Human Motion Detection and Extraction by Using FM-CW Range-Doppler Radar

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Abstract - **Sensing technology using radio wave has been attracting attention for various applications such as office/home security and surveillance. Classification of human motion has been extensively studied in these applications. They often utilize micro-Doppler signature, or Doppler frequency signature occurred by human motion. In this paper, 4 type of range-Doppler signatures in human motion at a certain range are studied, and difference of the motions is confirmed experimentally. Moreover, extraction technique for range-Doppler signature with several moving humans are studied. Experimental results show that we can easily suppress the undesired target responses and extract the desired target response by using range-Doppler filtering scheme.**

Index Terms — **micro-Doppler signature, range-Doppler Radar, human motion detection.**

I. INTRODUCTION

Sensing technology by using radio wave has been attracting attention for office/home security and surveillance [1]. One of these technology is detecting and tracking human in indoor environments. Several studies have been reported in the literatures [2], [3] that show validity of the radio system. Moreover, classification of human motion has also been studied. It utilize micro-Doppler signature, or Doppler frequency caused by human motion. Human motion can be revealed via Doppler signature due to the time-varying returns by human.

In this paper, we show that the range-Doppler distributions of Radar responses by human can be isolated easily and show features of distinct human motion effectively. We experimentally obtained the 4 type of range-Doppler signatures to show distinct motion characteristics in a radio anechoic chamber. These are the reference data for classification. In addition, we show range-Doppler signature of two moving humans in real environment with and without range-Doppler filtering scheme to show the performance of desired target extraction.

II. RANGE DOPPLER ESTIMATION

The range-Doppler Radar developed in this research in based on the FMCW Radar with successive pulses. In this paper, this FMCW measurement is repeated periodically for

TABLE I
RADAR SPECIFICATION

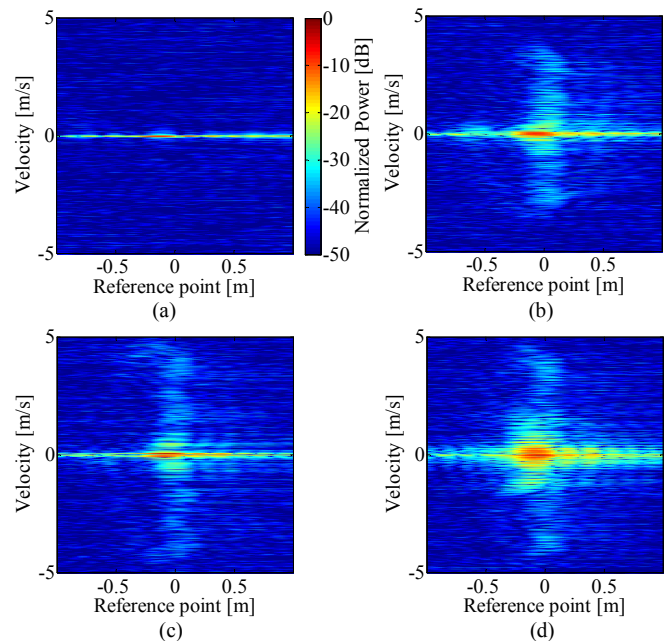| Center frequency	5 GHz
Swept frequency bandwidth	1 GHz
Frequency sweep time	1.0 ms
Pulse repetition interval	1.5 ms
Total observation time	4 s
Sampling frequency	400 kHz

Fig. 1. The 4 type of range-Doppler signatures

total observation time T_{ob} whose pulse repetition interval is Δt. The time-varying beat spectrum is obtained by taking Fourier transform of the beat signal every Δt snapshot. Moreover, the range-Doppler response is obtained by taking Fourier transform of the time-varying beat spectrum in each pulse. Accordingly, the range-Doppler response can be given by

$$F(r,f) = A\mathrm{sinc}\left(\frac{2\pi B}{c}(r - r(t))\right)\mathrm{sinc}(\pi(f + f_d)T_{ob}), \quad (1)$$

where A is a complex constant, B is the swept frequency bandwidth, $r(t)$ is the target position, f_d is the Doppler frequency.
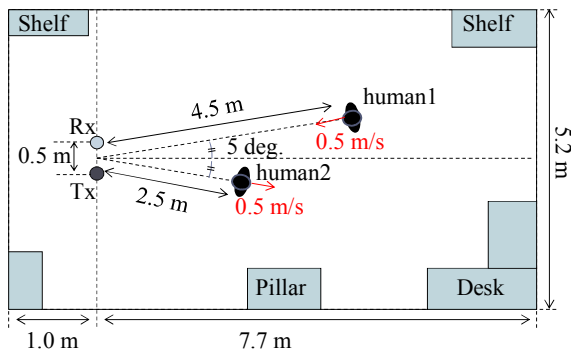
Fig. 2 Indoor environmental setup

(a) Time-varying beat spectrum   (b) Range-Doppler signature
Fig. 3 The experimental result of two moving humans

(a) With position compensation   (b)With range-Doppler filter and the
of the human2   position compensation of the human1
Fig. 4 The corrected range-Doppler signature

III. EXPERIMENT IN A RADIO ANECHOIC CHAMBER

In this study, we obtained the reference data of four motions in a radio anechoic chamber: (a) standing still, (b) swinging arms slowly and vertically, (c) swinging arms rapidly and vertically, and (d) walking. These motions are measured at a range of 4.5 m. Radar specification developed here is listed in Table 1.

Range-Doppler signatures of above four motions are shown in Figs. 1(a), (b), (c), and (d). Obviously, we can discriminate the difference of range-Doppler signature among them.

IV. EXPERIMENT RESULTS OF TWO MOVING HUMANS IN INDOOR ENVIRONMENT

In the actual measurements, the human targets will often move in range. In this section, we studied the experimental scenario as shown Fig.2. The human motion in this scenario is (d)walking. The antenna height was 1.0 m in this experiment, and the other. Radar specifications are the same as listed in Table 1.

Experimental results shown in Figs. 3(a) and (b) are the beat spectrum of each pulse and range-Doppler signature, respectively. Since the target was moving in this experiment, the range-Doppler characteristics in each target can hardly classified into the 4 categories from Figs.1 (a) to (d).

To suppress undesired response from human2, we first apply the position compensation of the human2 response in the time-varying beat spectrum as shown Fig. 3(a). that is to shift the peak of the human2 response to a constant range. From the shifted beat spectrum, we can obtain range-Doppler signature as shown in Fig. 4(a). In this result, the human2 response from 2.5m to 4.5 m in Fig.3 (a) can be focused at about 4 m. Next step is the elimination of the undesired response by using range-Doppler filter. We employ the filter which eliminates components from 3 m to 5 m and Doppler frequency below 10Hz. Furthermore, applying the inverse Fourier transform to the range-Doppler signature in its Doppler domain and compensate position of the human1 response in the filtered time-varying beat spectrum, we can
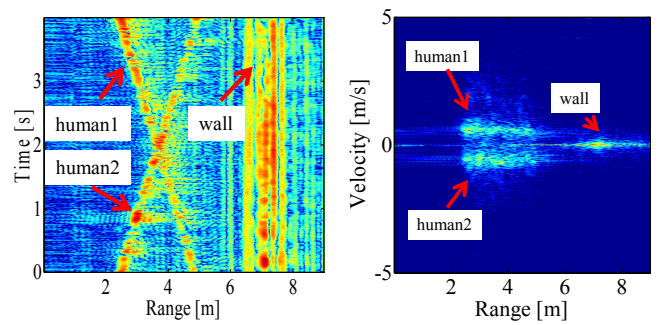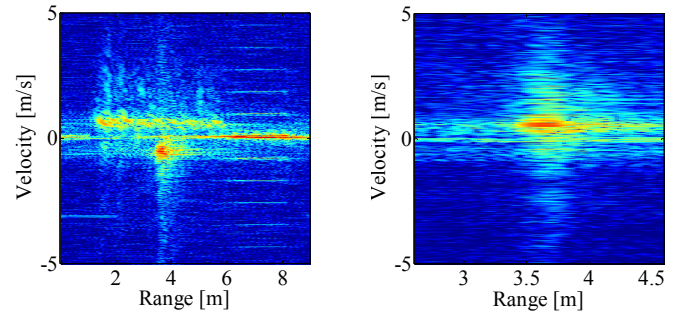
realize range compensated human1 response whose range-Doppler signature is shown in Fig. 4 (b). Since undesired response is removed and movement of the desired target in range is compensated, we can easily compare the range-Doppler signature in Fig. 4(b) with those in Figs. 1(a) to (d), and can classify the signature into walking category shown in Fig.1 (d).

V. CONCLUSION

In this paper, we have proposed human motion estimation by using range-Doppler filtering scheme. We have shown that the proposed scheme is effective to suppress undesired target response. Qualitative analysis on human motion classification will be done in near future.

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