Application Fields and Innovative Technologies

Room-Aware Behavioral Profiling for Cognitive Health Monitoring in Smart Homes L. Takahashi, D.J. Cook, M. Schmitter-Edgecombe. *Gerontechnology 25(s)*

Purpose Smart home monitoring offers the potential to serve as an early warning system for Mild Cognitive Impairment (MCI) but faces two barriers: (1) sensor data are frequently sparse and irregular, making it difficult to accurately localize residents; and (2) AI predictions often act as "black boxes" without providing actionable evidence. To address these challenges, we introduce a resident localization method that handles data sparsity and improves decision transparency through feature ranking. We hypothesize that improving localization accuracy will yield behavioral biomarkers more strongly associated with cognitive impairment. **Method** We utilized sensor parameters and behavioral distributions from the WSU Functional Assessment Study (*N*=41; *M*age=74.00; *M*education=16.51; 63% female; 34% cognitively impaired) to generate adversarial synthetic benchmarks representing cognitively healthy (*N*=30) and impaired (*N*=30) residents to evaluate algorithmic robustness. The source participants lived in smart homes equipped with unobtrusive sensor technology for a continuous 16-month period, enabling passive monitoring of daily activities and functional abilities. To solve the localization problem, we adapted a Kalman Filter to handle event-driven sensor updates. A key innovation is the model's "room-aware" mechanism: unlike standard filters that assume a fixed spatial reference (e.g., the home's geometric center), our model updates its mean-reversion point to the centroid of the currently active sensor cluster, effectively re-anchoring the spatial prior as the resident moves between rooms. We performed binary classification (Healthy vs. Impaired) and utilized LASSO regression to rank behavioral features, ensuring clinical relevance. **Results and Discussion** The room-aware mechanism reduced localization error by **18%** compared to baseline models. Crucially, the model achieved **92% statistical consistency** in its uncertainty estimates (vs. 65% for baselines), providing a safety assurance mechanism critical for clinical applications. In diagnostic classification, the model achieved an **AUC of 0.78**. Feature ranking (**Figure 1**) revealed that **Spatial Entropy** (β=−0.42, *p*<0.05) was the strongest protective factor, suggesting that reduced home exploration is associated with greater cognitive impairment. Conversely, **Night Activity Fraction** (β=+0.38, *p*<0.05) emerged as a primary risk factor, a pattern consistent with "sundowning" phenomena reported in dementia literature. These results demonstrate that improving data quality via localization and ranking features can bridge the gap between raw sensor data and clinically actionable insight. Current limitations include reliance on synthetic benchmarks for initial validation and the assumption of single-occupant homes. Future work will validate these findings on longitudinal smart home data with clinical ground truth and explore generalizability across diverse home environments.
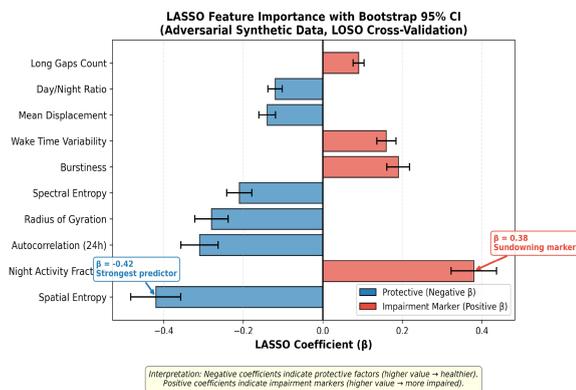
Fig 1. LASSO-selected behavioral biomarkers (Binary Classification: Healthy vs. Impaired). Blue bars indicate protective features where higher values are associated with healthier status. Red bars indicate risk markers associated with impairment (e.g., Night Activity), aligning sensor data with clinical phenotypes.