Poster Abstract: Human Detection with Weak Ranging Signal for FMCW Radar Systems

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ABSTRACT

The method is proposed to detect human body with frequency modulation continuous wave (FMCW) and millimeter-wave (mmWave) radar. Human detection is the first step before performing vital sign monitoring, which is one of the most important applications for mmWave radar. In this Abstract, we exploit the range profile (RP) variation within a certain distance to detect human. This requires less computational storage spaces than conventional approaches. First, we perform clutter removal processing to weak ranging signals, and then calculate the standard deviation of each chirp to identify whether there is human in radar's field of view (Fov). The experimental results confirmed that the accuracy our proposed method is higher than 97% even if the received ranging signals are weak.

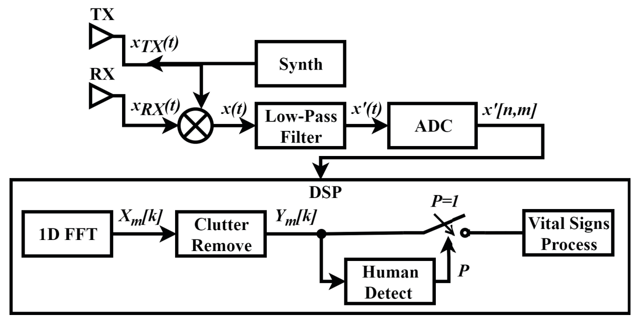

Figure 1: Block Digram for FMCW mmWave Radar Signal Processing.

1 INTRODUCTION

Recently, there has been an increasing interest in applying FMCW-based mmWave radar to measure vital signs [2]. Due to the high accuracy and high sensitivity of the FMCW radar, it can detect small amplitude variation caused by the human bodies, such as breathing and heart-beating. Before monitoring the vital sign of human, it necessitates to detect whether human presents in the monitoring region or not. Unfortunately, when the human is far from the radar sensor, the resulting ranging signal becomes weak to identify and becomes vulnerable to the static clutter. In [3], the authors have been used the deviation of the RP for each distance grid to determine weather human presented on that grid or not. However, it requires more memory spaces to store the samples of RP for each bins. This Abstract proposes a novel method that exploits the variation of RP over a certain distance. We propose observing the deviation of the RP over spaces. The main advantages is that our method requires much less computational storage. When the ranging signal is weak, we method gains higher detection rate then that of in [3]. Moreover, we have conducted real experiments to verify the effectiveness of our proposed method.

2 PROPOSED METHOD

Figure 1 depicts the blocks of our FMCW mmWave radar to detect human. More details can be found in the literature [1]

The mixer combines the transmitted signal and the received signal to produce a fixed intermediate frequency (IF) signal. The IF signal after one dimensional fast fourier transform (1D FFT) (1) will show multiple tones, and each tone is proportional to the distance detected by radar of each object. The formula of 1D FFT is as (1), and $|X_m[k]|$ is the RP. Where N is the number of FFT points, k is the index of each frequency point, n is n-th sample, and m is m-th chirps that get one chirp from each frame. After 1D FFT, the distance and phase information of the detection target including static objects can be obtained.

$$X_m[k] = \sum_{n=0}^{N-1} x'[n,m] e^{-j\frac{2\pi nk}{N}}, k = 0, ..., N-1 \tag{1}$$

where $x'[n,m]$ denotes the n-th sample for the m-th chirps. In order to obtain the position of the human body more accurately, the alpha filter is used to smooth the past phase (2), and then it is subtracted with the original phase to remove clutter. Hence, after removing clutter, we can get the frequency spectrum $Y_m[k] = X_m[k] - X'_m[k]$.

$$X'_m[k] = \alpha X_m[k] + (1-\alpha) X'_{m-1}[k], 0 \leq \alpha \leq 1 \tag{2}$$

Before calculating vital signs, it is important to determine whether there is there are still targets in the environment. If there is no target, the value of breathing and heart rate will be meaningless. However, it is difficult to determine whether there is target when the angle is large and the distance is long. This paper proposes a method that calculates the standard deviation (SD) $\sigma(m)$ of $|Y_m[k]|$ every chirps and can be expressed as follows:

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Table 1: System Parameters

Parameter	Value
Start Frequency	60.6 GHz
ADC Sample Rate	5300 ksps
Number of ADC Sampling	128
Chirp Duration	24.15 μs
Chip Slope	82 MHz/μs
Frame Frequency ($\mathcal{M}$)	10 Hz
Range Resolution	0.0757 m

$$\sigma(m) = \sqrt{\frac{1}{i_e - i_s + 1}\sum_{k=i_s}^{i_e}(|Y_m[k]| - \mu)^2} \tag{3}$$

where $|Y_m[k]|$ is value of frequency spectrum after removing clutter, μ is the sample mean of $|Y_m[k]|$ from the index i_s to i_e. We take the maximum value σ_{max} from every $\mathcal{M}$ $\sigma(m)$ as follows:

$$\sigma_{max} = max(\sigma(m)|_{m:m\rightarrow m+\mathcal{M}-1}) \tag{4}$$

where $\mathcal{M}$ denotes frame frequency. Lastly, we smooth σ_{max} by the following recursion:

$$\sigma'(m) = \alpha\sigma_{max}(m) + (1-\alpha)\sigma'(m-1), 0 \leq \alpha \leq 1 \tag{5}$$

If $\sigma'(m)$ is greater than the threshold value η, the symbol of human detection P will be marked as 1, which means radar has detected the existence of the targets and has started to calculate the vital signs. If $\sigma'(m)$ is smaller than η, P will be marked as 0 and radar will keep searching for existing targets in the place.

3 EXPERIMENTAL RESULTS

This experiment uses Texas Instruments (TI) IWR6843ISK-ODS Evaluation Module which works in the 60-64 GHz frequency and has 120°(±60°) azimuth and 120°(±60°) elevation FoV. The radar was installed on the ceiling of the lab with height of 2.8 meters, and the parameters is shown in table 1.

In order to verify whether the radar can still precisely detect the existence of the objects when the target is at the margin of radar's FoV, the experiment measured three cases: no objects (C1), an object lying at a distance of 3.7 meters from the radar and an angle of 57 degrees (C2), and an object sitting back to the radar at a distance of 3.7 meters from the radar and an angle of 52 degrees (C3). We deliberately chose the positions where the radar signals are weak to verify the effectiveness of the method. The result of comparing with-object and no-object is shown in Fig. 2. The solid line is calculated SD of RP every chirp from index i_s to i_e. In addition, we compared method [3] that calculates the SD of RP every index and taking the maximum value in $\mathcal{M}$ chirps. It shows the dotted line in Fig. 2. For C2 case (lying), both of method has 100% correct rate. However, our method outperforms the work [3] by 1.6% in terms of detection accuracy for C3 case (sitting back). To obtain σ'_{max}, the storage requirement used by proposed method is $(i_e - i_s + 1)$, but that for the method [3] is $\mathcal{M} \times (i_e - i_s + 1)$.

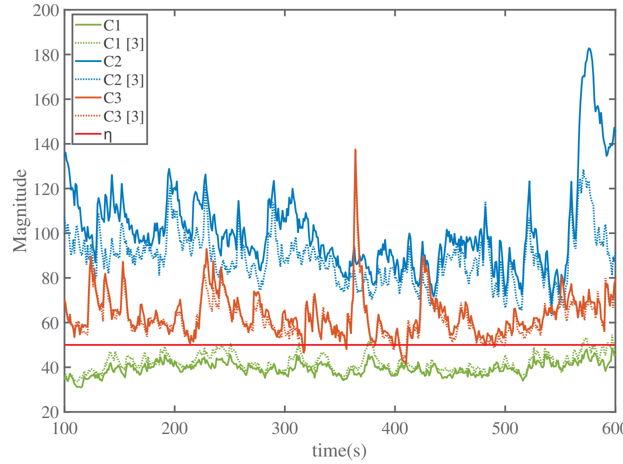

Figure 2: Resulting Standard Deviation of Range Profile (RP).

4 CONCLUSION

This paper provides a method to detect human body with weak ranging signal in FMCW radar's Fov. In the experiments, after removing clutter from signals, we calculate the SD of RP and smooth the values. The maximized values with a simple threshold value can detect whether there is object in the range. As follows, the experiments prove that the method in this paper can reduce the calculations and obtain higher accuracy with less storage requirements than the methods in other papers.

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