WIFI-BASED ROBUST CHILD PRESENCE DETECTION FOR SMART CARS

SAKILA S. JAYAWEERA, BEIBEI WANG, XIAOLU ZENG, WEI-HSIANG WANG, K. J. RAY LIU

IEEE ICASSP 2023 (PAPER ID: 4821)

INTRODUCTION

In-car child presence detection (CPD) has gained worldwide attention due to increased child deaths reported yearly when they are left unattended in a car.

Earlier CPD Solutions:

- Sensor based
  - Limited coverage
  - High False alarm rate
- Vision based
  - Rely on the quality of image /video
  - Not readily available
- RF-based
  - Coverage only in the field of view
  - Not readily available
- WiFi Based
  - Large coverage
  - Can reuse in-car WiFi

In this paper, we propose a WiFi-based robust CPD system consisting of a motion and enhanced breathing detector.

ROBUST CPD SYSTEM DESIGN

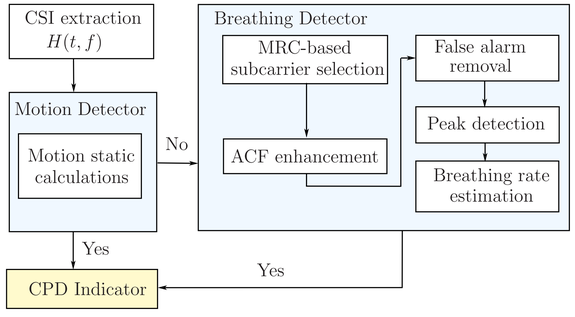


Figure 1: System Design

CSI MODEL

Considering the multi-path effects of WiFi, CSI estimated over a subcarriers with frequency f at time t can be estimated as,

$$H(t,f) = \sum_{m\in\Omega_s} a_m(t)e^{-j2\pi f\tau_m(t)} \text{(Static term)} + \sum_{n\in\Omega_d} a_n(t)e^{-j2\pi f\tau_n(t)} + n(t,f).$$

(Dynamic term)

METHOD

ACF of CSI power $G(t,f) = |H(t,f)|^2$:

$$\rho_G(\tau,f) = \frac{E_d^2(f)}{E_d^2(f)+\sigma^2(f)}\rho_\mu(\tau,f) + \frac{\sigma^2(f)}{E_d^2(f)+\sigma^2(f)}\delta(\tau).$$

- **Motion Detector**

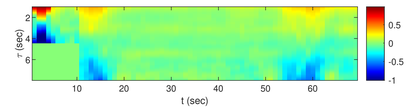
If motion: $\lim_{\tau\to 0}\rho_G(\tau,f) > 0$
If no motion: $\lim_{\tau\to 0}\rho_G(\tau,f) \approx 0$

- **Breathing Detector**

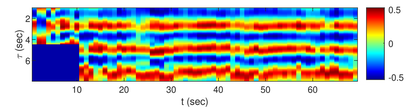
Boosted ACF using the maximum ratio-combining(MRC) method

$$\hat{\rho}_c(\tau) = \sum_{i=1}^{N}\rho_G(\tau = 1/F_s, f_i)\rho_G(\tau,f_i).$$

- **Enhancement on ACF**
  - Peak Enhancement:
    Apply a median filter in the time domain to remove high-frequency components. Then use 1D column filter to enhanced the ACF
    $\hat{\rho}_E(\tau) = \hat{\rho}_c(\tau) + k\hat{\rho}'_c(\tau)$
  - Histogram Equalization:
    To adjust the contrast of the ACF for better identification



(a) Original ACF



(b) Enahanced ACF

- **False Alarm Removal**
  - Zero Crossing Rate(ZCR) :
    if ZCR of $\hat{\rho}_c(\tau) > k_{ZCR} \implies$ noise
    if ZCR of $\hat{\rho}_c(\tau) \le k_{ZCR} \implies$ breathing
  - DTW distance:
    Compare ACF with pre-defined template

Why DTW? To address the out-of-sync issues with the template

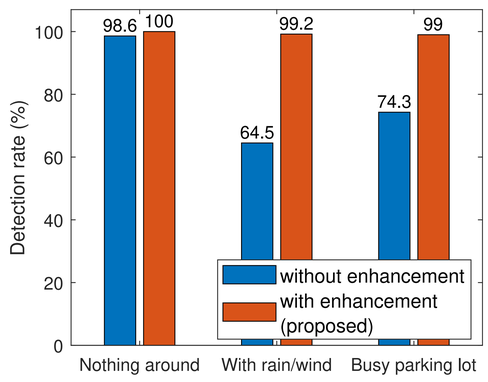
EXPERIMENTAL RESULTS

System is implemented using a commercial dual-band WiFi modules operating in both 2.4GHz and 5GHz bands. Both the transmitter and the receiver have two omnidirectional antennas.

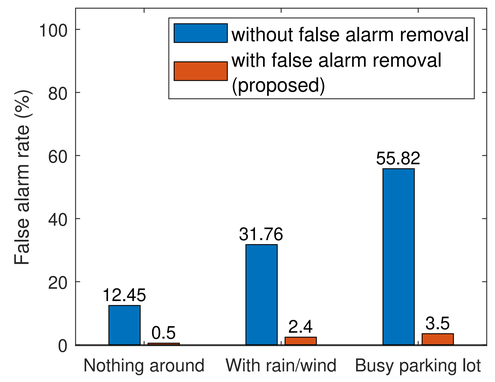
- Challenging data from the following cases:
  1. severe environmental conditions, such as rain and wind.
  2. target car parking in a busy parking lot.
  3. large motions around the target car, including periodic walking, hand waving near car windows, and loading/unloading bags from adjacent cars.
- Around 100 minutes long data samples for each challenging case collected over month
- More than 10 different car models
- Data from children under the age of six and a baby doll.

Table 1: Results comparison

	Detection accuracy	False alarm rate
WiCPD	82.4%	6.6%
Proposed method	99.0%	3.2%



(a) Detection under different conditions



(b) False alarm rate under different conditions

Can detect static child or child in motion within 10 seconds of responsive time.

CONCLUSION

- The proposed method is resilient to interference.
- Higher accuracy compared to state-of-the-art and low responsive time show great potential for commercial applications.

FUTURE WORKS

- Further reduce false alarm rate using the fusion method.
- Learning-based evaluation.

REFERENCES

[1] Sakila S. Jayaweera, Beibei Wang, Xiaolu Zeng, Wei-Hsiang Wang, K. J. Ray Liu. Wifi-based robust child presence detection for smart cars. In *ICASSP 2023 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP)*, 2023.