

Privacy-Preserving and Scalable Occupant Tracking in Indoor Environments

Occupant spatial tracking drives critical applications in building optimisation [1][2], energy reduction [3], shopper behaviour analysis [4][5], and the optimisation of patient flow in healthcare clinics to reduce wait times [6][7]. However, existing solutions face privacy risks which prevent people from participating or agreeing to be tracked [6]. In addition, the complex process of installing and deploying the needed infrastructure, such as dedicated wired networks and servers, adds further hurdles to practicality and scalability.

This work presents a novel indoor tracking system that delivers spatiotemporal tracking data while remaining privacy-preserving, scalable, and easy to deploy. By leveraging edge computing to process data locally, we ensure that raw sensor data never leaves the sensor network, thereby preserving privacy. Consequently, we also use an auto-calibrating wireless mesh network architecture to address deployment hurdles.

The nodes forming the mesh self-coordinate using the unlicensed DECT NR+ 1.9 GHz band, avoiding the crowded 2.4 GHz band for lower interference and latency [8]. At the network edge, we fuse camera vision and mmWave radar sensor data to: (1) extract visual features of individuals from cameras to create temporary, anonymous identity vectors, and (2) leverage the depth and Doppler data from the privacy-friendly radar to spatially track individuals.

As people move through a building, the system employs novel protocols to hand off feature vectors between sensor nodes in real-time, then aggregates the data to create cross-scene trajectories. The system ensures the feature vectors are immediately purged once the handover and aggregation are complete, leaving only anonymised data transmitted outside the system.

The proposed system is currently in the early development stage and will be validated through real-world deployments in Cambridge and London. Ultimately, it will output coordinates paired with anonymous IDs of individuals moving in a building over time, offering a solution that is both extendable and easy to deploy across diverse indoor environments.

References:

[1] <https://connected-environments.org/projects/trust2/>

[2] <https://doi.org/10.1038/s41598-025-23134-4>

[3] <https://doi.org/10.26868/25222708.2025.1472>

[4] <https://doi.org/10.1007/s40614-017-0121-x>

[5] <https://doi.org/10.48550/arXiv.2105.09299>

[6] Wilson, D., Gray, S., Eames, I. and Foster, P., 2023, July. Understanding patient flow using IoT in a pop up eye clinic. In The 30th EG-ICE: International conference on intelligent computing in engineering (pp. 4-7). London: University College London.

[7] Mills, G., Symons, A., Roufaeel, I., Unwin Teji, J., Scully, P., Sailer, K., Wilson, D., Jayaram, H., Sivaprasad, S. and Foster, P., 2022. Driving Innovation in Healthcare Design: The case of an interdisciplinary co-design process for a new rapid virtual diagnostics hub for eyes. In Proceedings of the 5th Architecture Research Care and Health conference (ARCH22 'Enabling health, care and well-being through design research') (pp. 2-10). Delft Open.

[8] <https://ieeexplore.ieee.org/abstract/document/9625340>