**A Novel Method for detecting vital signs**

**of moving subjects by tracks cathing and Parameters estimation(TCPE)**

Abstract-The impulse ultra-wideband(UWB) radar has been widely used for noncontact vital signs detection. However, it’s still a challenge to detect one moving subject. In this paper, a novel signal processing method based on track prediction and Parameter estimation(TPPE) is proposed to detect the vital signs of moving subjects.

**Ⅰ. INTRODUCTION**

In recent year, the noncontact vital signs detection has drawn more and more attentions. The current research methods mainly belong to two categories, Ultra-wide band(UWB) detection and Continuous Wave(CW) detection. Compared to CW radar, the UWB radar has more advantages in vital detection, such as low power, good noise immunity, strong penetrability and so on. Some works have been done in the early time in detecting vital signs by UWB [1-4]. But due to the poor performance of detection accuracy when facing breathing harmonic interference, strong noise and object movement, some useful methods are proposed to address these challenges. The moving target indicator and Wavelet Transform methods are proposed to suppress the breathing harmonics [5-7]. In [8], Spectrum-Averaged Harmonic Path Algorithm (SHAPA) is applied here to detect heartbeat rate when heart fundamental has not the highest peak of the spectrum, without suppressing respiration harmonics. In order to improve the signal to noise and clutter ratio (SNCR) or extract the vital signs even in low SNCR environment, some novel methods are proposed [9-17]. In [18], a 2D noncontact human respiration localization method using Ultra-Wideband (UWB) 1D linear antenna array are given. However, the object states analyzed in the above are all stationary. To detect the vital of moving subjects, some methods are proposed [19-20], but these methods need multiple antenna to acquire signals from different directions.

In this paper, a new method is proposed to detect the vital signs of moving subjects. By predicting the track of the subject movement through the raw Ultra-Wideband (UWB) signals, and get the periodic vibration signal caused by the subject respiration and heartbeat. Then, we use the parameter estimation method to extract the vital signs of the moving subject. The performance will be proved by simulation and experiment.

This paper is organized as follows. Section Ⅱ describes the mathematical model for noncontact vital signs detection based on ultra-wideband(UWB). In Section Ⅲ, the novel detection method based on TPPE is proposed. In Section Ⅳ, the simulation results are shown. In Section Ⅴ, the effectiveness of the novel algorithm is validated with experimental results. The conclusions are presented in Section Ⅵ.

**Ⅱ. UWB VITAL SIGN MATHEMATICAL MODEL**

The distance between the antenna and the human chest can be observing by the periodic variation due to respiration and heartbeat, which is expressed as

 (1)

Where  is the average distance between the antenna and the chest center,  and  are the chest variation amplitudes resulting from respiration and heartbeat,  and  are the frequencies of the respiration and heartbeat.  indicates slow-time.

Thus, the change of propagation time delay of reflected signal can be indicated by

 (2)

Where  is the propagation speed of the radar wave, and ,, can be given by ,,

Assuming that only the detected subject is motional and all other subjects are stationary, and the impulse response of the radar is

 (3)

Where  and  represent the fast-time and slow-time,  and  are the signal amplitude of the vital object reflection and the static target reflection ,  and  are the propagation time delay of the vital object reflection and the static target reflection.

So the received signal can be expressed as

 (4)

Where  represents the transmitted impulse signal.

To explain the actual received signals which is discrete, we can define the reflected pulse signals as

 (5)

Where  is the pulse repetition time interval ,,  is the sampling interval in fast time,  represents the fast-time sampling points.

**Ⅲ. DETECTION ALGORITHM**

In this section, the proposed detection algorithm is presented. We can get the respiration and heartbeat frequency even the received signals are suffering strong noise interfaces.

1. **some data processing method**
2. stationary clutter suppression

To suppress the stationary clutter from the static objects around the test vital subject, we should subtract the background data. Because the background is settled, so the background clutter signals can be thought as static components which can be described as



Where  is the slow-time sampling point,  is the fast-time sampling point, and the signals after subtraction is



1. non-stationary clutter suppression

We use singular value decomposition(SVD) to suppress non-stationary clutter. The

signals can be decomposed as



Where  (MxM dimension) , (NxN dimension) are the unitary matrices. Columns of U and V matrices are called right and left singular vectors. S matrix is ordered from higher to lower values . The first eigen values of the matrix generally represents the clutter. The result can be constructed as



1. **Tracks catching**

Under normal circumstances, when the vital object doesn’t move and the average

distance between the antenna and the chest is unchanged. But when the vital subject is moving, the average will change and the distance formula (1) will be rewritten as



Where the  represents the moving model which defined as



Where  represents the accelerated speed and  is the initial moving speed.  is the original distance between antenna and the chest.

To obtain the periodic signal of chest vibration, we can use the received impulse signals at slow time to predict the subject moving model.

We can get the dataset ,  represents the label meaning the received impulse signal at one instantaneous time which contains effective reflected signal component.  represent the time point when the signal is received.  represents the impulse signal peak position. Because the subject is moving, so the position of the peak of received signal is moving with the same status as well, and we can use this dataset to estimate the moving track well.

After we get the moving tracks, we can get the periodic signals caused by chest vibration. Then we will use the Parameter estimation method to get the respiration and heartbeat frequency components as following.

1. **Parameter estimation method**

The processed signal model can be written as



Which can be rewritten as



Where the  represents the  harmonics,  and  are the initial phase of respiration and heartbeat signals

The real received signal is



Then, we can find the matched parameters by solving



Where  represents the parameters . And we can rewritten equations as



Where

 

We can solve the equation() by







The Equation() can be solved by particle swarm optimization (PSO) .

To simplify the calculation, we can extract the parameter step by step. We know the fact that the chest vibration amplitude caused by respiration is much more strenuous than that by heartbeat,  , And the equation () is mainly influenced by the respiration movement. So we can get the respiration rate by the simplified equation:



Where

 

From Equation () , The received signals can be presented as



The received signals will contains the respiration harmonic interferences whose amplitudes might be greater than heartbeat amplitude. Thus , before extracting the heartbeat component , we need to eliminate the respiration harmonics influences .

We know the amplitudes of respiration harmonics are diminishing and the third respiration harmonic frequency may be close to the heartbeat. So we just need to consider the second and third respiration harmonics. The detailed procedure is shown in Table



Firstly, we solve the equation () and get the respiration fundamental component, Then, we search the second harmonics at the frequency region which we set is and the third frequency region is  ,where  represents the estimated respiration fundamental frequency,  is the frequency searching scope which we set is 1/60 Hz (i.e., 1 beat/min) .

**Ⅳ. SIMULATION RESULTS**

1. **Simulation model and parameters**

The UWB signals received from the periodic vibration due to respiration and heartbeat is

is simulated by MATLAB. The transmitted UWB signal is the second derivative of the Gaussian pulse and the detail simulation parameters are described in Table 1.

1. **Simulation result with stationary object**

As is shown in Fig 3, the method proposed this paper is applied to one stationary object.

Fig 3.(a) show the origin received vital signal matrix with heavily clutter. After suppressing the clutter, the result is shown in the left side of the Fig3.(b) and the tracking result curve can be seen from the right side of the Fig3.(b). Due to the static state of the detection subject , the curve is a line parallel to the x axis which means the distance between the antenna and the object chest is fixed . Through this tracks, we can get the vital signs signals which is shown in Fig3.(c) and the reference FFT result is also represented at Fig3.(d). We can see from the FFT result that we can get the respiration rate through the peak searching but we can’t be able to get the heartbeat rate . So we use the Parameters Eestimate method to extract the heartbeat rate . According to the steps shown in table 1, we can first get the respiration rate and then suppress the respiration harmonic and we can catch the heartbeat at last. The process is show in Fig3.(e) and (f) , the g(w) before the suppression of respiration harmonic at the frequency of heartbeat range , it reveal that the third respiration harmonic value is higher than the heartbeat value. After suppressing the third respiration component , the highest value occur at the heartbeat rate frequency 1.2Hz .



1. **(b)**



**(c) (d)**



**(e) (f)**

**Fig 3 . (a)the original matrix with clutter. (b)signal processed and the tracks catching result curve. (c)the signal obtained along with the tracks. (d)reference FFT method on the tracking signals. (e)the g(w) before the suppression of the respiration harmonic. (f)the g(w) after the suppression of the respiration harmonic**

1. **Simulation result with moving object**

As is shown in Fig 4, the method proposed this paper is applied to one moving object

with speed of 0.2m/s and acceleration speed of 0.01m/s2. Fig 4. (a) show the origin received vital signal matrix with heavily clutter. After suppressing the clutter, the result is shown in the left side of the Fig4. (b) and the tracking result curve can be seen from the right side of the Fig4.(b). Due to the moving state of the detection subject, the curve extending upwards means the distance between the antenna and the object chest is changed with acceleration. Through this tracks, we can get the vital signs signals which is shown in Fig4. (c) and the reference FFT result is also represented at Fig4.(d). We can see from the FFT result that we can get the respiration rate through the peak searching but we can’t be able to get the heartbeat rate. So we use the Parameters estimate method to extract the heartbeat rate. According to the steps shown in table 1, we can first get the respiration rate and then suppress the respiration harmonic and we can catch the heartbeat at last. The process is show in Fig4. (e) and (f) , the g(w) before the suppression of respiration harmonic at the frequency of heartbeat range , it reveal that the third respiration harmonic value is higher than the heartbeat value. After suppressing the third respiration component, the highest value occur at the heartbeat rate frequency 1.2Hz .



**(a) (b)**



**(c) (d)**



**(e) (f)**

**Fig 4 . (a)the original matrix with clutter on moving object. (b)signal processed and the tracks catching result curve. (c)the signal obtained along with the tracks. (d)reference FFT method on the tracking signals. (e)the g(w) before the suppression of the respiration harmonic. (f)the g(w) after the suppression of the respiration harmonic**

**Ⅴ EXPERIMENTAL DATA ACQUISITION**

1. **Radar system**

The UWB impulse radar used in this paper for data acquisition was X4M03 made in

XETHUR company. Table1 show the details. The center frequency of the the radar is , the fast sampling rate is , so the num of fast sampling point is and the actual distance between two point is 0.00514m. The slow-time sampling rate is 17Hz ，and we use a segment time window of 30s， so the num of slow sampling point is ,

1. **Measurement Setup**

To validate the performance of the proposed method this paper, Two data sets were acquired in the experiment. Firstly, the human subject is stationary whose a and v are all zero . As shown in Fig . the average distance between the antenna and the human subject nearly stay stationary. Secondly, the human subject is moving facing the antenna with a and v . As shown in Fig the tracks has a moving a and v .

**Ⅵ. EXPERIMENT RESULTS**

**Ⅶ CONCLUSION**

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