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Gaits Classification of Normal vs. Patients by Wireless Gait Sensor and Support Vector Machine (SVM) Classifier

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ABSTRACT

Due to the serious concerns of fall risks for patients with balance disorders, it is desirable to be able to objectively identify these patients in real-time dynamic gait testing using inexpensive wearable sensors. In this work, the authors took a total of 49 gait tests from 7 human subjects (3 normal subjects and 4 patients), where each person performed 7 Dynamic Gait Index (DGI) tests by wearing a wireless gait sensor on the T4 thoracic vertebra. The raw gait data is wirelessly transmitted to a near-by PC for real-time gait data collection. To objectively identify the patients from the gait data, the authors used 4 different types of Support Vector Machine (SVM) classifiers based on the 6 features extracted from the raw gait data: Linear SVM, Quadratic SVM, Cubic SVM, and Gaussian SVM. The Linear SVM, Quadratic SVM and Cubic SVM all achieved impressive 98% classification accuracy, with 95.2% sensitivity and 100% specificity in this work. However, the Gaussian SVM classifier only achieved 87.8% accuracy, 71.7% sensitivity, and 100% specificity. The results obtained with this small number of human subjects indicates that in the near future, the authors should be able to objectively identify balance-disorder patients from normal subjects during real-time dynamic gaits testing using intelligent SVM classifiers.

KEYWORDS

Balance Disorders, Fall Risks, Gait Analysis, Support Vector Machine (SVM), Wearable Gait Sensor, Wireless Gait Sensor

INTRODUCTION

The number of patients with balance disorders is increasing rapidly because of an aging-related factors such as muscle and joint weakness with arthritis, inner ears degeneration with vestibular impairments, vision impairments caused by glaucoma and macular degeneration, diabetic peripheral neuropathy and other associated factors (Fuller, 2000). Elderly people with chronic balance disorders and/or

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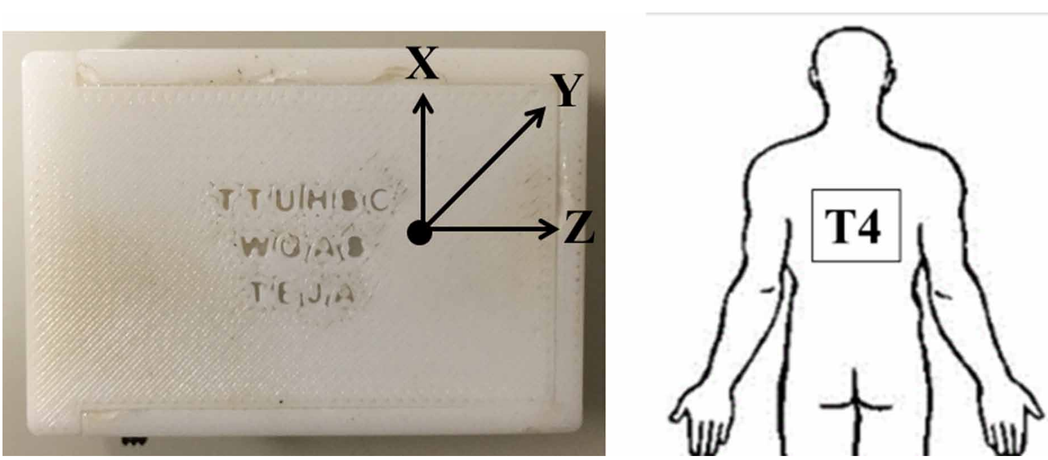
dizziness are two to three times more likely to fall than those who do not experience these problems of the similar ages. Walking is the most important method of human mobility; however, patients with balance disorders often have difficulties in walking and are of significant fall risks. Rehabilitation is crucial to recovering patients' mobility, while the diagnosis and evaluation of walking gaits are necessary to investigate the cause of the balance disorders for proper treatments. In recent years, sensors that measure inertial acceleration (i.e., the G-forces) and/or the angular velocity are used to analyze walking gaits. By using the miniaturized accelerometers and gyroscopes similar to the inertial measurement unit (IMU) equipped in larger inertial navigation systems, these small sensors can be worn on the human body to detect an acceleration change and an angular rate change for effective gait analysis (Aminian, Rezekhanlou, De Andres et al., 2006; Yoshida Mizuno, Hayasaka et al., 2006). An advantage of using the accelerator and gyroscope integrated circuit (IC) sensors is that they are of low-cost and with good reliability and can detect gait issues objectively. We have, therefore, designed a custom wireless gait sensor with a tri-axial accelerometer IC, 2 gyroscopes ICs, and a MSP430 microcontroller to sample the dynamic gait data of six degrees of freedom (i.e., *x, y, z* and θ_x, θ_y, θ_z). In previous work (Nukala, Shibuya, Rodriguez et al., 2014a; Nukala, Shibuya, Rodriguez et al., 2014b), we used this wireless gait sensor and demonstrated that it can detect falls with 99% accuracy vs. average daily activities (ADL) by using Back Propagation Artificial Network (BP ANN) and SVM classification algorithms. In this work, we use a smaller but similar wireless gait sensor specifically for gait analysis to detect patients and normal people by using various Support Vector Machine (SVM) classification algorithms. During the gait testing, this sensor is placed at the T4 vertebrate position of each subject.

SENSOR SYSTEM AND EXPERIMENTAL METHOD

The Wireless Gait Sensor

The wireless gait sensor orientation and placement location at the T4 thoracic vertebrate are shown in Figure 1. The custom-designed wireless gait sensor consists of a 3-axis linear accelerometer IC, a single axis gyroscope IC, and a dual axis gyroscope IC to measure 3-D human body translations and rotations during a gait pattern with the help of these Micro-Electrical and Mechanical system (MEMS) ICs. This wireless gait sensor system is supported by a Texas Instruments (TI) MSP430 microcontroller, and a wireless 2.4 GHz USB transceiver using the SimpliciTI protocol with a range of ~12 meters (40 ft). The 2 AAA batteries used in our earlier wired sensor (Jacob, Nguyen,

Figure 1. Wireless gait sensor orientation and placement location at the T4 thoracic vertebrate



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