Radar Human Gait Signal Analysis Using Short Time Fourier Transform

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Abstract. Human gait detection and identification by using radar signal is one of the recent subject of increased research area in signal processing. It has been indicated human gait information/signal is highly unusual which can be used for human detection and identification from one person to another. Most previous works related to this area extraction of features from the pace of pedestrians is only depending on the motions rhythm signal analysis and synthesis. Then Fourier transform and more recently time-frequency transforms are used to analyze the time shift/delay and identify the different parts of the human body playing part during the human movement. The analysis of the time/frequency shift usually needs to observe the process by taking a bit long time, at least long enough to get the gait signal cycle. However, the presence of several people simultaneously in the radar field of sight could involve interferences. Hence, in this paper we have been trying to use one of a powerful tool short time Fourier transform for the analysis of time-varying signals among the time frequency methods to extract some feature of human gait.

Keywords: Time frequency analysis · Radar signal · Matlab

1 Introduction

This work introduces radar signal analysis which retrieved from a number human gait movement signals. Unlike the analysis of the movement of rigid bodies within the context of conventional autonomous target recognition, the analysis of human gait signal exhibits substantially a bit more difficulties because the individual portion of the human body experience different signal movements that change over time/frequency results in a dynamically alternating the wave of the target which in turn produces a high perplexed time–frequency (TF) construction of the radar signals that determine the target movement via time [1–3].

While the analysis of human gait has been studied in a deep way by the various fields for different application starting from the last few decades [3]. Some recent research works attempts to generalizing the frame work of human gait from radar signals are relatively more recent [4]. Here also we try recognize/identify the response human gait signal information from radar spectrum signal of various human scenarios

F. Mekuria et al. (Eds.): ICT4DA 2017, LNICST 244, pp. 82–88, 2018.
https://doi.org/10.1007/978-3-319-95153-9_8

like walking and running and so on using different extracting techniques of signal processing method for individuals are different [4].

2 Related Work

Human gait is composed of very complicated body structures and reflects radar signals with time shift modulations that shows data about pedestrian movement has various dynamic behavior. The overall frequency shift signal of a human movement, including breathing and heartbeat, which includes the biometric radar signals, has get substantial concern in the time of some courses [4]. Recognizing this signal using time-frequency representations (TFRs) are an efficient tool for non-stationary signal classification of human gait analysis has typically been performed with joint time-frequency signal techniques [5]. The scatter diagrams of stride and appendage/torso ratio vs. velocity are also taken as gait signature and a linear classifier is built to identify gender and human presence [7].

Furthermore, the extraction of data from the nature of the motion of human being using time shift radar echo signals are represented by their time-frequency signatures in the most of previous related works. The time-frequency classifier used in this paper follows the work in which no specific feature is extracted, but rather the entire time-frequency representation is used.

The human gait model is the starting point for human signal performance description. Dealing with the relationship between the different body components at the time of movement; factors that gives us gait signal distinct can easily be identified from the experiment data analysis. The basic significant human gait parameters of radar dependent behavior controlling are velocity profile and radar x-section.

Consider an individual is walking at a constant velocity, V wrt an initial point in a certain direction. Another assumption is we may segment the body into m rigid body portions. Each of the body parts including the torso have a velocity profile, $V_m(t)$ that can be expressed as a summation of sinusoidal signals in the form of equation [9]:

$$V_m(t) = v + A \cdot \{k_{m1} + \sin(\omega_c t + p_m) + k_{m2} \cdot \cos(\omega_c t + p_m) \\ + k_{m3} \cdot \sin(2\omega_c t + p_m) + k_{m4} \cdot \cos(2\omega_c t + p_m)\}$$

Where, $k_{m1}, ---, k_{m4}$ and $p_m\{0 \le p_m \le \pi$ are constants that characterize each of the body components.

3 Radar

A simple experimental radar generates continuously a sinusoidal wave signal which can operate in the frequency ranges of 50 Hz. This continuous wave radar is like the hand-held machines applied by police to determine the speed of moving vehicles. As mentioned above human beings are complex target due to having many complexly arranged elements during movement of body components in motion along different trajectories with various speeds. It's always make even more complex human kinematic modeling when we consider extreme excess of different human motions, which all have radically different kinematics, such as running, walking, jumping, swimming, slithering creeping, or playing ball and so on. Even within the same type of movement, such as running as an example, by handling something load or running in a ring, as opposed to linear, trajectory can change the kinematics. In this work, we confine our coverage particularly by assuming human walking, which is the most common human motion.

3.1 Human Motion Identification Using Radar

CW radars employ continuous sinusoidal signal wave-forms, expressed as $\cos(2\pi f_0 t)$. Transmitting and receiving the frequency spectrum of the radar echo from stationary body will be considered when frequency in Hz is at f_0. The frequency shift during echoes or radar signals from non-stationary bodies represented as fd in Hz, which is called Doppler frequency as depicted in the Fig. 1 below. Hence, by determining continuous wave radar signals frequency shifts or differences, radar signals vary in the same manner of perfect target radial velocity. Because of the continuous nature of CW emission, range measurement is not possible without some modifications to the radar operations and waveforms

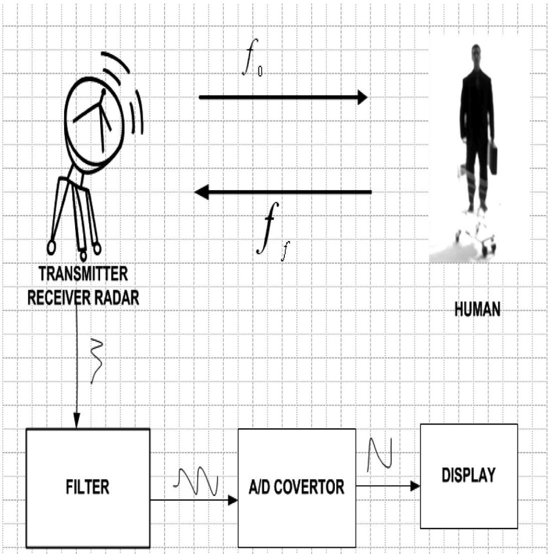


Fig. 1. Expermental setup

The bandwidth of our experimental radar signal ranges about 50 Hz. From this simple diagram the person told stay in front of the radar at about 50 m distance for few seconds. Then, s/he begins walking in relation to the radar at unvarying rate. This experiment is done in a 2 m wide and 50 m long corridor. A time counter indicate that many people takes 12–14 s finish about 15 m.

3.2 Requirements of CW Radar for Human Movement Characterization

Unlike, the optical system of human gait signal analysis continuous wave radar signals do not need light signal to take information/signature from human movement which can be used as identification even though the signal are needs to analyzed and synthesized from different parts of the body [12, 13].

It has indicates that human movement signature is different and can help for recognition. Though the performance is more challenging by radar transceiver signals, previous studies also proved that radar signature can discole information on the human's behave or manner of acting.

Another very important requirement of this CW radar is when someone moves, the various parts of his/her body (heads, torso, arms, legs) have a especial movement that develops feature of Doppler signatures. Finally as the nature of the Doppler spectrum is mostly periodic, a time Doppler variation analysis permits to extract features of the human gait easily by using time frequency representation analysis techniques.

4 Time Frequency Representation

The analysis of non-stationary signals are mostly existed in many field practical application areas, like speech signal processing, earthquake excitations, medical instrument, electromyography, radar, sonar, and machine vibration signals. Nonstationary signal models account for possible time variations of statistical functions and spectral characteristics of signals. Understanding these variations is important because they are often indicative of the underlying processes that generate the signal. The main purpose of this special session is to include research work on theory, methods, and applications of non-stationary signal models.

Accordingly, a fundamental role has been played in the growth of Time-Frequency (TF) methods, which makes a virtual representation of the spectral behaviors of the informatios/data. Some TF methods include the Fractional Fourier Transform (frft), Short-time Fourier Transform (STFT), the Wavelet Transform (WT), the Wigner-Ville Distribution (WVD), and Hilbert Transform.

4.1 Short Time Fourier Transform (STFT)

The STFT assumed as a method that breaks up non-stationary signal into many small constitute manageable signal segments, which can be considered to be locally stationary, and implements traditional FFT for signal build up analysis [5, 12].

The STFT of a signal $s_t(\tau)$ is obtained by convolving the two signals to gather, $h(\tau)$, centered at τ, to produce a modified signal.

$$S_t(\omega) = \frac{1}{2\pi} \int_{-\infty}^{\infty} e^{-j\omega\tau} s(\tau) h(\tau - t) d\tau$$

The energy density signal at time τ:

$$p(t,\omega) = |s_t(\omega)|^2 = \left| \frac{1}{2\pi} \int_{-\infty}^{\infty} e^{-j\omega\tau} s(\tau)h(\tau - t)d\tau \right|^2$$

The main shortcoming of signal analysis method STFT is the resolution tradeoff between time and frequency. Resolutions in time and frequency will be determined by the width of window h(τ). A large window width gives high resolution in the frequency domain, but less resolution in the time domain.

The other limitation of STFT is with regard to its computation is somehow expensive, but ways of accelerating it by avoiding redundant calculations are available. These drawbacks however, STFT is an ideal tool various aspects, the most vital being its nature of best spectrogram structure, which is consistent with its regarding frequency spectra, which makes spectrum visualization better.

5 Evaluation and Discussion

- Human gait analysis by time-frequency algorithm.
- Received signal analysis according to the setup shown below.
- The signal extracted during stationary state is very small as relative to the signal during movement. This is due to:
  - The unidirectional antenna helps to decrease the direct signal from transmitter to receiver.
  - The experiment was processed in a corridor where potential reflectors from a faraway (Fig. 2).

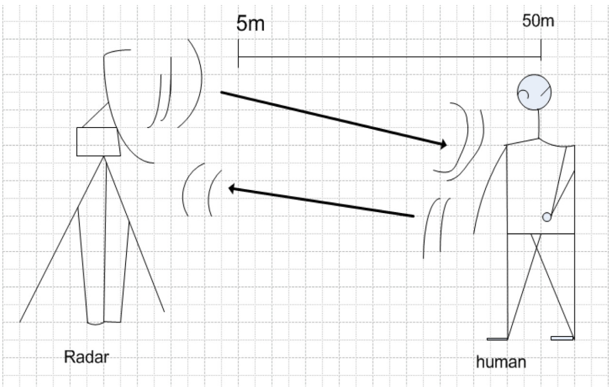
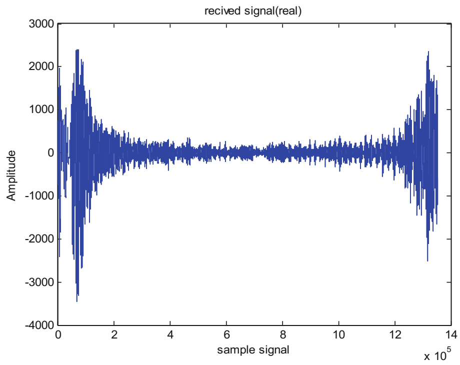
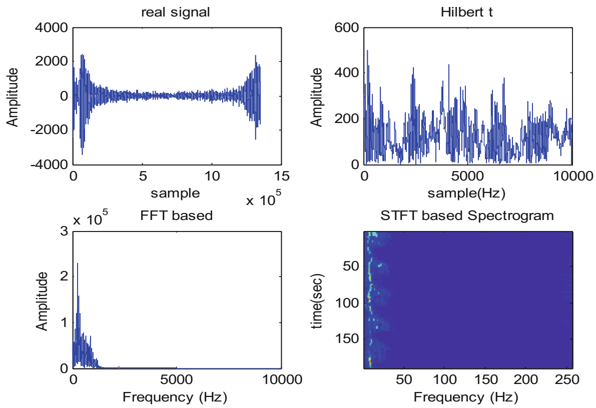


Fig. 2. Practical experiment setup during record

- As we can see from the waveform when the person is moving toward the radar is different from moving away, when the movement is lose by to the radar the signal is very strong.



– Gait feature extraction from radar signal using different frequency signal analysis method are shown below.



6 Conclusion

All techniques signal analysis method good at detecting a single elements of signal but no techniques whether it's traditional or new paradigms can able to detect and identify and provide all the best results for all cases. When the moving part is not clearly not known it's a great to choose which signal analysis techniques affords the better result. From this paper work, someone could find a lot of signal analysis and syntheses methods that can utilize to analyze non-stationary and stationary data's has been discussed in detail. The betterment and drowbacks of each method of time-frequency analysis has pointed out, and the practical application of these techniques in the extracting information from human gait radar signal have been highlighted especially using STFT.

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