

Housing and Daily Living

Unsupervised, Personalized, and Interpretable Activity Recognition and Anomaly Detection in a Real-World Smart Home K. Wang, A. Saragadam, J. Kaur, Y. E, Mahmoud, D, Istrate, P. P. Morita *Gerontechnology* 25(s)

Purpose Ambient Assisted Living (AAL) research frequently contends with limitations, including a reliance on supervised data, a lack of personalization and interpretability, and evaluations in artificial laboratory settings (Márquez & Taramasco, 2023). These challenges hinder real-world deployment by requiring burdensome data labelling and failing to capture individual-specific routines (Cruz-Sandoval et al., 2019). This study's key contribution is an unsupervised, personalized, and interpretable AAL system developed to address these gaps in real-world deployment. The primary aim was to use low-cost, multi-modal sensors for long-term, real-world activity recognition (cooking, couch-sitting, showering) and behavioural anomaly detection in a genuine home environment (Wang et al., 2023). **Method** A multi-modal sensor network—including contact, vibration, smart outlet, and air quality sensors—was deployed in a single participant's apartment (Figure 1) for over 90 days, ensuring high ecological validity. Primarily, unsupervised machine learning techniques were employed. K-means clustering, validated by the Silhouette Coefficient, was used to identify appliance states (for cooking) and to cluster bathroom events (showering). Isolation Forest models were used to detect personalized behavioural deviations in each room. These models were augmented with interpretability methods (SHAP values) to explain anomaly flags. A minimally supervised Random Forest, evaluated using Accuracy, Precision, Recall, and F1-score, was also compared. **Results and Discussion** The unsupervised K-means clustering for appliance states showed high cluster separation (e.g., Silhouette Scores > 0.93) and high fidelity (e.g., >99.6% agreement). The unsupervised shower model achieved a Silhouette Score of 0.867 and 99% accuracy. In comparison, the minimally supervised Random Forest model (trained on ~20 days of data) achieved 99.8% accuracy and an F1-score of 0.989. The system effectively identified interpretable anomalies, such as abnormally long non-shower bathroom stays (over 60 minutes), atypical late-night bedroom activity, and unusually long cooking durations. These deviations were explained using SHAP and confirmed by the participant, validating the personalized model's ability to learn the individual's baseline routines. This study confirms the feasibility of leveraging unsupervised, interpretable methods with affordable, non-intrusive sensors for personalized and ecologically valid AAL, which significantly reduces the dependence on exhaustive data labelling. This real-world evaluation provides a critical contrast to artificial lab settings and highlights important privacy and ethical considerations. The work provides a validated framework for developing unobtrusive health monitoring systems that learn individual routines and enhance trust, representing a critical step toward real-world AAL deployment.

References

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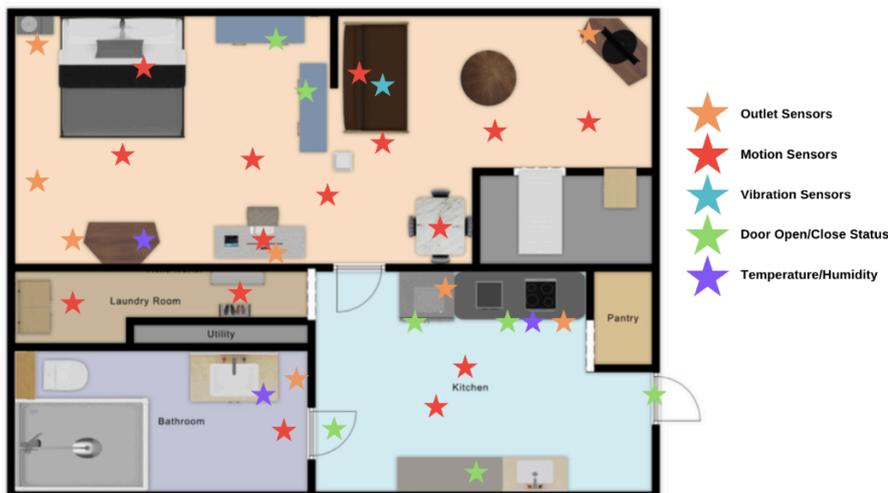


Figure 1. AAL environment