Demo Abstract: FindIt - Real-time Through-Wall Human Motion Detection Using Narrow Band SDR

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ABSTRACT

We present a system utilizing narrow band software defined radio to detect the moving human through walls, and give some motion details, such as motion orientation which includes relative moving direction. To achieve high accuracy, FindIt applies Short Time Fourier Transform (STFT) and statistical methods to received signals. In order to adapt to different environments, FindIt uses clustering and classification methods to determine thresholds. Moreover, FindIt provides user-friendly real-time detection results, which can be used as a trigger of high-level functions.

1. INTRODUCTION

In recent years, device-free human motion detection based on wireless signals has received a lot of attention. A variety of applications, such as emergency handling, intrusion detection and elderly care, would benefit from such device-free detection techniques. As a pioneering system, Wi-Vi [1] detects moving objects through walls using software defined radio, and get space angle by treating the moving human body as an antenna array. However, it only provides relative motion angle information and performs processing in an off-line manner. WiTrack [2] and WiTrack2.0 [3], utilize Ultra Wideband technology to generate Frequency Modulated Continuous Wave (FMCW) signals and calculate relative distance based on the frequency shift between transmitter and receiver, at a cost of more than 1.7GHz bandwidth that is very scarce [4]. Recently, Tadar [5] uses RFID Reader and RFID Tags to simulate antenna array to work through walls. However, it needs to train a set of channel parameters of an empty room and requires high transmission power beyond FCC limits.

In this abstract, we propose FindIt, a real-time through-wall human motion detection system based on narrow band software defined radio (SDR). FindIt is able to provide detailed human motion information such as motion orientation and relative moving direction, which can be used to trigger an alert for caution or other purposes. Most importantly, it can achieve high accuracy and is adaptive to different environments.

(a) Front view (b) Back view

Figure 1: System Platform.

2. SYSTEM ARCHITECTURE

FindIt consists of a hardware platform for sending and receiving signals and removing flash effect, and a software that controls the transmission and runs detection algorithms.

We implement FindIt using a software defined radio platform (GNU Radio v3.7.6) with USRP N210 and UBX daughter board. Figure 1 shows the system platform. It consists of three USRP N210 (two as transmitters and one as receiver) that all integrated with a horn antenna and connected to a kilomega Ethernet switch and a external clock source OctoClock-G for time and frequency synchronization.

We design a PHY layer for our detection system to eliminate reflection from static objects using MIMO interference nulling method proposed in [1]. In our research, we find that interference nulling method cannot completely eliminate the reflection owing to the constant transformation of channel parameters. So the differences of static and moving situations are not very obvious. Therefore, we try to magnify the differences by using time-frequency transform and statistical methods so that we can set the transmission power to less than 100mW. In addition, since the nulling method is based on OFDM code rather than bandwidth, we can lower the bandwidth to 1MHz to minimize the deployment and computation cost. We build our own signal processing modules and PHY layer modules on GNU Radio, which include power detection, channel estimation modules and so on.

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3. HUMAN MOTION DETECTION

FindIt is able to identify the moving human, recognize relative moving direction and motion orientation. In addition, it can be used in different places by introducing machine learning methods so as to achieve adaptive detection.

3.1 Identifying moving human

How to extract the weak human-induced reflection signals from the received signals is a big issue to be solved. Although the differences of static and moving situations is visible to the naked eyes by interference nulling, the nulling method has a limit and we should magnify the differences to increase the detection accuracy. Therefore, we introduce STFT, which is one of the general radar technology, and signal processing to our detection system in order to magnify the differences. STFT is generally applied into Ultra-wide bandwidth signals, so it can finish the computation rapidly due to narrow bandwidth meanwhile provide both time and frequency information. At last, we get range data, which is compared with the pre-set threshold to detect whether there is a moving human, by statistical methods.

3.2 Relative moving direction

Utilizing Doppler effect is a general way to recognize the relative moving direction. However, the sample rate (1MHz) is too high to disambiguate slight Doppler shifts. In FindIt, we resample the received signals and extract corresponding channel state information (CSI). By doing time-frequency transform for CSI signals and using their phase information, we can get slight Doppler shifts, and are able to know that the moving human is near or far away from the receiver.

3.3 Motion orientation

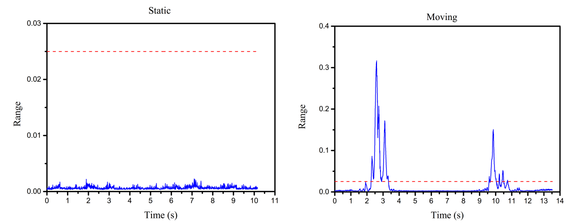
Owing to obvious Doppler shift, it is easy to spot vertical moving relative to the receiver. But distinguish the parallel moving is difficult by tiny shift. In our research, we find that these two type signals have some differences that enable us to get each type of the standard signal by means of signal and data analysis. We classify parallel and vertical moving relative to the wall via using dynamic time warping (DTW). DTW computes the similarities with parallel and vertical standard signals.

3.4 Adaptive detection

The above method of identifying moving human relies on proper thresholds, which are vary among different environments. In order to adapt to multiple scenarios, we introduce machine learning methods into our detection system. Firstly, we devise a novel detection algorithm to determine whether there only exists static situation. Then we utilize a K-mean technique to cluster range data into two categories and label them. Finally, a trained classifier by Support Vector Machine is adopted to classify the detection results.

4. DEMONSTRATION

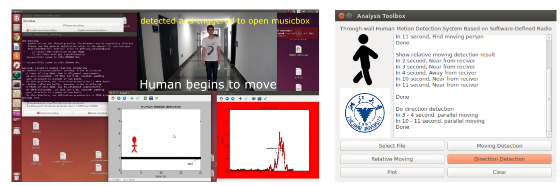
After interference nulling, we do STFT for received signals and then utilize statistical methods to get range data. As shown in Figure 2, the curve is smooth and rarely changed largely in static situation. However, the curve of moving range changed sharply and amplitude is above the threshold when human moved. Using the above human motion detection method based on STFT can achieve above 90 percent accuracy (true positive rate) to detect whether there is a moving human.



(a) Static (b) Human Movements

Figure 2: Detection result graph.

In the actual operation process, the background color of plot and line style will be changed when it detects the moving human and an animated window will display simulant motion when the human moves as indicted in Figure 3(a). In addition, it also will trigger some process, such as opening the music box for alarm and so on. Also, motion information will be displayed in the graph and the detection results will be shown in the terminal. In addition, we allow the signal data to be stored on disk. This way, we can load the signals and perform further analysis off-line (Figure 3(b)). Demo video can be found at [6].



(a) On-line demonstration (b) Off-line GUI

Figure 3: On-line demonstration and off-line GUI.

5. ACKNOWLEDGMENTS

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