors
- Shorter chirps tended to yield more detection errors. However, this might be compensated by higher chirp rates, lower processing overhead, and on-line filters, e.g., Kalman filters

Doppler Correction



- Current solution is based on the "brute force" approach
  - Test Doppler shifts in the neighborhood of last speed estimate in 0.2 m/s increments
  - Test all emitter/receiver pairs and find max confidence value
  - If peak confidence is at least 2 std. dev. above the mean, accept the estimated value
  - Else, double the Doppler search range and repeat

Velocity Estimation



- Velocity of car needed to correct for Doppler shift
- OBD reports in Km/H
- Appears to lag (internal smoothing filter)
- Implemented acoustic velocity estimator
- Tracks OBD output, but with finer granularity and without lag

Synchronization Issue

- We implemented wireless synchronization
- Single broadcaster radio emits periodic signals
- Receivers feed correlated sync symbols into the ADC
- Offline processing matches up sync symbols
- Rate conversion to correct for ADC clock skew (166 PPM)
- For an on-line system, must be integrated into RF protocol

Position Tracking

- Each line represents a tracked location, corresponding to the axis between emitters
- Time is represented by color: Blue→Green→Red
- The array is positioned at (0,0) → (3.5,0)

In this test, we:

- Drove towards the array, and stopped
- Drove back quickly in reverse
- Drove forward, weaving intentionally from side to side