Safeguarding Automatic Speech Recognition Systems on Driverless Vehicles

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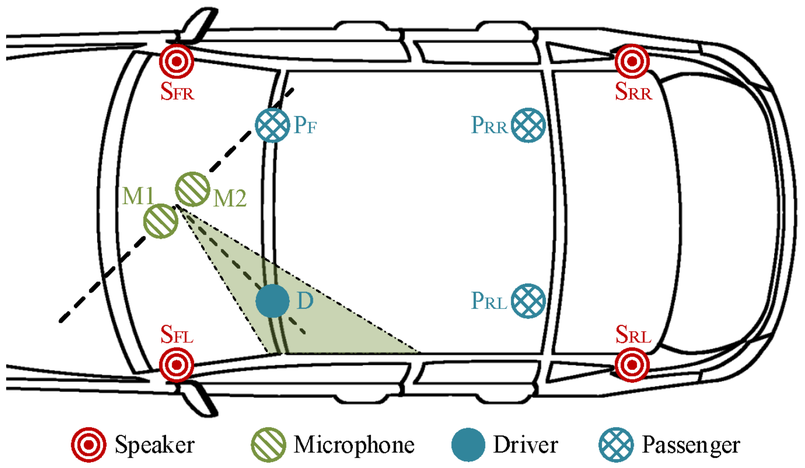
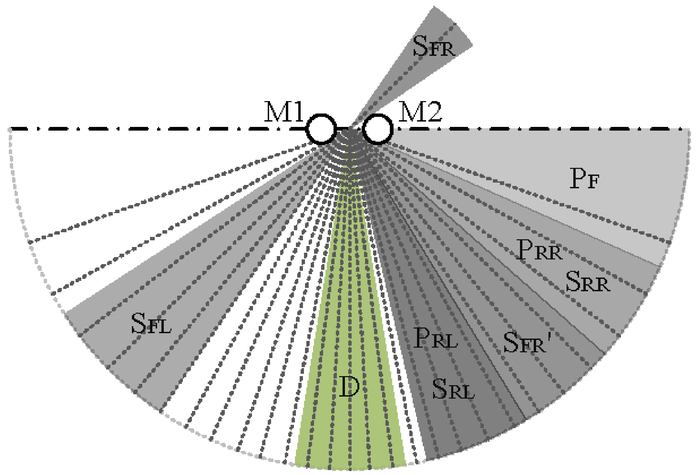
Motivation

- Automatic speech recognition (ASR) systems suffer from several adversarial voice attacks.
- Prior work [1] focus on the distinction of voice using the frequency and noise features.
- For driverless vehicle application, we want to find more robust features through the physical attributes of the received signals because of the fixed voice source locations.
- By using a pair of close-coupled microphones, we developed a secure ASR system (SASR) which contains three detection steps.



Location and Orientation of a Dual Microphone



Directions of Voice Sources to Microphones

Technique Approach

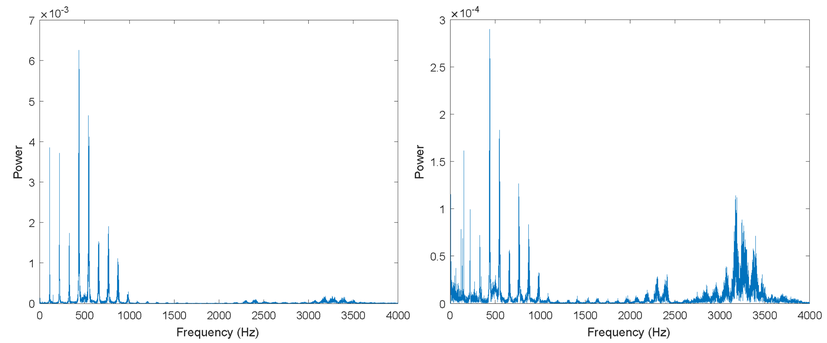
- **Detecting Multiple Speakers**

  Through autocorrelation analysis of linear prediction residual of the received voice, we filter out the multi-speaker signals.
- **Identifying Single Voice Source**

  We measure the voice propagation direction via time difference of arrivals (TDOA).
- **Detecting Voice from Mobile Phone**

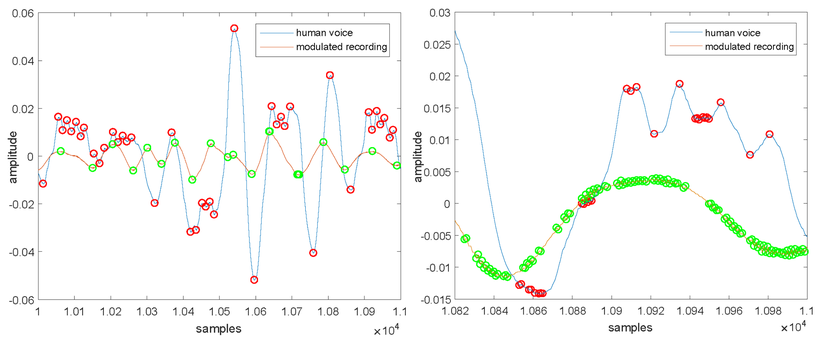
  We distinguish the replay attacks through frequency-domain power spectrum due to the low-frequency energy loss of mobile speakers [2].

  To prevent the modulated voice which can compensates the energy loss in frequency domain, we develop a time-domain double granularity extrema cross-check approach.



(a) Human voice (b) Relay voice

Frequency-domain Power Spectrum



(a) Coarse granularity (b) Fine granularity

Time-domain Double Granularity Extrema

Results

- **Detection Accuracy** for three detection steps is 83.3%, 96.8%, 97.6% respectively.
- **Performance Overhead**

Detection Step	Running Time	Memory
Multi-speaker Detection	134 ms	111 MB
Single Source Identification	33 ms	23 MB
Mobile Replay Detection	47 ms	10 MB
Total Overhead Costs	214 ms	144 MB

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References

[1] M. Zhou, Z. Qin, X. Lin, S. Hu, Q. Wang, and K. Ren. 2019. *Hidden Voice Commands: Attacks and Defenses on the VCS of Autonomous Driving Cars*. IEEE Wireless Communications (2019), 1–6.

[2] Jesús Villalba and Eduardo Lleida. 2011. *Detecting Replay Attacks from Far-Field Recordings on Speaker Verification Systems*. In Biometrics and ID Management, Springer Berlin Heidelberg, Berlin, Heidelberg, 274–285.