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Early Diagnosis of Parkinson's Disease using a Smartphone

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Abstract

Diagnosing Parkinson's disease (PD) is often difficult, especially in its early stages. It has been estimated that nearly 40% of people with the disease may not be diagnosed. Traditionally, the diagnosis of Parkinson's disease often requires a doctor to observe the patient over time to recognize signs of rigidity. In this work, we propose a PDR-based method to continuously monitor and record the patient's gait characteristics using a smart-phone. Our tool could be useful in providing an early warning to the PD patient to seek medical assistance and help the doctor diagnose the disease earlier.

Keywords: pedestrian dead reckoning, parkinson's disease, gait characteristics, smartphone

1. Introduction

Gait disturbance is an early feature of brain disorder such as Parkinson's disease, dementia and stroke which lead to apraxic gait patterns where there is loss of ability to move properly. This is due to the disruption of the human locomotion control and sensory feedback system, which controls balance allowing safe negotiation of the environment. Several prior studies have showed how a person walks may predict whether they'll develop Alzheimer's or Parkinson's disease. Mobility impairments are often associated with these brain disorders, and some gait changes may even appear before cognitive decline can be detected by some selected gait characteristics such as gait speed and stride length. For example, [1] found that found slower walkers with a lower cadence and less of a stride length were more likely to have problems in cognitive, memory and other processing functions, compared to

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faster walking counterparts. These studies suggest that continuous monitoring of changes of gait characteristics may provide useful information at detecting motor changes associated with future cognitive decline.

In this work, we propose a method that utilizes the accelerometer sensor in a smart-phone to continuously monitor the changes of walking patterns of a potential patient who might be developing some brain disorder like Parkinson's disease. Tracking people is an important component of ubiquitous networking. In this paper, we consider the use of a pedestrian dead reckoning (PDR) system to capture the gait characteristics, such as step length and step frequency, of a person. On average, the accuracy of our step length estimation is about 98%. Using a simple binary classification method like SVM, we also show that we can identify the changes of walking pattern of the patient using the recorded gait data from the phone with high accuracy.

2. Related work

A PDR system can be classified into two types depending on where the sensor is mounted: foot-mounted [6] and waist-mounted [8-10]. To calculate the step length, the foot-mounted methods typically perform a double integral on the horizontal acceleration. However, without further calibration, the problem of sensor drift [7] could introduce serious inaccuracies when estimating the step length. One way to calibrate the sensor drift error is called zero velocity update (ZUPT). When the swinging-foot touches the ground, the angular velocity of this foot will be close to zero, which can be used to reset the system to avoid sensor drift errors accumulating into the length estimation of the next step.

On the other hand, for a waist-mounted PDR system, ZUPT is not directly applicable, since one will not be able to find zero velocity in the horizontal direction. Some waist-mounted PDR systems use a constant step length [2-5] while the others [9] use a trace-driven approach, by first collecting empirical data from multiple users and then using linear regression to find the relation between step length, walking frequency, and the variance of acceleration. The limitation of this approach is that one might need to collect new training data for a new user. Weinberg [10] observed that the upper body moves vertically when walking, and suggested that one can estimate the step length as follows: $StepLength = 2 \times heightchange / \alpha$, where α is the swinging angle of the leg from the body, and the *heightchange* can be estimated based on the vertical acceleration. However, he did not discuss how to measure α. Our idea is similar to Weinberg's, but we estimate the step length based on the height change and length of the leg using the Pythagorean Theorem. In addition, we use the concept of Simple Harmonic Motion (SHM) to find the zero velocity in the vertical direction, and apply ZUPT to avoid the accumulation of sensor drift errors on the vertical-axis.

3. Sensing gait characteristics using a smart-phone

As described above, Weinberg [10] proposed that one can estimate the step length using the height change of the waist and the swinging angle of the leg during walking, but he did not discuss how to measure this angle, and we found that, in practice, it is difficult to measure such a small angle during walking. Based on Pythagorean Theorem, in this paper we proposed a different way to estimate step length using the change in height. During walking, a person's body moves up and down. If we assume the length of the leg is L, the waist-line will move up-and-down between L and (L-h) from the ground, where h is the change in the height of the waist. Considering the triangle in Figure 1, formed by two feet of a person and their step length D. Given that L is known, using the Pythagorean Theorem, we can estimate D if we know the height of this triangle, i.e., (L-h). To obtain (L-h), we first need to calculate h, which is the change in height of the waist during walking. Therefore, if we mount an accelerometer on the user's waist, the readings of this can be used to estimate the height change h, which can then be used to calculate the step length D based on the Pythagorean Theorem (the length of the leg (i.e. L) and half of the step length (i.e.

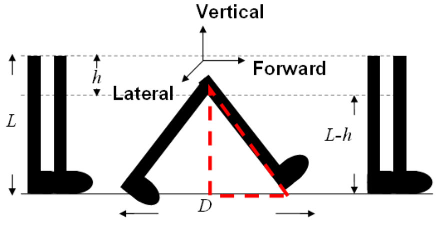

Figure 1: Walking Diagram