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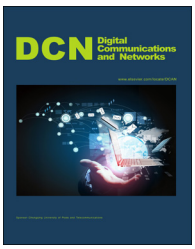

A review on radio based activity recognition

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Abstract
Recognizing human activities in their daily living enables the development and widely usage of human-centric applications, such as health monitoring, assisted living, etc. Traditional activity recognition methods often rely on physical sensors (camera, accelerometer, gyroscope, etc.) to continuously collect sensor readings, and utilize pattern recognition algorithms to identify user's activities at an aggregator. Though traditional activity recognition methods have been demonstrated to be effective in previous work, they raise some concerns such as privacy, energy consumption and deployment cost. In recent years, a new activity recognition approach, which takes advantage of body attenuation and/or channel fading of wireless radio, has been proposed. Compared with traditional activity recognition methods, radio based methods utilize wireless transceivers in environments as infrastructure, exploit radio communication characters to achieve high recognition accuracy, reduce energy cost and preserve user's privacy. In this paper, we divide radio based methods into four categories: ZigBee radio based activity recognition, WiFi radio based activity recognition, RFID radio based activity recognition, and other radio based activity recognition. Some existing work in each category is introduced and reviewed in detail. Then, we compare some representative methods to show their advantages and disadvantages. At last, we point out some future research directions of this new research topic.

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1. Introduction

Activity recognition aims to accurately detect human's daily activities based on a predefined activity model [1]. It is a hot research topic in the field of ubiquitous computing and widely used in many human-centric applications, such as health and fitness monitoring [2-10], assisted living [11-17], context-enabled games and entertainment [18-20], social networking [21,22] and sport tracking [23-25].

To recognize human activities, physical sensors (camera, accelerometer, gyroscope, etc.) are often deployed in environments, attached on objects or worn on human bodies to continuously collect sensor readings. Then, based on predefined pattern recognition models, the activity types are identified at an aggregator for upper layer applications. These sensor based methods are called traditional activity recognition methods in this paper. They can be roughly divided into three categories: (1) wearable motion sensor based methods [26], which utilize on-body motion sensors (accelerometer, gyroscope, etc.) to sense the movements of body parts, such as [4,5,11,27-32]; (2) camera sensor based methods [33], which take advantage of camera to record the video sequence and recognize the activities using computer vision algorithms. According to the camera type, the video may be RGB video (e.g. [34,35]), depth video (e.g. [19,36]) or RGB-D video (e.g. [37,38]); (3) environmental variable based methods, which use physical sensors (pressure, proximity, RFID, etc.) to infer human activities from the status of used objects or change of environmental variables, such as [16,17,39]. Although traditional activity recognition methods obtain good performances and are widely accepted, they require specific sensing modules and raise some concerns such as privacy, energy consumption and deployment cost.

In recent years, a new radio based activity recognition approach has emerged. As the existence and movement of human body in a radio field may attenuate the radio strength and change the communication patterns (e.g. channel fading) between the transmitter and receiver, radio based activity recognition takes advantage of body attenuation and/or the characters of channel fading to discriminate human activities or gestures. Compared with traditional activity recognition methods, radio based activity recognition methods only exploit wireless communication features. Thus, no physical sensing module is needed. This accordingly relaxes the device deployment requirement, reduces the energy consumption for sensing and data transmission, and protects user's privacy.

For radio based activity recognition methods, the wireless radio types include ZigBee [40], WiFi [41], RFID [42], etc. As different radio data may have different characters and processing steps, we roughly divide the radio based methods into four categories: ZigBee radio based activity recognition, WiFi radio based activity recognition, RFID radio based activity recognition, and other radio based activity recognition. In this paper, we first introduce and review some related work in each category. Then, some representative methods are compared to show their advantages and disadvantages. At last, we discuss some future research directions of this new research topic.

The rest of this paper is organized as follows. ZigBee radio based activity recognition is reviewed in Section 2. Section 3 introduces WiFi radio based activity recognition. Section 4 describes RFID radio based activity recognition. Other radio based activity recognition is presented in Section 5. Section 6 shows the comparison of radio based activity recognition methods. Section 7 presents future research directions. Conclusion is drawn in Section 8.

2. ZigBee radio based activity recognition

ZigBee is a low-cost, low-power, wireless mesh network standard [43]. It is widely used in wireless sensor network, e.g. body sensor network [44-48]. Qi et al. [40] propose RadioSense, a prototype system of ZigBee radio based activity sensing. Fig. 1 and 2 show the sensor deployment and system architecture of RadioSense, respectively. RadioSense contains three main components: (1) two dedicated on-body sensor nodes placed at user's wrist and ankle. They work as radio transmitters. (2) A sensor node placed at the center of user's body. It is the base station of body sensor network and works as the radio receiver. (3) A laptop works as an aggregator. At the aggregator, the time and the Received Signal Strength Indicator (RSSI) value of each arrival message are recorded.

With the observation that different human activities result in different wireless communication patterns between the sensor nodes and the base station, RadioSense extracts packet delivery ratio (PDR) feature from message arrival patterns and 18 statistical features (the max, min, max-min, mean, var, median, mean crossing rate, values of the RSSI histogram with 10 bins, and interquartile range) from RSSI values for each sensor node. Then, the feature selection algorithm with sequential forward strategy [49] is used to select the best features. Based on the selected features, the support vector machine (SVM) based classification model is trained for online testing. Fig. 3 shows the runtime accuracy of classifying seven activities for three

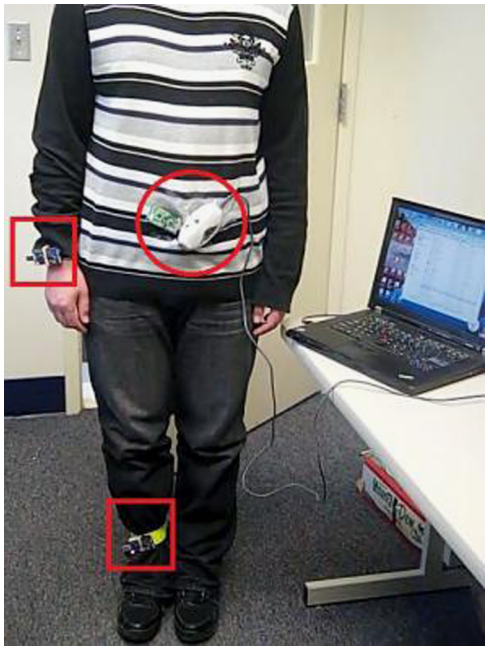

Fig. 1 Sensor deployment of RadioSense [40].