Real-time Detection System of Gait Event for Disabled People

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Abstract. The gait detection technique provides objective and quantitative kinematic and dynamic evidence for lower limb amputee, which plays an important role in supporting gait analysis. Whether a prosthesis orthotic is reasonable and can achieve the best therapeutic effect depends on the doctor, therapist and orthotist to conduct a complete physical examination, walking ability test, gait analysis assessment and reassessment after completion. This paper mainly studies and designs a portable gait detection system for lower limb amputees based on the inertial measurement unit, including the hardware and software design of the data acquisition module, the software and hardware design of the data receiving module and the real-time display of the gait detection data of the upper computer software.

1. Introduction
Gait detection and analysis first appeared in the 19th century, which is a systematic study on walking ability of human body, aiming at objective quantitative and qualitative analysis of walking function of human body through related knowledge of kinematics and dynamics. Gait detection has always been a hot research topic, especially in biomechanics, physical medicine and psychology. Walking of the human body is usually a continuous and regular periodic movement. In the gait analysis, the foot of a single foot is generally in Contact with the ground, namely Initial Contact or IC for short, and all the time until the foot of the foot makes Contact with the ground again is called a gait cycle, the cycle is divided into two phases: stance phase and swing phase as shown in figure 1 [1].

Figure 1. Gait period.
In recent years, with the continuous development of gait detection research, its related fields also include multi-sensor fusion, image processing, computer vision, pattern recognition and many other aspects. Marianiet et al. [2] proposed placed on the front foot inertial measurement unit (IMU) quantitative evaluation method of posture and gait in gait events, the results showed good accuracy and precision in terms of time differences compared to the reference system, but the system was only tested off-line and on horizontal ground walks. Mulleret et al. [3] put forward a kind of gait phase estimation algorithm, using placed on each foot instep wireless IMU inertial measurement unit for real-time detection of four gait events, however, control object and data delay is very high in patients with above knee amputation. Boutaayamouet et al. [4] presented a primitive signal processing algorithms, the proposed algorithm can on the basis of step automatically from the application in his right foot and left foot of wireless accelerometer extract continuous walking four basic events.

The visual based detection system has high requirements on hardware, software and professional operation of the camera operator, and the cost is very high. Sensor based gait detection method is to collect sensor signals and input them into the computer for corresponding analysis and processing by amplifying AD conversion, etc. [5] therefore, sensor detection method is more universal, reliable and convenient. The sensor adopts MPU-6050, a six-axis motion processing component in this paper [6]. At present, data transmission of gait detection system mainly adopts wired communication such as CAN communication and RS485 communication, which has such defects as small transmission distance, inconvenient installation and small transmission speed. In view of this situation, the system adopts the form of WI-FI wireless transmission. The aims of this study are,

• To develop a convenient and portable gait detection device based on MPU-6050.
• To develop a gait analysis system in real-time.

2. Design of gait detection system

Gait detection system basic principle is: the data acquisition device fixed on the subject of lower limb calf, when PC sent starting test command, the data acquisition device will walk on the subjects in the process of gathering real-time gait information, and the attitude information, after processing the data sent to the wireless data receiver, data receiver will receive the data sent via USB to a computer for analysis and real-time display. The structure diagram of the gait detection system is shown in figure 2.

![Figure 2. Structure diagram of the gait detection system.](image)

2.1. System hardware module design

The main function of the data acquisition device is firstly to collect the gait information of the patients with lower limb amputation, then to fuse the original gait data and attitude to solve the problem, and finally to transmit the data wirelessly to the data receiving device. It is mainly composed of power supply unit, control module unit, motion sensor module and wireless communication module. The main function of the data receiving device is to receive the data from the data acquisition device and transmit it to the upper computer. It contains control module, serial port module, and power unit and wireless communication module.

The motion sensor uses the world's first integrated 6-axis motion processing component, the MPU-6050, from Inven Sense, which integrates a 3-axis gyroscope and a 3-axis accelerometer, as well as an expandable DMP. It can also output the gait data of the 6-axis fusion solution through the IIC interface.
The motion sensor reduces the axial difference between the combined gyroscope and the acceleration sensor and reduces the mounting space. The control module chooses STM32F103C8T6 microcontroller, which has powerful processing performance, enough memory storage space, abundant man-machine interface and security peripherals, and internal IIC interface, which can greatly simplify the system hardware design and software development difficulty. The Wi-Fi wireless communication module adopts the ESP-12S of Anxinke technology co., LTD. The platform integrates the extremely complex communication protocols of wireless products into the built-in MCU, greatly simplifying the complex development process of wireless products. This module has low power consumption, reliable and stable performance, and meets the functional requirements of the system. The data acquisition device is powered by a 3.7v lithium battery, while the power module of the data receiving device is powered by a TP5400 chip, which is a lithium-ion battery charger for low-power mobile power supply and a constant 5V boost controller, meeting the system design requirements. The system hardware module design diagram is shown in figure 3.

![Design drawing of data acquisition device](image1)
(a) Design drawing of data acquisition device

![Design drawing of data receiving device](image2)
(b) Design drawing of data receiving device

**Figure 3.** Hardware design of the gait detection system.

2.2. **System software module design**

The software system of the data acquisition device includes the system initialization program and the timing interrupt program, the reading of the original data, the attitude calculation and the conversion output of Euler Angle and the wireless transmission of Euler Angle to the data receiving device. In the process of data collection by the data acquisition device, the wireless communication module of the data receiving device is always in the monitoring state. When the data is detected, the wireless communication module of the data receiving device begins to receive the data, and the data is transmitted to the upper computer through the USB-TTL serial port. The upper computer adopts the serial port debugging assistant to receive the data and save the data in the computer. The workflow is first system initialization including microcontroller STM32F103C8T6 port, serial communication and wireless communication module ESP-12S initialization, then the system will determine whether to start receiving data and transfer it to the top machine via USB. The software flow of the system is shown in figure 4.

![Data acquisition software flow](image3)
(a) Data acquisition software flow

![Data receiving software flow](image4)
(b) Data receiving software flow

**Figure 4.** Software flow of the gait detection system.
3. Results
In order to verify the performance of the proposed gait detection system, respectively, on the eight healthy adult gait data acquisition and testing, experimental process for the data acquisition device worn on the subjects of calf gait data collection, the collection process as starting test of signal when the PC software, after the subjects began with comfortable walking pace, walk to the designated area after the subject to stop walking, send stop command data acquisition device, the distance of about 6 meters. The experiment should be repeated 5 times for each subject to ensure the diversity and accuracy of experimental data collection.

Figure 5 shows the key phase detection results of a group of collected normal gait data, in which three key phase packages IC are represented by square, TO by circle and MSW by triangle. The detection results shown in the figure show that the gait analysis system proposed in this paper can completely identify the key phases in a gait cycle, indicating the reliability of the system.

![Figure 5. Gait analysis results.](image)

4. Conclusion
In the design of the gait detection system, the fusion of multiple sensors, low power consumption, wireless transmission and easy installation are fully considered. For multi-sensor fusion, the MPU-6050 with integrated gyroscope and acceleration sensor is adopted in this design. It can work continuously for 30h under full charge, with accuracy up to 0.05°, which meets the requirement of dynamic posture information monitoring of man-machine system. This system has the characteristics of fast collection rate, low power consumption, high cost performance and small size, which can be applied in the fields of authentication, rehabilitation medicine, humanoid robot and skeletal clothing, etc., and has a broad market prospect.

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