Data Quality-Informed Multiple Occupant Localization using Floor Vibration Sensing

Laixi Shi
laixishi@cmu.edu
Carnegie Mellon University

Yue Zhang
yzhang58@ucmerced.edu
UC Merced

Shijia Pan
span24@ucmerced.edu
UC Merced

Yuejie Chi
yuejiechi@cmu.edu
Carnegie Mellon University

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1 DATA QUALITY-INFORMED DESIGN

Floor vibration-based sensing technology provides an alternative approach for occupant localization, which enables various indoor applications such as elderly/child monitoring and energy usage management. Localization of multiple people is challenging due to the overlap of their footstep signals. Prior work mainly focuses on detecting the onsets of individual footsteps from overlapping signals for localization. However, due to the interference caused by the overlap, the localization error is often much higher than that of the single person case [1, 3].

In this work, we present a data quality-informed localization system for multiple occupant localization using vibration sensing. Figure 1 shows our proposed system. The **vibration sensing module** obtains floor vibration signals from the vibration sensing node array. The **step-level localization module** utilizes Time Difference of Arrival (TDoA) to localize each detected single step [3], where the TDoA is extracted from the onset of each footstep signal.

Figure 1: Overview of our proposed system.

When multiple footstep signals partially overlap, the tail of the earlier signal will distort the onset of the later arrival signal – reducing data quality and localization accuracy. When the extent of the overlap varies, the distortion to the onset estimate also varies. The **data quality evaluation module** quantifies this variation by ranking the overlapping condition into three different statuses gradually deteriorating: (1) clear separation; (2) visually separable; (3) visually non-separable [3], and sets different data quality parameters r_1 , r_2 , r_3 for these statuses respectively. The **step assignment**

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and **localization refinement module** assigns the detected step to each person based on the detection time, estimated location and history [2]. Then the location estimate is refined through a data quality-informed Kalman filter, where the data quality parameters are used as the variance of the localization report error σ_L in the state-of-the-art tracking algorithm [2].

2 EXPERIMENTAL EVALUATION

We utilize 1000 synthetic footsteps and 14 real-world footsteps data (collected in [3]) when two persons walk in the same area simultaneously. In our localization refinement module, fixing three quality parameters $r_1 < r_2 < r_3$, the position report error σ_L is set as one of them for footsteps in different overlapping conditions, for both synthetic and real-world data. We compare our method to 6 baselines without data quality prior: (1) No refinement; (2) σ_L is chosen randomly in $(0, r_3]$; (3) $\sigma_L = r_1$; (4) $\sigma_L = r_2$; (5) $\sigma_L = r_3$; (6) σ_L is chosen to make the smallest average localization error.

Figure 2 shows the localization error using synthetic data, which demonstrates that our system achieves an average localization error of just 0.42m, which represents 1.4X to 2.2X improvement over all the baselines. In real-world experiments, our system achieves an average localization error of just 0.46m, which represents 1.4X to 1.7X improvement over all the baseline approaches.

Figure 2: Localization error of our method and baselines.

3 CONCLUSION

In this paper, we present a data quality-informed system for multiple occupant localization through structural vibration sensing. Our system assesses data quality for detected footsteps and utilizes it as a prior for localization refinement. Our system achieves a half-meter average localization error for the two-person case, which is comparable to the single person case.

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