Use of High-Frequency Radar to Capture Gait Parameters

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Abstract

Features related to gait can be fundamental metrics of human motion. Gait speed and stride length are increasingly being recognized as a measure of a person’s health status; changes in these parameters from a person’s normal values often indicates changes in health. However, variations in gait characteristics as a result of cognitive or other conditions may go undetected as the effect can be gradual and often goes unnoticed during clinical visits. Technologies that detect changes in the gait of older adults could support detection, evaluation, and monitoring of parameters related to changes in mobility, cognition, and frailty. For better biomedical applications, it is extremely vital to extract crucial gait parameters with high accuracy while maintaining ease of use for practical implementation. We have been developing an ultrahigh-frequency radar sensor that can measure walking speed and stride length in range of indoor environments. Since our approach uses non-invasive wireless technologies, people do not need to wear or carry a device on their body. Additionally, due to the fact that there is no visual camera privacy is preserved.

Introduction

Despite the gait cycle appearing to be simple, a closer analysis of the unique features and patterns generated by an individual can give very valuable biodata that can be utilized to enhance patient care. Analyzing the average gait velocity, rhythm, as well as any abnormalities, gait cycle can indicate musculoskeletal fitness, cardiovascular health, mental wellness, and even the expected mortality [1,2]. It is crucial that the method for capturing the data be precise in order to correctly diagnose a variety of latent conditions that can later be resolved through gradual adjustments by therapists and practitioners. Corrected gait cycles can then result in long term fitness through enhanced sleep quality, lowered stress levels, improved fitness, strengthened bones [3]. The most commonly available gait feature and motion capturing methods include force mats, wearable sensors and video camera systems. The crucial factors that must be examined for each method include patient comfort, practicality, expense, precision, and portability for ideal implementation into healthcare. Force plates embedded into a mat can observe the body mass and changes in pressure output during a series of steps to output velocity, stride length as well as force distribution on the feet during moments of the gait cycle [4].

GAITRite, a portable single layer pressure sensitive walkway mat, has proven to be easy to use and very reliable for determining step asymmetry and stride lengths for various walking speeds [5]. However, the usefulness of the gait analysis on patients with documented disease, physical injury, and young children need to be further examined as currently there isn’t enough valid data. Another potential problem would be the length of the mat which would restrict the time duration for gait assessment. Additionally, GAITRite systems incur substantial overhead cost. Similar limitations also apply to video camera system. For video camera system, methods such as the interval particle filtering algorithm could be implemented for a comprehensive motion analysis [6]. Potential implications of a video camera system would be the difficulty in constant tracking of the individual when performing tasks other than straight line walking such as sitting or turning. Another potential problem would be parts of the body crucial for gait analysis that are in blind spots to the camera. Using multiple cameras could be a potential fix, however, it would dramatically decrease the portability, and significantly increase the cost as well as the potential for gait analysis errors. Additionally, camera-based systems can lead to privacy issues. Although wearable sensors are less expensive and much accurate [7], people should wear or carry a device on their body which is not applicable for long term monitoring. Radar sensors could be one promising technique which could be used to monitor gait parameters frequently [8, 9].
In this paper we use a low-cost, low power frequency modulated continuous wave (FMCW) radar to acquire gait speed and stride length. Since the radar sensor is a non-invasive technology, propagating electromagnetic waves, people do not need to wear or carry a device on their body. Additionally, due to the fact that there is no visual camera privacy is preserved.

**Procedure and Measurement Results**

As one of the most promising among other radar techniques, we chose using FMCW radar in the 79GHz band. We can obtain linear combination of sinusoid signals with low frequencies by multiplying the received signal by the transmitted signal. Therefore, FMCW radar systems can enable simpler hardware and architecture types and provide information about the range and radial velocity of multiple targets by processing the observations of beat signals [10]. We asked our participants to walk over 5 m for 6 times. Then, we collected the data to analysis the corresponding gait parameters. In order to obtain information about the speed of walking, we first applied Fast Fourier Transform (FFT) on received signal from the FMCW radar. Then, based on the information of the position of the target (e.g., a person walking) and the time, we can easily measure the speed of walking. Figure (1a) shows the trajectory of a person waking in front of the radar. As depicted, we can clearly see the distance to the radar increases when the person moving away from the radar, and decreases when the person moves toward the radar. In one test case, post-processing the result (Figure 1) shows that the speed of walking was 0.98 m/s while the real speed was around 1m/s. Also, to get the stride length, we need to know about the motion of other parts of the body, since the maximum reflection changes between torso and legs during walking. When we walk, different parts of our body move at different velocities, which leads the micro-Doppler effect. This effect can be calculated using a joint time-frequency analysis [11]. We can then use a Short-Time Fourier Transform (STFT) to calculate the spectrogram of the back-scattered signal and visualize the micro-Doppler effect of a person walking. The spectrogram shown in Figure(1b) demonstrates an example of the overall micro-Doppler effects of walking obtained by our FMCW radar sensor.

![Figure 1](image-url): FMCW radar results of (a) trajectory of walking and (b) STFT method.

**Conclusion**

In this paper, we addressed the problem with existing measurement methods. Compared with radar, they are expensive. Moreover, most of them are used for infrequent monitoring. We investigated the gait parameters measurement with a low-cost, mm-wave FMCW radar. We showed using FMCW radar, gait parameters could be obtained wirelessly which also preserves the privacy of people.

**References**

3. Anonymous . Why is Gait Analysis Important?