Using mid-range RFID for location based activity recognition

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ABSTRACT
Development of smarthome home application depends on the ability to identify resident activity and track occupancy of rooms as people move within a residence. Existing solutions to home activity recognition are evaluated using controlled experiments and having participants maintain logs of daily activities as ground truth. In our study, we evaluate the effectiveness of using mid-range RFID as a research tool to perform in-situ evaluation of smarthome systems. We propose that using bracelets and anklets embedded with passive RFID tags can provide an accurate ground truth system, which can help evaluate the performance of research solutions for smarthomes with higher accuracy - in presence of natural variability of people in activities and movement in homes.

Author Keywords RFID, Activity sensing, Activity recognition, Occupancy Monitoring

ACM Classification Keywords H.5.2 Information interfaces and presentation (e.g., HCI)

General Terms Experimentation, Performance, Verification

INTRODUCTION
The ability to identify who has performed an activity or where a resident is located allows smart home applications to perform tasks such as: controlling building systems like HVAC and room lighting to prevent energy waste while maintain occupant comfort, record valuable information about residents' daily behaviors that can be provided to medical personnel to help diagnose health problems, and determine who, using what appliances, consume energy in a home.

Existing solutions to home activity recognition, evaluated by controlled experiments and having participants manually record daily movements and appliance usage [2, 4] have drawbacks, as controlled experiments do not always represent the variability of people in daily life and participants often forget to record their own ground truth for lengthy experiments of weeks or months.

The mid-range RFID system requires residents to only wear small passive RFID tags which do not require battery changes and are easily water proofed. This approach can be used to detect when home residents are using a specific appliance, and detect room occupancy for long term experiments of weeks or months. The main limitation of this system is the cost of the RFID readers and antennas.

Using passive mid-range RFID tags on humans is significantly more challenging than attaching them to objects. Firstly, human body interferes with mid-range RF signals and therefore the location of the tags on a person's body matters greatly. The proximity of a tag to the person's body, as well as its orientation with respect to the antenna, affects the readability of the tag by the antenna. Secondly, people move differently than boxes or carts of equipment - on two feet. One foot is planted in one spot for a few moments while the other leg is in stride, moving rapidly. As shown in Figure 1, this issue of foot planting, where the foot that strides over the antenna coverage area goes undetected, makes the intuitive solution of tagging only one of the residents' ankles infeasible.

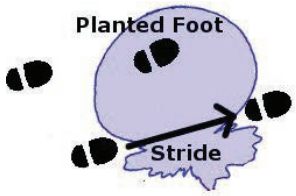

Figure 1. The feet that strides over the antenna coverage area goes undetected

In the past, many studies [1, 3] have used RFID to track residents in homes, but have used either short range or long range RFID systems. The short range RFID systems typically had objects tagged with passive RFID tags, and a short-range RFID reader mounted on the occupant. Based on the tags detected by the reader the system inferred the activities perform by the resident according to which objects are detected. The problem with using this approach is that wearable RFID readers require periodic battery replacements and people often forget to put them back on after removing them for sleep, bathing, etc. The long range RFID reader typically use the RSSI of RFID tags attached to objects to help localize the objects within homes. However, the drawback with this approach is that complex environments and rapidly moving people can make signal-strength a weak indicator of physical location, and small errors in signal strength can place a person in the wrong room or near the wrong appliance.

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We evaluate this system in the context of two major applications: location-based appliance usage, and room occupancy.

APPLIANCE USAGE

To identify residents as they use appliances within the home we place RFID antennas around the room of our test site to monitor various appliances. The goal of this appliance detection is to determine which individual in the home used an appliance, not if an appliance is in use.

The appliances we studied for this experiment were the fridge, microwave, sink, dishwasher, and two lights of a kitchen. In order to evaluate the best position to attach RFID tag to a person's clothing, we evaluated detection accuracy when tags were attached to hat, shoes, belt, shirt, pants, wrists and ankles.

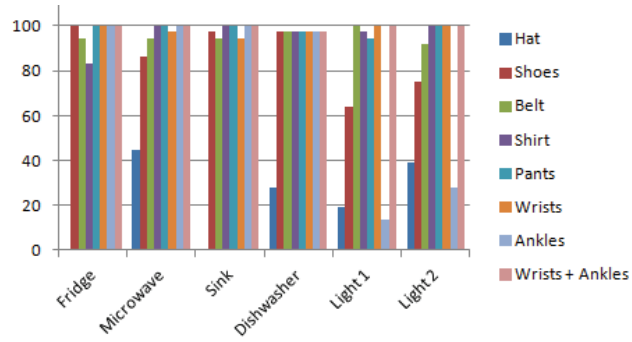

Figure 2. Resident identification with appliance usage can be accurately determined using the combination of ankles and wrists alone.

Figure 2 shows that though a combination of tags any appliance usage, excepting the dishwasher, can be matched with the acting individual with 100% accuracy. Tags located on the ankles of residents can correctly identify individuals at appliances where an individual would stop and stand for use, i.e. the dishwasher. Ankle tags, however, have very little accuracy when the individual uses a light switch. This is due to the fact that most people do not stand right next to a light when they turn it on or off. Often people lean over to turn on lights, which may mean that their ankles are 4 or more feet away from where the light switch is located–and where the RFID antenna is detecting tags. Wrist tags are needed to achieve 100% accuracy with light switches. However, wrists alone do not accurately identify the standing appliances that ankles do. Therefore in order to get high accuracy on all appliances in an room residents must wear both ankle and wrist tags.

ROOM OCCUPANCY DETECTION

Room occupancy changes only when a resident moves from one room two another, exiting or entering through a doorway. Therefore our examination of occupancy looks at the accuracy of detecting when an individual crosses a doorway. Obtaining directionality of motion is not an easy task for RFID since it detects only the existence of a tag in the vicinity of an antenna and not its exact location. By varying the number of antennas, three configurations were used to evaluate the accuracy of occupancy detection. A single antenna placed at the center of a doorway cannot identify directionality of motion across doorway. Thus, at least two antennas are needed for each doorway to disambiguate room entry and room exit. The foot planting problem manifests itself in our second configuration where two antennas are placed in the doorway, with one inside the room and one outside. Here the ankle tags, which are good for tracking and have very low false positives, easily generate false negatives when the person strides over the second antenna since only one antenna picks up the individual and directionality cannot be determined. To alleviate the foot planting problem, our third configuration consists of four RFID antennas completely covering the doorway.

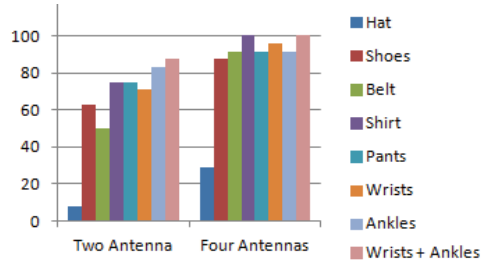

Figure 3. The four antenna configuration covers more of the doorway and identifies the individuals entering and exiting with higher accuracy.

The two antenna setup provides moderate accuracy but is not sufficient to serve as ground truth due to "foot planting" issue. The directionality of doorway crossing and room occupancy could be determined with high accuracy in the four antenna configuration. Figure 3 shows that anklet tags being more close to the floor, have better detection accuracy than other tag locations on a person's clothing.

REFERENCES

1. M. Bouet and A. dos Santos. Rfid tags: Positioning principles and localization techniques. In Wireless Days, 2008. WD '08. 1st IFIP, pages 1 –5, nov. 2008.

2. J. Fogarty, C. Au, and S. E. Hudson. Sensing from the basement: a feasibility study of unobtrusive and low-cost home activity recognition. In Proceedings of the 19th annual ACM symposium on User interface software and technology, UIST '06, pages 91–100, New York, NY,

3. M. Philipose, K. P. Fishkin, M. Perkowitz, D. J. Patterson, D. Fox, H. Kautz, and D. Hahnel. Inferring activities from interactions with objects. IEEE Pervasive Computing, 3(4):50–57, Oct. 2004.

4. E. M. Tapia, S. S. Intille, and K. Larson. Activity recognition in the home using simple and ubiquitous sensors. In In Pervasive, pages 158–175, 20