A Solution of Activity Recognition in Smart Home Using Passive RFID Tags

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1 Introduction

The concept of building a home that can automatically control and manage the resources for the inhabitants has been put forward many years before. Smart home can be considered to be a kind of context-aware system that provides services based on the knowledge it sensed in home environment. As depicted in Fig.1, the knowledge of home environment contains two parts: surroundings and inhabitants. Due to the development of sensing technology, it is not difficult to know the state of the surroundings such as temperature, humidity, etc. The bottleneck is how to perceive the inhabitants in an appropriate way. Here, the knowledge of inhabitants should include location and activity.

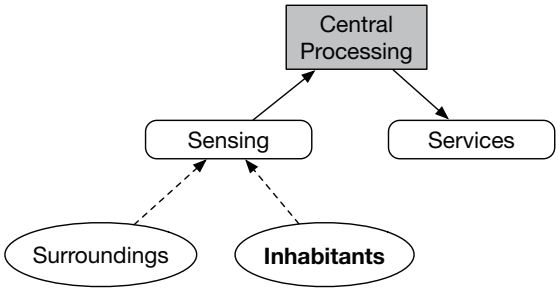


Figure 1: A simplified architecture of smart home.

This area attracts a lot of attention in recent years[1]. However, there is still no product can completely achieve the goal of smart home. Some research use cameras to trace the location and detect the activity[2]. This may inevitably bring the privacy problem which makes it can not be widely used. Some approaches like [3] utilizes wearable devices which may cause additional inconvenience to the users especially the elder and children. Thus, device-free wireless sensing approaches such as CASAS[4] are more suitable rather than the other kinds of approaches in home environment. Usually, such smart home systems need to combine different kinds of sensors to get a good performance. Is there a way to perceive the inhabitants with only one kind of sensors?

Radio Frequency IDentification(RFID) shows its potential possibility in this paper. Rather than the other wireless sensing technology, RFID has several distinct advantages. As shown in Table.1, we analyse five characteristics of feasible smart home architecture for perceiving the inhabitants. Wi-Fi requires the surroundings to be fixed, otherwise the system need retrain again. Ultra-wideband(UWB) can only work well in line of sight. In the past several years, RFID has made many progresses on indoor localization and gesture recognition. In this paper, we explore a new function of RFID that is perceive the inhabitants.

Table 1: Contrast of state of the art wireless sensing technologies in smart home.

Characteristics	Wi-Fi	UWB	RFID
Low-cost	✔	✔	✔
Perceptive	✖	✔	✔
Multi-function	✔	✖	✔
Non-invasive	✔	✔	✔
Easy to implement	✖	✖	✔

This paper proposes a novel solution for sensing inhabitants in smart home. This approach utilizes passive RFID tags to detect specific actions of the inhabitants and further recognize the activity for smart home.

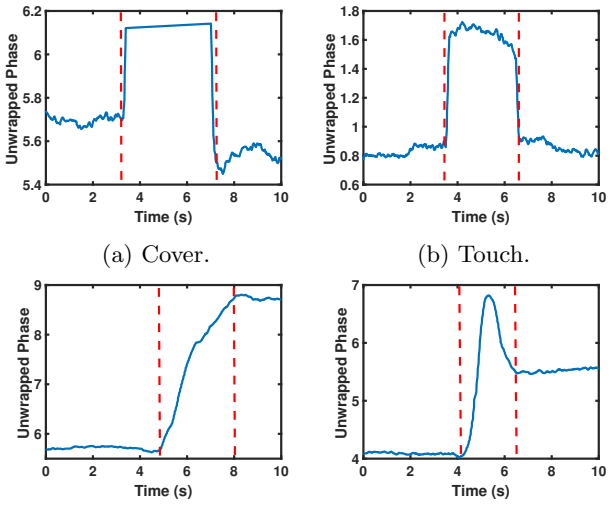
2 Motivation

The basic idea of our approach is that infer the actions by analyzing the phase data of one or several tags. For passive tag, phase is an attribute which is collected by the reader in every query. The interactive actions between inhabitants and tags will influence phase value in different aspects. Note that, specific action will cause the corresponding phase waveform. Thus, it is reasonable to detect the action by monitoring the phase change.

As depicted in Fig.2, these four pictures represent four actions that affect the phase value. To show the waveform more clearly, we use unwrapped phase rather than the original phase. Fig.2a represents that a hand covers the tag completely. Fig.2b represents a finger touches the tag. Fig.2c represents a finger sweep on the surface of the tag from one side to the other. Fig.2d represents a hand waves above the tag. The reason that different action causes different waveform is discussed in several research before. Electromagnetic shielding, multi-path[5] and capacitive coupling[6] can be seen as the main causes.

3 Approach

As introduced in Section 2, the action can be inferred by the phase waveform. Then we can use this to construct a novel usage-based activity recognition



(a) Cover. (b) Touch.

(c) Sweep. (d) Wave.

Figure 2: A simplified architecture of smart home.

model combine with the activity theory[7]. As shown in Fig.3, we modifies the activity theory aim at our approach. One activity includes several actions,and one action is defined by four attributes: who, where, when and what. And all of these four attributes can be obtained through RFID tags.

We attach passive RFID tags to all the object that the inhabitants will use in the daily life include cup, toothbrush, switch, cloth, etc. The tags are so light and thin and even can be customized into different shapes that makes them can be attached on every object, yet cause no uncomfortable to the inhabitants. Then, the tags on the neckband of clothes will tell the identity and location of the action. And the tags on the objects will tell the time stamp and the object ID of the action. Although the accuracy of RFID tag localization is not that high, it is enough for our approach since the location here is only used to distinguish multiple users.

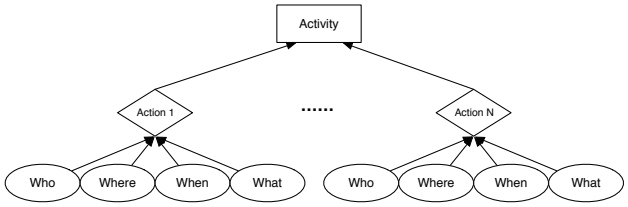


Figure 3: Modification of Activity Theory

Another part of the approach is recognize the activity through actions. Here we use time series analysis technology to solve this problem. We assume that the inhabitant always do the actions in similar order in one activity. For example, a user first opens the refrigerator, then uses the knife and gas stove in the morning. The most likely activity he does is making the breakfast.

In this way, we can finally recognize the activity of the inhabitants just using the phase of passive RFID tags.

4 Conclusion

This paper summarizes the corresponding relationship between action and phase value of passive RFID tag. And a novel approach to recognize the activity of inhabitants based on the object usage is proposed. This approach is a feasible solution for smart home in the future.

5 Acknowledgements

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