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Design of an Ultra-Low Power Sensor Platform for the Detection of Activities of Daily Living in Residential and Commercial Environments

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Abstract

In this work, we present the Design of an Ultra-Low-Power sensor platform for the Detection of Activities of Daily Living in Residential and Commercial Environments. We performed field trials in the residential setting to validate the system and translate the knowledge to the domain of office buildings where we tested the systems ability to estimate the number of people present during meetings. The results show that our sensor platform is able to estimate the number of people with a mean absolute error of 1.3.

Motivation

Detecting and tracking human activities are of great importance in many fields such as security, urban planning, medicine and healthcare. Activities of daily living (ADL), as a subgroup of all possible human activities, are especially important to measure the ability of a person to live independently at home [1][2]. Depending on how people conduct ADLs, caregivers can adapt their level of support to the needs of the patient. By automatically tracking ADLs over long periods, it is also possible to detect changes in behaviour, which might provide important information about the state of cognitive functioning [3][4]. In this project, we want to translated the knowledge of ADL detection in residential environments to office buildings to enable user-centric building control.

Sensor Platform

The current version of the multi-sensor platform includes a total of 9 ambient sensors which measure variables such as ***temperature***, ***humidity***, ***light intensity***, ***VOC*** (Volatile Organic Components), ***sound pressure***, ***3D acceleration***, ***magnetic field strength***, ***motion*** and ***distance*** (based on Time of Flight). The advantages of this sensor system are as follows: 1.) The multi-sensor platform is optimized to a small form factor (80 x 40 x 30 mm) which increases the flexibility of the installation process and reduces visibility and therefore the level of intrusion. 2.) Because of its small form factor, the manufacturing cost is reduced. Compared to other solutions we only have to maintain a single platform and codebase. 3.) The multi-sensor platform is based on the new Bluetooth 5.0 standard, which provides a simple and secure interface for configuration and data exchange. All communication is encrypted via AES128. 4.) The platform and all its sensors are energy optimized and operate for 2 years on two coin cell batteries

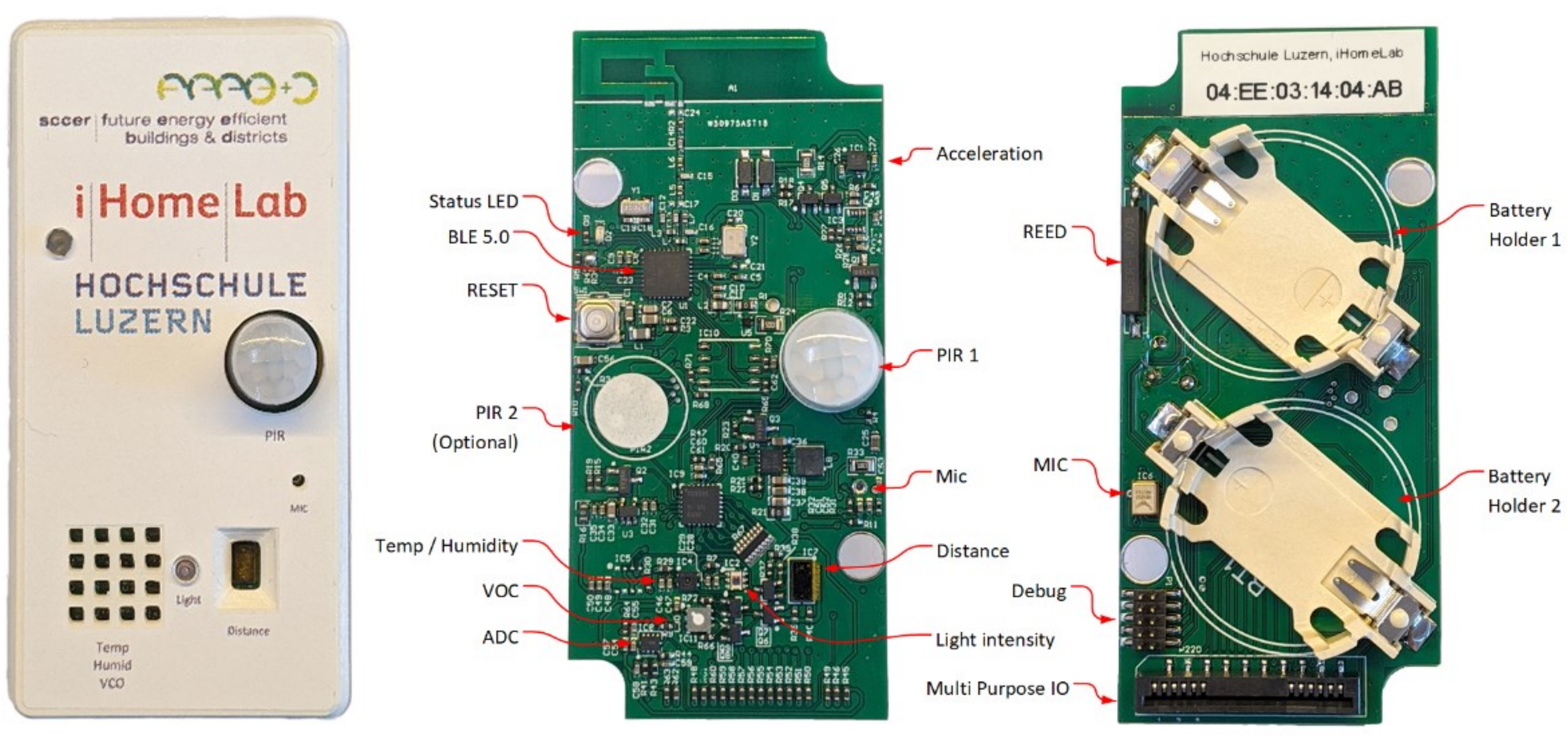

Figure 1: Developed sensor platform. Front PCB (centre) and backside (right) show the location of the most important sensors and controllers.

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Field Trial

To validate the ability to detect ADLs in a residential environment, we installed a set of 13 sensor units in two apartments of two healthy participants. During a period of 6 and 8 weeks the participants were instructed to keep a journal of their daily activities. A simple random forest classifier was trained on the dataset using a 7-fold Cross Validation methodology. The resulting classifier achieved a mean precision and recall over all tested activities of 0.97 and 0.96 respective. To validate the sensor platform in an office environment, we conducted two field trials in two meeting rooms where we analysed the reliability of the system and its performance detecting the number of people. We compared multiple neural network architectures such as GRU, LSTM and Deep separable 1D Conv-Nets. For model selection, we monitored the mean absolute error (MAE) for the estimated number of people on the validation data.

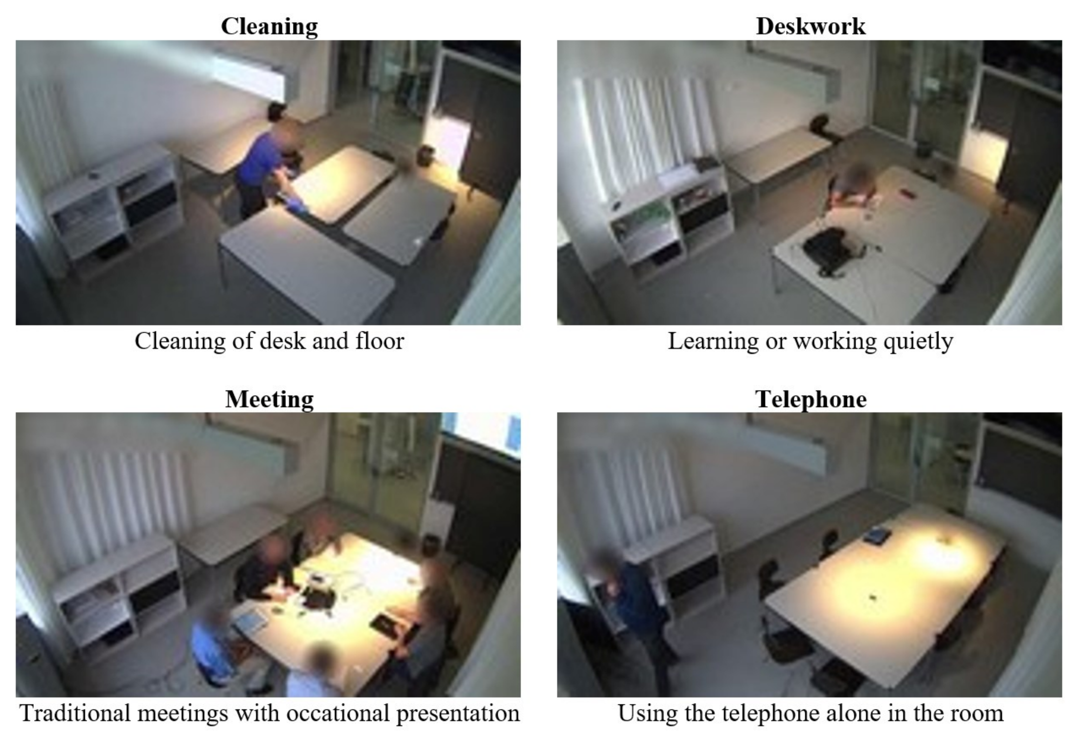
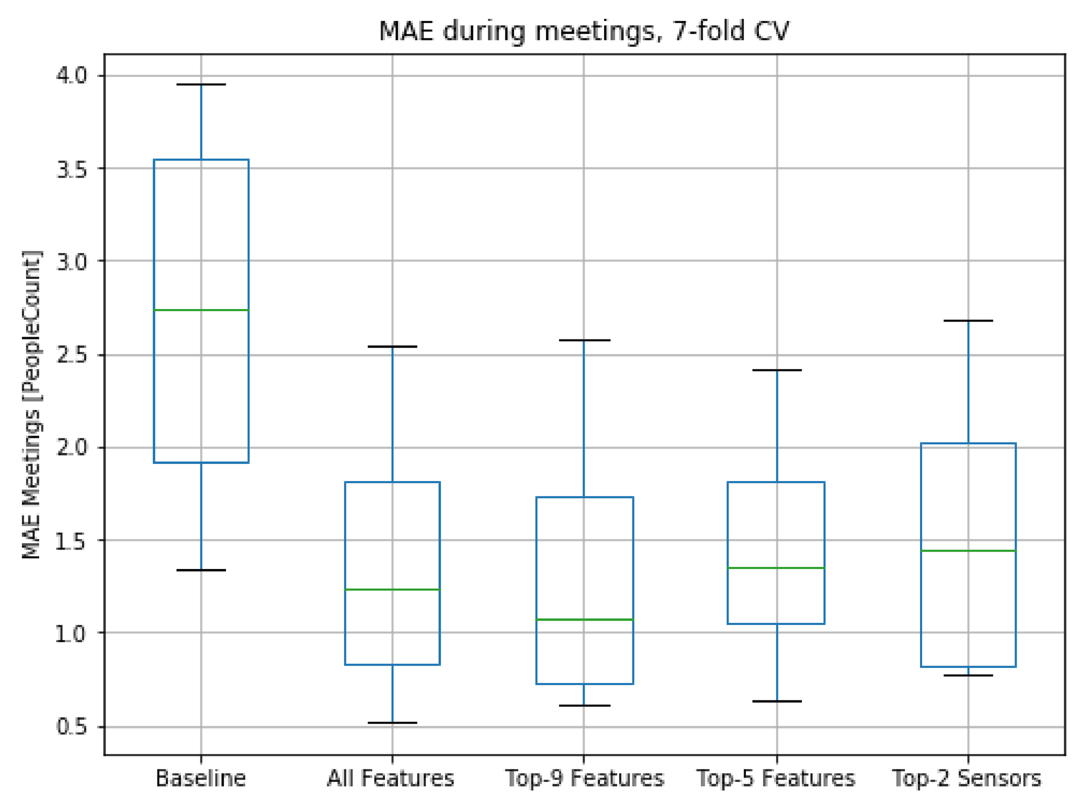


Figure 2: Ground-Truth collected via IP-Camera .

Results

We found good agreement with few people in the room and high deviation where several people occupied the room. The MAE of room-1 was 0.069 (SD=0.05) over all data. The MAE calculated only for time frames with presence amounted to 1.31 (SD= 0.75). To test the transferability of the model , we used it to predict the number of people using data of room-2 where we got a MAE for time-frames where people were present of 1.4.



Conclusions

- The sensor platform has proven to be a reliable tool for collecting sensor date in residential and commercial settings
- The developed model for people count estimation suggest some ability to generalize to similar rooms.
- The variability in the predictions is high which poses some limitations on the applicability of the predictions as an input to building control systems

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