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Walking Motion Real-time Detection Based on Walking Stick Equipped with MPU and Raspberry Pi*

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***Abstract*— This paper proposes walking motion real-time detection by employing intelligent walking stick which includes MPU 6050, portable power and Raspberry pi zero w embedded with machine learning algorithms. Firstly, several types of walking motion data are collected by utilizing the walking stick. These walking motion types include fast walking, slow walking, turning left, turning right and stopping. Secondly, the machine learning classifiers can be obtained by training the collected data set. After that, the accuracy rate comparison among these classifiers are given by utilizing the testing data. Finally, the classifiers are embedded into the Raspberry pi zero w to detect walking motion in real time.**

I. Introduction

A large number of papers have investigated motion detection for the human [1, 2, 3, 4]. In [1], a method for learning the structure and parameters of a decomposable triangulated graph was described, and it was applied to learn models of biological motion. By assembling the carbon-nanotube sensors on stockings, bandages and gloves to fabricate devices, different types of human motion including movement, typing, breathing and speech can be detected in [2]. Based on [2], the highly sensitive, tunable, reproducible, and durable strain sensors were used for monitoring large-scale body and small skin in [4]. Since strain sensors can be used for measuring strains on human activities, they have recently received a great deal of attention. However, these strain sensors are covered on the body, which is not convenient for human activities.

In order to help the visually impaired people to walk safely and independently, the smart walking sticks equipped with sensors and algorithms were researched, and several kinds of smart walking sticks were designed in [5-10]. In [5], a smart walking stick based on an electronic approach was designed to assist visually disabled people. By using ultrasonic sensors and a vibrator motor scheme, the haptic walking stick was proposed, modeled and successfully tested in [6]. After that, an intelligent walking stick was represented for visually challenged people to guide them to reach their destination safely without facing any difficulties in [9]. On the other hand, in order to aid elderly people to avoid falling and connect with their family in times, the walking sticks with GPS and sensors were presented in [11-14]. Being different from these existed walking stick, a walking stick with low-cost MPU 6050 and Raspberry pi zero w possesses machine learning algorithms, which is effective to collect human motion data and realize the real-time detection based on trained machine learning classifiers.

Raspberry pi was developed in the laboratory of university of Cambridge, and the first generation was released by Raspberry pi foundation in February 2012 [15]. As a single board computer, Raspberry pi is affordable and widely available in the scientific community and practical application [16], and they are used in many products. Raspberry pi zero w with 1GHz BCM2835 single-core processor and 512MB RAM is used in the walking stick, which is about four times faster than the original Raspberry pi. The main advantages of this walking motion real-time detection system based on the walking stick can be summarized as follows. (1)The prices of Raspberry pi zero w and MPU are very low and affordable, and they are used in the walking stick. (2) Walking motion detection system is based on Scikit-Learn and python language built in Raspberry pi, which is efficient to implement the data collection, data training and real-time detection. (3) Based on this walking stick, five walking motion data are collected, and the accuracy rate comparison among several machine learning algorithms is given by using the collected data.

II. Design and Implementation

Two MPU 6050 are located on the top and in the middle of the walking stick respectively. By using jumping cables, Raspberry pi and two MPU6050 are connected to collect data, which can be seen in figure 1.

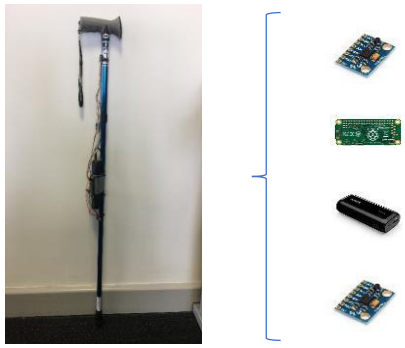

Figure 1. The composition of the walking stick

A. Data Collection

The portable power in the walking stick provides power for the Raspberry pi and MPU 6050. By using VNC or PuTTY, the Raspberry pi is connected with laptop. Each MPU 6050 has 3-axis accelerometers and 3-axis gyroscopes. Based on python

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language codes, three thousand rows of data are collected for each walking motion by using this walking stick. Each row of data is thirteen columns vector. The first three elements represent x-axis, y-axis and z-axis accelerometer of the top MPU. The second three elements represent x-axis, y-axis and z-axis gyroscope of the top MPU. Similarly, the third and fourth three elements represent x-axis, y-axis, z-axis accelerometer and x-axis, y-axis and z-axis gyroscope of the middle MPU respectively. The last element represents the label of the walking motion.

B. Machine Learning algorithms

In order to achieve the real-time detection of walking motion, the classifiers should be obtained in advance. Based on Raspberry pi zero w, we build Scikit-Learn software machine learning library for the python programming language. For the collected data, 70% data are training set, and the rest of 30% data are testing set. Firstly, we select 100 rows data as a window, and the column elements are accelerometer and gyroscope values. The data of each window is a 100×12 dimensional matrix. Secondly, some useful statistical features such as, median, mean, variance, skewness, kurtosis, minimum, maximum, etc, are extracted for each column in the window matrix. After that, all these statistical features are connected to compose a big row vector. The calculation methods for a part of extracted features are shown in Table I.

TABLE I. CALCULATION METHODS OF THE FEATURE

Feature name	Calculation methods
Mean value	$\bar{x} = \frac{1}{m}\sum_{i=1}^{m} x_i$
Variance	$V = \frac{1}{m}\sum_{i=1}^{m}(x_i - \bar{x})^2$ $\bar{x}$ is mean value
Standard deviation	$Sd = \sqrt{\frac{1}{m}\sum_{i=1}^{m}(x_i - \bar{x})^2}$ $\bar{x}$ is mean value
Skewness	$S = \frac{\sum_{i=1}^{m}(x_i - \bar{x})^3}{m-1} Sd^3$ $\bar{x}$ is mean value
Kurtosis	$K = \frac{\sum_{i=1}^{m}(x_i - \bar{x})^4}{m-1} Sd^4 - 3$ $\bar{x}$ is mean value

We use machine learning algorithms, such as Support Vector Machine (SVM), Decision Tree (DT), K-Nearest Neighbours (KNN), Random Forest (RF), and Gradient Boosting Decision Tree (GBDT), to train the training set and obtain several different types of machine learning classifiers. After that, these classifiers are embedded into Raspberry pi zero w, and the classifier with the highest accuracy rate is used as walking motion detection algorithm.

III. RESULTS AND DISCUSSIONS

In this section, we used the rest of 30% data as the testing set. We can get several different accuracy rates for these obtained classifiers, which is shown in Table II. The GBDT and RF have the highest accuracy rate of 97.78%, which is 40% more than SVM with the lowest accuracy rate of 57.78%. In addition, the accelerometer and gyroscope readings for these types of walking motions based on intelligent walking stick are shown in Figs 2-6.

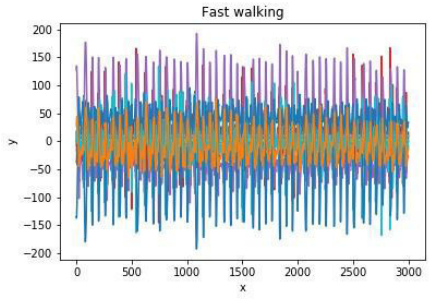

Figure 2. Accelerometer and gyroscope readings of fast walking

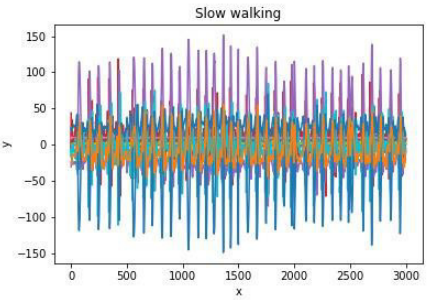

Figure 3. Accelerometer and gyroscope readings of slow walking

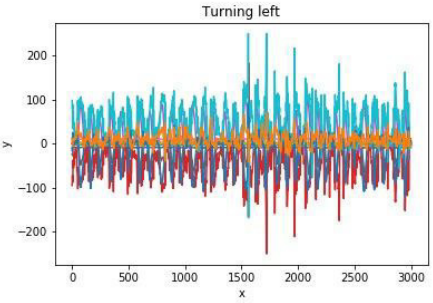

Figure 4. Accelerometer and gyroscope readings of turning left

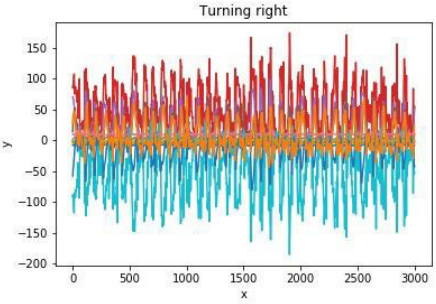

Figure 5. Accelerometer and gyroscope readings of turning right

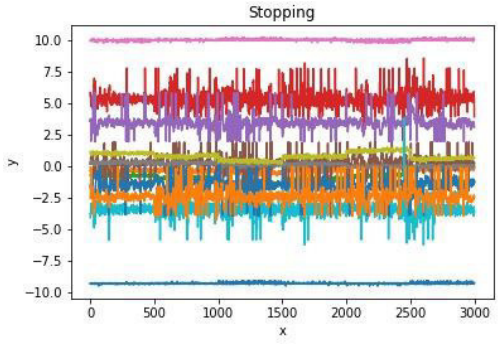

Figure 6. Accelerometer and gyroscope readings of stopping

From these Figures, we see that the 3-axis accelerometer and 3-axis gyroscope readings have pronounced difference for different type of walking motion. Hence, from extracting features of these states, we get high accuracy rates of walking motion detection by using machine learning algorithms. In this walking stick, the GBDT is embedded in the Raspberry pi. When the users apply this walking stick to do fast walking, slow walking, turning left and turning right, the motion can be detected in real time, and the detection time is about one second.

TABLE II. ACCURACY RATES OF DIFFERENT MACHINE LEARNING

Classifiers	Accuracy rates
Support Vector Machine	57.78%
Decision Tree	91.11%
k-Nearest Neighbor	95.56%
Random Forest	97.78%
Gradient Boosting Decision Tree	97.78%

The trained machine learning classifier is embedded into the Raspberry pi of the walking stick, and the real-time detection results can be recorded in the walking process. Hence, when elderly people use this walking stick, we acquire their motion situation and know their living status. In addition, we also can collect more types of walking motions to obtain more kinds of real-time detection results.

IV. CONCLUSION

In the walking stick, Raspberry pi and MPU are illustrated as affordable and effective in the data collection and real-time detection of walking motion. In this paper, based on Scikit-Learn and python language, we have collected several kinds of walking motion data including fast walking, slow walking, turning left, turning right, and stopping by using walking stick and obtained several classifiers by training these data in Raspberry pi zero w. After that, the machine learning classifier with high accuracy rate is embedded into Raspberry pi to achieve walking motion real-time detection.

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