https://doi.org/10.21289/KSIC.2019.22.4.457

Gate Data Gathering in WiFi-embedded Smart Shoes with Gyro and Acceleration Sensor

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〈Abstract〉

There is an increasing interest in health and research on methods for measuring human body information. The importance of continuously observing information such as the step change and the walking speed is increasing. At a person's gait, information about the disease and the currently weakened area can be known. In this paper, gait is measured using wearable walking module built in shoes. We want to make continuous measurement possible by simplifying gait measurement method. This module is designed to receive information of gyro sensor and acceleration sensor. The designed module is capable of WiFi communication and the collected walking information is stored in the server. The information stored in the server is corrected by integrating the acceleration sensor and the gyro sensor value. A band-pass filter was used to reduce the error. This data is categorized by the Gait Finder into walking and waiting states. When walking, each step is divided and stored separately for analysis.

Keywords : Gait Recognition, Multi-sensor Fusion, Wearable Sensor, Gait Identification, Inertial Sensor

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1. Introduction

In recent years, importance of continuously observing information such as a step change and a walking speed has increased. There is a lot of information about human's health in the footsteps of a person. For example, Parkinson's disease is a disease that can be inferred from foot deformity or wrong posture adherence due to genetic reasons, muscle degeneration, and/or gait disorder [1-3].

The gait pattern monitoring and assessment system can be classified into two different approaches [4-6]; marker-based and wearable sensor-based. The marker-based approach include video-based systems, active magnetic trackers, and optical marker systems to obtain human gait movement. However, they could not be used outside the laboratory environment, usually cause invasion of human privacy, and are expensive. While, the wearable sensor-based approach, which uses an inertial sensor or bio sensors, could be worn on the clothes or shoes with low-power and portable memory module for long-term ambulatory monitoring. It could obtain real-time capture and analysis of gait information over longer distance and outside of the laboratory environment.

The wearable sensor-based system consists of three layers such as sensing layer, network layer, and analyzing layer as shown in Fig. 1. [7] The sensing layer roles acquisition of raw signal of wearable sensor embedded in wearable devices or smart shoes. The low cost wearable sensor, such as inertial sensors (e.g., accelerator, gyroscope, or pressure sensors) is embedded in wearable devices (e.g., clothes, shoes, fitness band, or mobile phone) to monitor and measure the health information.

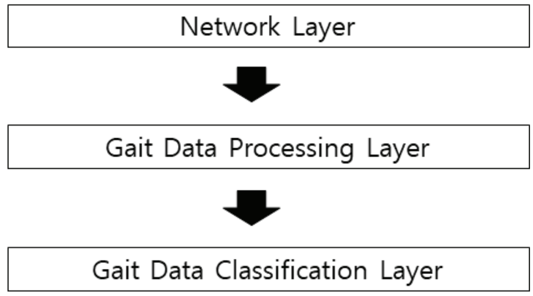

Fig. 1 General layer architecture for gait pattern monitoring and assessment system

The network layer connects wearable sensor and wearable devices together, and allows them to share raw sensor signal. Traditionally, the wireless sensor network (e.g., Bluetooth or Zigbee) transmits raw signal of wearable sensor embedded in smart clothes or shoes to processing device such as mobile device (e.g., tablet or mobile phone) or fixed device (e.g., personal computer or notebook). On the other hand, recently popularized wearable device (e.g., fitness band or smart watch) allow the wearable sensor to be embedded in itself, and allow to acquire raw signal without wireless sensor network technology.

After acquisition of raw signal, the desired health information such as gait patterns is extracted from raw signal in the analyzing layer using a variety of algorithms. There are three categories such as temporal segmentation, feature extraction, and learning methods. The temporal segmentation is typically solutions where sensor data is usually broken down with temporal series using time windows, and health information is extracted from temporal series of raw signal using feature extraction and pattern classification methods. The feature extraction is most well-known method including time domain feature and frequency domain feature extraction such as root mean square (RMS) or fast fourier transform (FFT). The learning method is more effective method including machine learning algorithms such as Bayes networks, support vector machine (SVM), or artificial neural network.

Despites ongoing researches into sensing, networking, and analyzing layer, there are still some issues, such as uncontrolled environment, life-logging data, high volume of data, and security, to be addressed. The most important issue is completely uncontrolled environment problem. The majority of research focused on attaching wearable sensors to the body or wearable device and acquiring raw signals in a controlled environment such as a laboratory or limited space. This is due to the difficulty in transmission of large amounts data, lack of wearable devices' storage capacity, limitation of the communication distance of the wireless sensor network module, and the limitation of the battery capacity. The gait pattern monitoring system for the control environment makes it difficult to get accurate health information for the user, by making the user feel a sense of heterogeneity and making the user take different walking from the daily life. Fortunately, due to the smaller battery with increased capacity, lower power consumption of wireless local area network module, and more miniaturized sensor, the wearable sensor can be embedded directly in smart clothes or smart shoes. Also, it is now easy to connect to the WiFi environment [8] due to communication technology.

In this paper, we collected the walking information using the walk-behind collecting module built in the shoe to make continuous measurement by simplifying the walking measuring method.

2. Experimental Model of Gathering Gait Data and Determining Gait Step

In our experimental model, a wearable sensor is used to attach to the wearable device to collect walking information. The existing walking reports were collected by attaching sensors to the joints of the feet using a fixed support stand [9].

In this paper, a wearable sensor was built inside the shoe as shown in Fig. 2. The walking information gathering module was designed using MPU6050 with 3-axis acceleration and 3-axis gyro sensors. Data measured by an accelerometer does not have

Fig. 2 Experimental shoes with embedded modules.

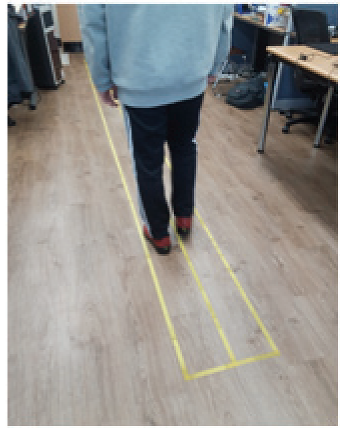

Fig. 3 Snapshot for gathering gait data.

a large error even after a long-term continuous measuring the information. The gyro system combines the data using the advantageous points in the measurement of the attitude change. We want to grasp walking information of pedestrian through fused data information.

Starting gathering gait data, an experimenter was allowed to walk freely for 2 minutes. And, he was allowed to stand for 5 seconds after starting the measurement, and then started walking. He walked a distance of 5m on a straight line as shown in Fig. 3. In this experimental environment, the measurement device and the measurement PC were connected using WiFi.

Gait information was collected independently for each foot condition and information. The collected raw data is sent to the server and stored. The stored data uses a band-pass filter to reduce gait information errors. Peak-to-Peak method was used to find information about one step. The peak value of each value is found, and the distance between the peaks is measured to find the step. In order to verify the information of the found step, a method of extracting the characteristic of the gait signal is used. Calculate the data for the measured acceleration, gyro sensor x-, y-, and z-axis to find the number of steps.

$$Data = |Acc_x[n]| + |Acc_y[n]| + |Acc_z[n]| + |Gyro_x[n]| + |Gyro_y[n]| + |Gyro_z[n]| \quad (1)$$

where Data equation (1) is the value of the acceleration. $Acc_x[n]$ is the value of the acceleration x, $Acc_y[n]$ is a value of acceleration y, and $Acc_z[n]$ is a value of acceleration z. $Gyro_x[x]$ is the value of the gyro x, $Gyro_y[n]$ is the value of the gyro y, and $Gyro_z[n]$ is the value of gyro z.

Time-specific acceleration x-, y-, and z-axis data and the data of the x-, y,- and z-axis divided by the offset value is set to Power, and algorithm proceeds to find a step.

$$Power = Data - Offset \quad (2)$$

The calculated value of Power must be greater than 0 as shown in Fig. 4, confirming that the specified data has been included. If the value of Power is less than Threshold (5000) and the differential value of Power is less than Threshold (1000), it will be judged by the step data. Otherwise, the offset value is calculated and stored as walking data, otherwise the value of the walking data is judged to be false and classified and stored in the walking waiting state data.

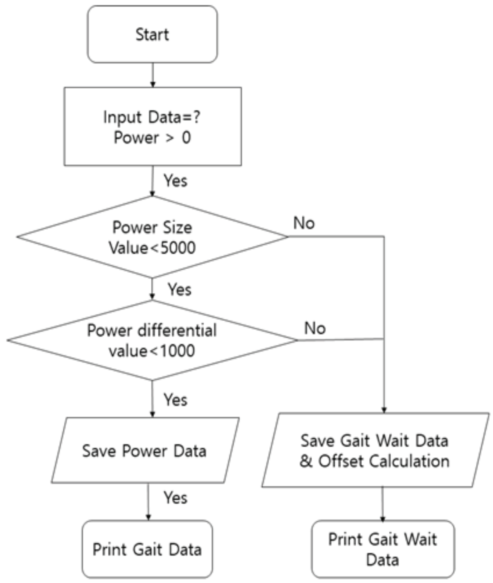

Fig. 4 Gathering procedure of gait step.

3. Experimental Evaluation

Figure 5 shows the acceleration and gyro sensor data for five steps detected from the left foot when walking a straight line distance of 5m. The figure shows the walking step using the walking step calculation method shown in Fig. 4.

The data is compared with the number of steps of the data classified as the walking state and the actual number of steps as shown in Table 1. In our experimental setup, we find that the step recognition rate is 96.72%.

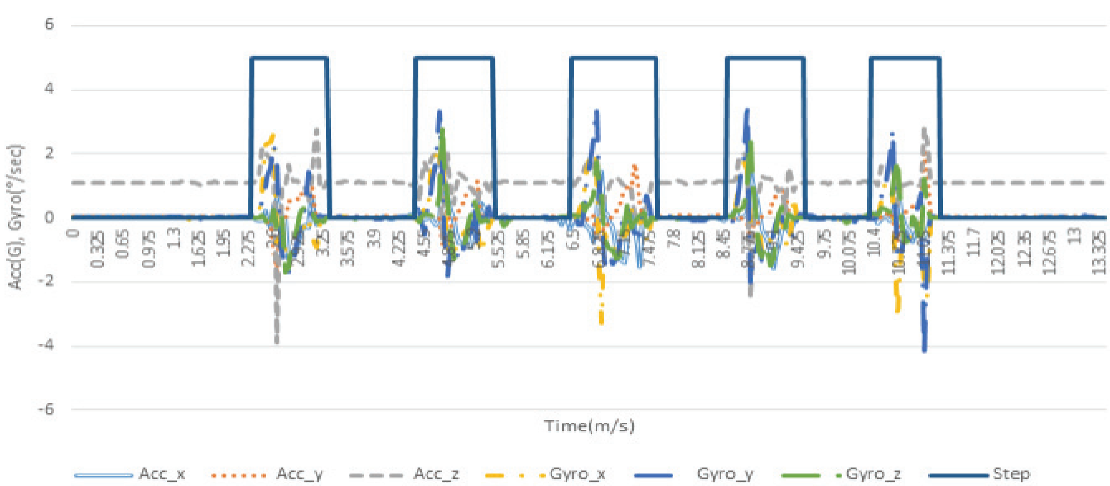

Fig. 5 Gait step determination using gathering procedure.

Table 1. Comparison of Actual Steps and Measures Steps

Experimenter	Actual Steps	Counter Measuring Step Count
A	23	23
B	22	20
C	25	26
D	26	25
E	26	24

4. Results and Discussion

In this study, it is possible to easily collect walking information by using the designed walking information collection module. Our experimental setup was used to find the walking information and to store information about the step on the server. The information stored in the server is analyzed in terms of step classification (general steps, stepping steps) and steps.

Acknowledgments

This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Ministry of Education (NRF-2017 R1A2B4010448)

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(Manuscript received May 16, 2019;
revised June 7, 2019; accepted June 14, 2019)