Device-Free Localization and Activity Recognition using Array Sensor

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Thesis Abstract

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Thesis Title

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Thesis Summary

In recent years there has been a growing interest in localization and activity recognition of people indoors. Most of the existing systems such as the Global Positioning System (GPS) and wearable sensors, which require wearing sensing devices on the person to estimate their locations and activities, might be inconvenient from the users' perspective. This is particularly relevant for users who have some physical or mental disabilities. There are other scenarios where it might be impossible to attach the sensors, since the person that is being monitored is not expected to cooperate with the system, such is the case with intruders in an alarm system.

Device-free sensing technology is a novel concept to estimate location and to recognize activity of people using radio frequency (RF) as the sensor, where the people do not need to carry any sensing device. It can be applied in various scenarios such as intruder detection in security and elderly monitoring in healthcare. Recently, many researchers have proposed state-of-the-art device-free sensing methods using received signal strength (RSS) measurements. These methods show high localization accuracy and provide reliable performance in real environments. However, RSS-based systems have some limitations, because the RSS itself contains noise and fluctuates even in a static environment.

In this dissertation, we discuss novel methods for device-free localization and activity recognition using signal subspace features such as signal eigenvectors and eigenvalues measured by an antenna array on the receiver, referred to as array sensor. There are significant challenges to use the array sensor for localization and activity recognition. To achieve accurate localization and activity recognition, we need as many signal features as possible. However, the conventional array sensor approach provides only a pair of signal eigenvectors and eigenvalues due to the assumption of a single channel transmitter. Moreover, a binary classifier used in that approach, cannot classify locations and activities. In particular, for activity recognition, the temporal changes of a person should also be considered.

In Chapter 1, we provide the motivations and objectives of this dissertation.

In Chapter 2, we describe the related work in device-free sensing technologies including conventional sensor

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technologies such as computer vision, passive infrared (PIR), and ultrasound sensors. We then review the state-of-the-art in RF-based technologies using ultra wideband (UWB), Doppler radar, RSS and signal subspace. We also briefly describe the array sensor and support vector machines (SVM), which were used for the proposed methods.

In Chapter 3, we present a localization method based on multiple channels and multiple subarrays using the array sensor. The proposed method uses spatial smoothing processing (SSP) to obtain radio wave features such as the signal eigenvectors and eigenvalues from multiple channels. The localization is based on an SVM exploiting the signal subspace features. The experimental results show that the localization accuracy is improved using the proposed method.

In Chapter 4, we propose a multiple SVM-based localization method to enhance localization accuracy. Unlike the method in Chapter 3 which requires multiple channels, the proposed method can extract more reliable features from a single channel transmitter, using a probabilistic-based feature selection via multiple SVMs. Using outlier detection and error mitigation methods based on spatial-temporal averaging, the localization error can be reduced.
The experimental comparisons with state-of-the-art methods show the efficiency of the proposed method.

In Chapter 5, we introduce a state classification method that can be used to estimate the activities of a person, such as walking, standing, sitting, and falling. We show feature extraction and selection methods for several activities, and apply the SVM to classify the target entity's activities. We then demonstrate using experimental data obtained in a bathroom and laboratory environments.

In Chapter 6, we conclude the dissertation with key findings in this study and future work.