Demo Abstract: Demonstration of Using Sensor Fusion for Constructing a Cost-Effective Smart-Door

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ABSTRACT

As buildings get smarter they need to be aware of their spaces and occupants to improve prediction and management of energy consumption and environment customization based on user preference. User identification is crucial to this. However, accuracy of identification, intrusiveness and cost are important factors that one considers before installing such a system. Accounting for these factors, we built a Smart-Door that incorporates fusion of not-so-smart sensors, soft information available and learning algorithms to build an economical and accurate user identification system that requires no user intervention to monitor the occupant count and identities in a shared office space that can be scaled up to a building. It provides real-time occupancy status for the area and it can also learn to identify new users. In addition to energy management, such a user identification system has significant applications including evacuation procedures and localizing malfunctioning appliances.

General Terms

Occupancy Identification

Keywords

Smart Door; Smart Building; Energy Saving; User Comfort

1. INTRODUCTION

The ever increasing consumption of electric energy has resulted in wide spread research and initiatives to reduce and manage consumption of energy. In light of this ever increasing energy consumption smartmeters have become a boon in analysing and gaining new insights to power consumption patterns. Studies have shown that buildings consume 40% of total energy produced [3]. Hence it is important to focus on energy management of buildings. Though smartmeters provide information about total consumption, base consumption and patterns of usage, a new dimension of inferences can be made when information regarding occupancy of the building is added to the mix. This throws light on per capita consumption, contributors to base load, user device interactions, etc. Having inferred these, proactive steps to curb and reduce power consumption can be made in reducing base load, detecting anomalous devices, implementing energy quota system based on per capita consumption, customized setting of building spaces based on user preference, feedback systems to bring awareness to users about their consumption and hence in the process make users actively participate in reducing power consumption. The new dimension of user identity and count has been implemented by many systems with good accuracies but are expensive, require user intervention, have scalability issues, etc. These motivated us to come up with a smart door that identifies and counts the users, at the same time does not have the above drawbacks. The smartdoor is built using the sensor fusion of 'not so smart'cheap sensors which provides accurate identification of the users. Apart from saving energy a smartdoor can also aid in evacuation procedures during emergencies to pin point locations of children and senior citizens in a building for faster and efficient response of rescue team.

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2. SETUP

2.1 Hardware

A Smart-Door [2] consists of a door frame with multiple sensors installed on it. Two laser-phototransistor pairs of the door have been installed to detect entry or exit. The change in voltage generated by the phototransistor detects the cut of the laser. An ultrasonic sensor has been placed on top of the door, in order to get height of a person as he walks through the door. A weight mat has been installed as well, which measures the weight of the person as he walks through the door when he steps on it. The height and weight sensors are connected to individual Arduinos which are connected to a Raspberry Pi installed on the door.

When either of the lasers is cut, it triggers an interrupt to the Raspberry Pi, which in turn triggers the height and weight sensors to start recording their respective readings. The order of the laser cut denotes an entry or an exit event. The sensors are reset after the second laser is cut. The Raspberry Pi assigns a unique session id to each entry/exit event and the recorded height and weight readings are tagged to this session id and stored in the database. During the training phase, each event is tagged with the ground truth - who the person is - using the two tablets installed at the door. After the training period, a classification algorithm runs on the recorded readings and the user identity is determined and displayed on the tablets again. This architecture is shown in Figure 1.

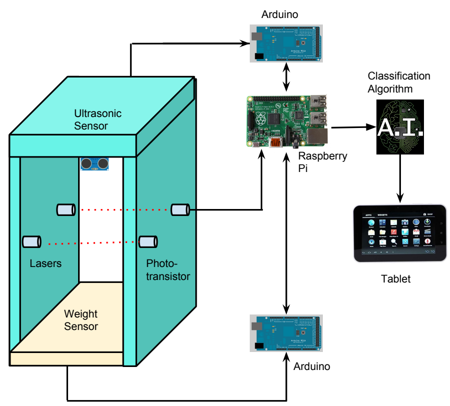

Figure 1: Smart-Door Architecture

2.2 Software

We use the Random Forest Classifier for learning and prediciting the user identity. Random Forest Classifier is an ensemble of decision trees [1]. In a Random Forest classifier many decision trees are built by taking the sample of data from the training set with replacement and a randomly selected subset of features is used to split at each node. To classify a new object, the classifier presents the object to each tree generated and makes the identification. The prediction of the object is the class which is predicted most number of time. We also use other soft information to improve the correctness of prediction. Soft information may include academic schedules or room schedules or knowledge of current occupants of the room, etc. Therefore for a person entering the room, from height + weight basd (hard sensor) information, we identify the set of possible occupants.
— For example, {A, B or C}.
We prune this set using soft sensors like user schedules or room schedules or current occupants of the room to identify who the person is.
— C has a meeting elsewhere, so person has to be {A,B}.
— B usually comes after lunch (that is, at the current time, B is usually not present), so has to be A.

3. ACCURACY AND EVALUATION

There are many ways for detecting and identifying a person as described by [2]. But, instead of using SVM, we have used a Random Forest Classifier. Similarly, as in [2], we also observed that the low cost height and weight sensors provided more insight into predicting the occupant with greater accuracy when compared to the body signatures obtained from the costly device Kinect. In order to justify this we trained an ensemble model Random Forest Classifier and observed the impact due to the different features on the accuracy of prediction, as can be seen in Figure 2.

The training data comprised around 2500 entries corresponding to 18 people and, the recorded data was used to train the machine learning algorithms in order to predict the person coming in or going out of the room. We employed both classifiers namely SVM and Random Forest Classifier to provide a valid comparison. Figure 2 shows the accuracies obtained by using different features and classifying using SVM and Random Forest Classifier.

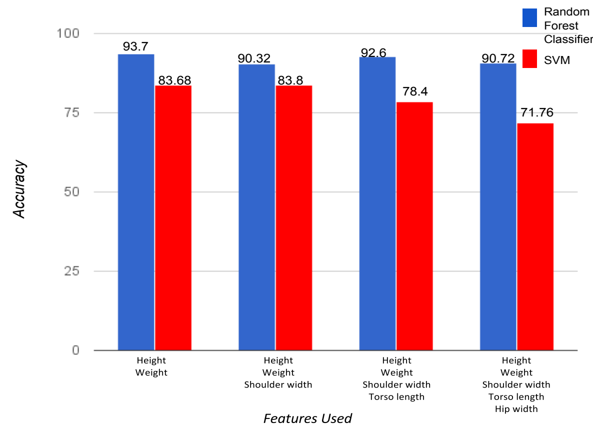

Figure 2: Performance of Classifiers Using Different Features

4. ON-SITE DEMONSTRATION

The on-site demonstration will have the Smart-Door set up to let visitors pass through and tag themselves on the tablets provided during the training period. After sufficient training data is obtained, each subsequent passing of the tagged participant will trigger identification of users on the tablets.

5. CONCLUSIONS

The demo will illustrate the Smart-Door: an economical, accurate and non-intrusive setup for tracking occupant count and user identification in an room. User identification is very crucial in customized environment management, evacuation procedures and in locating faulty appliances - especially if there is an appliance to user mapping. These features make the Smart-Door a very efficient and easy-to-deploy system in any building.

6. REFERENCES

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