Designing the Smart Foot Mat and Its Applications: as a User Identification Sensor for Smart Home Scenarios

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Abstract. Due to radical advancement of sensor network technologies, smart home service market has been growing than ever before, that enables our life easier, simpler, and safer. Floor sensors in houses have been developed to locate user presence and to provide location-based, context-aware scenarios as well as to minimize privacy invasion. However, there is an installation cost and user identification issues where the sensors are installed on whole floor and have low scanning resolution. In this paper, we propose a novel smart home sensor system with a smart-textile-based, foot-mat-shaped user identification sensor, which equipped wireless communication capability and have less limitation on installation places. Our smart mat based smart home scenarios are suggested.

Keywords: Smart Home Scenario, Smart Textile, Footprint Recognition, Ambient Intelligence, Sensor Network

1 Introduction

Smart home service is blooming in the virtue of development of sensor network technologies, so that delivering more convenient life style in our home. Lights, dish washers, coffee machines work according to context information such as user identity, his activity, weather, indoor temperature, and so on. Commercialized its applications are demonstrating various simple, useful use cases which is mainly focusing on in-and-out scenarios. This results from not only that users carry their cell phone with them since they leave their houses so that the service system can easily recognize their locations, but also that there is much miscellaneous work.

Based on these scenarios, user localization technologies have been investigated. However, a large quantity of them has focused on whole floor sensing, which cause enormous installation cost and time. In this paper, we propose a foot mat sensor which allows easy installation and market feasibility. This smart mat system is designed to be capable of capturing user identity information, building wireless sensor network, and transmitting the information to the central control system.
2 Related Work

Helal [1] proposed a programmable pervasive space as a scalable and cost-effective method for smart home services. In his paper, he introduced a lot of smart house technologies such as smart bed, smart refrigerator and smart plugs. He also devised Smart space middle ware to cover heterogeneous sensors and actuators, and provide various intelligent applications by making it to have an open architecture. A knowledge layer was included, so the system may serve more accurate semantic information which advertisers can register.

Recognizing users with on-floor sensors has been investigated to figure out user activities and context information. Middleton [2] introduced a floor sensor with relatively low resolution, which aims to identify person via gait information. More accurate recognition sensor for user activity and identity is demonstrated by Cheng [3]. It is equipped with low precision pressure sensors and categorizes discriminative weight distribution on both feet. He enabled it to identify users with an accuracy of 88.6% and classify 5 activity directions with an 86.3% accuracy in average.

3 Smart Mat Sensor Design

In this paper, we design a smart home architecture for the smart mat as shown in figure 1, which can enable diverse scenarios.

![Smart Mat Sensor Design](image)

One sensor mat works as a gateway as shown in Fig. 1 (a). The other mats communicate with a nearby mat which has smallest hop number to data their data to gateway. The gateway combines received data and its own data, and send it to the central decision making server. The central decision making server may receive user environment data from other sensors and/or context information from external service providers. Based on its logic, it select relevant service scenario and send operating data to actuators. The mat size should be similar to existing foot mat to be placed easily by users and harmonize with other furniture as a prop, part of interior design. As it could be randomly placed in any room, the communication module should be wireless and able to access to the gateway regardless of its location.
We used conductive thread and piezo-resistive fabric to implement our smart mat more similar to existing foot mats (Fig. 1(b)). We sewed silver-plated thread on two normal fabrics along row and column direction. Piezo-resistive fabric was placed between them. As the resistance value between a row and column is changed when the surface is pressed, it is possible to measure user weight with it. Zigbee module is used to build ad-hoc network.

We developed PC side software to receive the sensor data via USB. A microprocessor connected to the sensor matrix controls the scanning sequence as did UnMousePad [4][5][6]. It sends acquired data to the PC. We visualized and analyzed the acquired data. As shown in Figure 1 (c), it is enough to retrieve necessary personal identification information from a footprint.

4 Smart Home Scenarios with Smart Foot Mat

Smart mat is capable of providing a wide range of applications by sensing a user's identity and activity in the house. Various user scenarios are provided by combining smart mats and actuators.

![Smart mats installation scenarios. Laid at entrance (a)-1, each room and a place with flaw in security (a)-2. They acquire user identity and location. Services can be provided by associated with nearby actuators (b-d)](image)

Smart mat systems recognize the person who is on it, and can provide personalized services according to each family member. When mother come back from the work, the entrance mat (a)-1 in Fig. 2 recognizes her and can turn on the light (b) in her room. As it is sensing the position of all family members, if every member is gathered in the living room, the television would recommend a family movie or drama can be seen together.

Moreover, our system can assist in day-to-day healthcare by checking the user's body weight more conveniently. When they are on the smart mat, it converts the pressure data to weight and send it to the server, so that the users can their regular weight measurement unconsciously.

The smart mat assures safety and security. When a child go nearby the stove (c), for instance, our system can make the hot stove turned off and prevent burn. A stranger’s weight and foot shape will be different from those of family members. Our system can recognize the intrusion. If someone enter through a place where family
members usually do not use and the footprint’s direction is different from as usual, it can ring the alarm. As shown in (a)-2, users can lay the mat at vulnerable points.

Existing automatic lighting controller (d) turns off the light in a room if there is no movement for a certain time. The light can be turned off while a person is wearing his shoes, or can be kept turned on for a while even though there is no one. With our smart mat, the smart home system can detect user’s presence, so that the light will be turned off as soon as users leave the room and reduce energy consumption.

5 Discussion and Conclusion

In this paper, we proposed a novel sensor pad which is capable of sensing user identity, moving direction and weight. Several issues would be dealt in further researches.

Identity and weight sensing. We need to improve our system to recognize user’s id and weight. User id can be recognized by analyzing the shape of foot and pressure distribution. Weight can be inferred once it has a reference value. For example, if the pressure value of one point is 1 and it means one kilogram, the other value 10 can be inferred as 10 kilogram. By accumulating the weight over sensed points, the mat can recognize the user weight.

Part of foot problem. In real environment, it would be more frequent that user steps on the mat with only part of their foot. Algorithms should be compromised to deal this issue.

ZigBee networking. As it has not yet tested, we need to evaluate the feasibility of the proposed algorithm in a place with lots of doors and walls.

Our proposed smart home architecture and scenarios compose attractive features for smart home. Smart home services can be more intelligent where provided each users location and activity data. We continue to explore accurate and realistic solution for indoor user localization and identification.

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References