

Research on recognition of intelligent wearable monitoring equipment based on BLE protocol in students' motion state

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Abstract: This paper designs and manufactures a human posture detection and measurement system based on BLE technology. The system uses three-axis acceleration sensor to collect human posture information, and sends it to the client through Bluetooth. Finally, the processed information is displayed on the client. According to the user's needs, the functions of fall detection and step counting can be realized through different combinations of the sensor's wearing position and number. The acceleration information of different positions of human body is studied. The results show that different human postures can be detected by different combinations of the number and position of sensors. In addition, several experiments have been carried out to verify the feasibility and practicability of the system.

1. Introduction

Most college students suffer from posture problems such as round shoulder, excessive anterior curvature of cervical spine, hunchback, shrug or collapse of shoulder and excessive anterior curvature of lumbar spine [1-4]. The most important reason for bad posture is irregular sitting, standing and walking posture in normal life. According to the detection methods, human posture detection is mainly divided into non-wearable detection and wearable detection [5]. In reference [6], a human pose recognition method based on gradient feature of depth image is proposed. The gradient values in horizontal and vertical directions are calculated by using depth information in the image, and the eigenvalues are extracted. Then the classifier is used to classify the human body posture. However, it can only recognize the static image posture, and can not be applied in real life [7-8]. All the above human posture detection methods are non-wearable. In addition to their own problems, there are still some shortcomings, such as limited detection range and large equipment limitations. In this paper, a wearable combined human body detection device based on BLE technology is proposed. The attitude information is detected by a digital acceleration sensor and displayed on a Tablet computer. The device has the characteristics of small environmental interference, flexibility, low power consumption, easy to carry and can detect a variety of postures. It can be used in sports rehabilitation, posture correction, fall detection and step counting and other fields.

2. System design

2.1 Analysis of general system architecture

In order to acquire personal motion data and monitor the motion state, a motion monitoring system based on Bluetooth 4.0BLE is designed. The system consists of three parts: sensor subsystem, interaction subsystem and Web service subsystem. Its architecture is shown in Figure 1.

The core of the sensor system is wearable sensor equipment. The sensor integrates three-way accelerometer, microprocessor and antenna to collect motion data, process data, identify motion state, and realize motion statistics. Then the processed results are transmitted to the intelligent terminal through low-power Bluetooth.

The hardware of the interactive system is an intelligent terminal, which can be a smart phone supporting Bluetooth 4.0BLE or a specially designed Bluetooth terminal device, such as a smart

set-top box [9]. The intelligent terminal receives the monitoring data from the bottom layer, presents the monitoring results in the form of graphs and charts through the graphical interface, has certain control functions for the sensor equipment, and uploads the data to the server at the appropriate time.

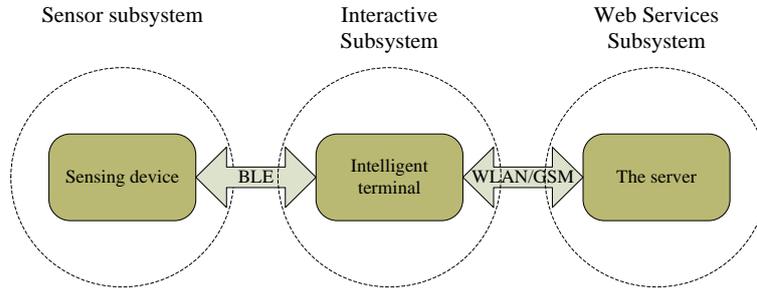


Figure 1 General system architecture

2.2 Functional requirement analysis

Motion state monitoring: Real-time acquisition of sensor data, through the corresponding algorithm to determine the user's motion state, and achieve state switching.

Abnormal monitoring and alarm: When there are abnormal situations such as falls and syncope, enter abnormal monitoring, record abnormal conditions, judge the severity of the abnormal by the corresponding algorithm, and decide whether to make an alarm treatment [10].

Gait Recognition: Users can effectively judge their walking state and realize gait counting. According to the gait counting data and gait type, corresponding conversion can be carried out, and then the statistics of the amount of movement and the time of movement can be realized.

Wireless communication: Sensors communicate with intelligent terminals through Bluetooth 4.0 low-power protocol to achieve data transmission, motion data preservation and presentation [11-12]. In case of serious abnormal situation, alarm information is sent out and transmitted to relevant personnel by means of wireless network of intelligent terminal.

3. Design of system algorithms

3.1 Principle of human posture detection

In this paper, three-axis accelerometer is used to detect human posture, as shown in Figure 2.

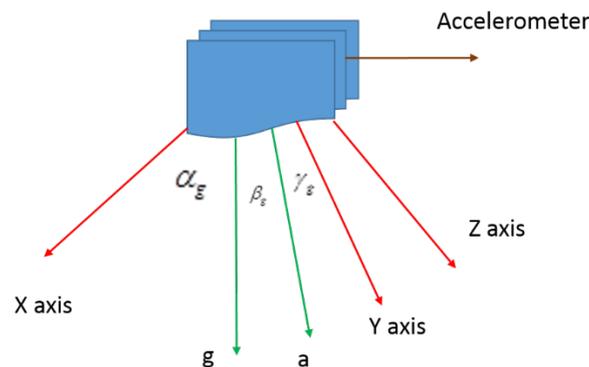


Figure 2 Force diagram of triaxial accelerometer

Figure 2 is a three-axis force diagram of the accelerometer. α_g , β_g and γ_g are the angles between the gravity acceleration g and the x , y and z axes respectively. When the accelerometer is not acted by external forces, only the gravity acceleration can be detected. Assuming that the gravity acceleration is g , the sensor should satisfy in all directions:

$$\partial_x = g \cos \alpha_g \quad (1)$$

$$\partial_y = g \cos \beta_g \quad (2)$$

$$\partial_z = g \cos \lambda_g \quad (3)$$

In the formula, a_x , a_y and a_z are the components of gravitational acceleration g on the x , y and Z axes respectively. Formula (1) ~ (3) can be used to calculate:

$$\alpha_g = \arccos \frac{\partial_x}{g} \quad (4)$$

$$\beta_g = \arccos \frac{\partial_y}{g} \quad (5)$$

$$\gamma_g = \arccos \frac{\partial_z}{g} \quad (6)$$

The natural coordinate system $O-x_0y_0z_0$ is established for human vertical standing posture. The normal phase direction of coronal plane is taken as the positive direction of x_0 axis, the normal phase direction of sagittal plane is the positive direction of y_0 axis, and the normal phase direction of horizontal plane is downward as the positive direction of z_0 axis. At this time, the direction of z_0 is the same as that of gravity acceleration g . So when the acceleration sensor is put on a part of the static human body, the angle of the part relative to the direction of gravity acceleration can be detected, and the attitude of the part can be determined. For human pose detection in motion, attitude information can be obtained by filtering and eliminating vibration from acceleration data in motion.

In horizontal walking, the acceleration in both vertical and forward directions will change periodically, as shown in Figure 2. In the movement of foot closing, the vertical acceleration increases positively as the center of gravity moves upward and one foot touches the ground, then continues forward, while the center of gravity moves downward and two feet touch the bottom, the acceleration is opposite. Horizontal acceleration decreases at the end and increases at the step. Reflected in the chart, it can be seen that in walking, the acceleration and time generated by vertical and forward motion are approximately a sinusoidal curve, and there is a peak value at some point. The acceleration in the vertical direction changes the most. By detecting and calculating the peak value of the trajectory and making the acceleration threshold decision, the step number of the user's motion can be calculated in real time, and the walking distance of the user can be further estimated, as shown in Figure 3.

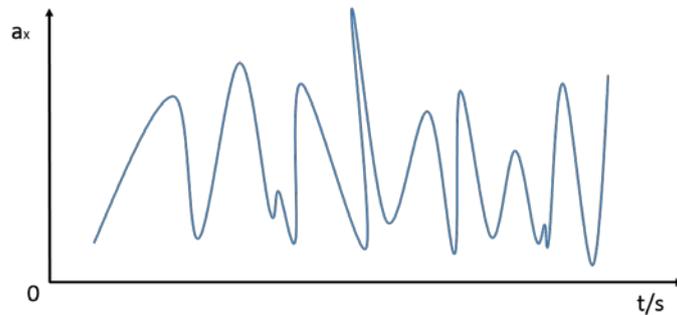


Figure 3 Waveform of human walking

4. System function testing and analysis

4.1 Step counting function test

The step-counting module is worn on the legs according to the requirements, and the step-counting can be started after the corresponding working mode is set. In order to verify the

accuracy of step counting, the system and Apple mobile phone are used to detect 200 steps. As shown in Table 1, the test results are given. It can be seen from the Table that the mean value of this system is closer to the true value of 200 steps and the standard deviation is smaller than that of the Apple mobile phone. Therefore, the step-counting method and algorithm used in this system are superior to the step-counting function of the Apple mobile phone.

Table 1 Step-counting function test and contrast Table

	1	2	3	4	5	Mean value	Standard deviation
Note taking system	192	195	189	192	191	191.8	1.95
Mobile phone	187	186	183	177	179	182.4	3.89

4.2 Module power detection and analysis

The power supply of the attitude detection/step-counting module is supplied by a regulated power supply, and the multimeter is connected in series to measure the current of the module, switch all the working modes of the module, and the power consumption of the module in each mode. The results are shown in Table 2 and Figure 4. According to the chip used in the module, the minimum voltage of normal operation of the module is 2.0 V. When the supply voltage is less than 2.0 V, the module will automatically stop working and enter deep sleep mode. After actual testing, in the step function mode, the new 3.0 V button battery of Nanfu is used to supply power. It can work 97.8 hours from module startup to automatic dormancy.

Table 2 Power consumption of attitude detection/stepping module under 3V power supply

	Head	Shoulder	Waist	Leg	Back
Average current	2.68	2.56	2.67	2.72	2.46
Average power consumption	8.02	7.76	7.96	8.14	7.36

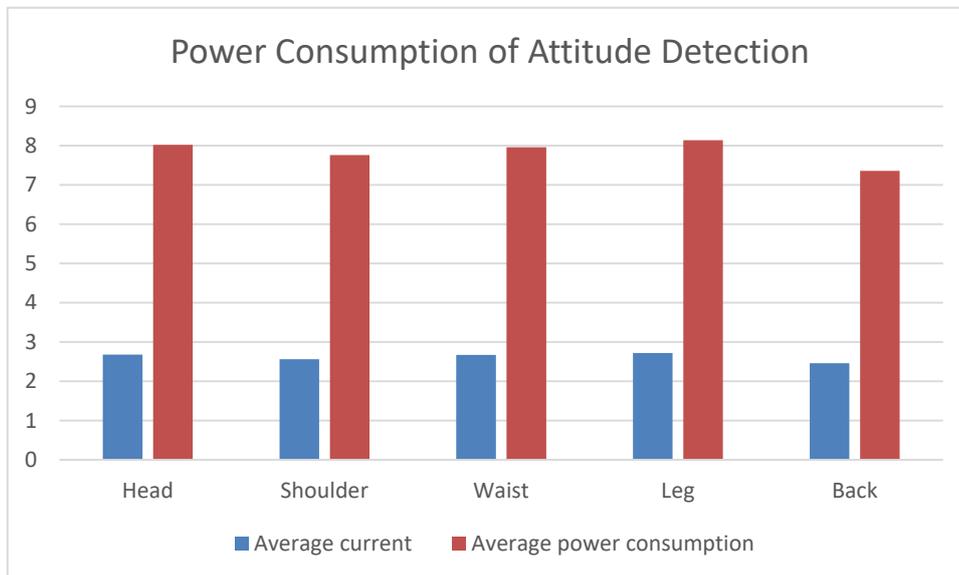


Figure 4 Power consumption of attitude detection/stepping module

5. Conclusion

In order to detect the human body's attitude, a wearable attitude detection system is designed in this paper. Because the device only collects acceleration signals and transmits them by Bluetooth, it has the characteristics of easy carrying, little interference from the environment and almost unlimited range of use. In addition, it can flexibly realize many functions by using different combinations of sensor wearing position and number of carriers. The chips used in the device are of low power consumption and can work for more than 90 hours. Due to the limitation of time and experimental equipment, there are many aspects of the system that can be further studied, further

study of biomechanics related knowledge, explore more human posture information that can be conveyed through acceleration, enrich the functions of the device, and try to use other wireless transmission technologies (such as Wi Fi) to achieve long-distance human posture monitoring.

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