Planter Pressure Information Acquisition System Based on STM32

Xiaoyu Liang, Jingbo Zhao, and Youyu Wu*
Wuhan University of Technology, Wuhan, 430070, China

*Corresponding author e-mail: wuyouyu1@whut.edu.cn

Abstract. This paper introduces a plantar pressure detection and analysis system based on flexible membrane pressure sensor. The system collects and analyzes the data through the wireless Bluetooth module, and transmits the data and results to the upper computer. The performance of the system was tested and analyzed through the upper computer platform written in C++. The results showed no significant jumps and mutations.

1. Introduction

With the development of information age, many areas have adopted biometric technology based on fingerprint, face, iris and other biometrics to ensure personal and public security. Gait is a kind of way or habit of human walking, which is a biological characteristic of human being. Compared with other biometric recognition technologies, gait recognition has the advantages of non-contact, non-invasive, easy to perceive and difficult to camouflage. At present, there are two kinds of gait recognition methods. One is based on machine vision, through the image processing, and extracts motion features for gait recognition. Another one is based on the plantar pressure. The physiological characteristics of the human body can be determined by collecting the distribution of the plantar pressure when the human body is walking [1].

To sum up the development level and existing problems in China, there are mainly two aspects: the pressure detection system is not easy to wear, and many studies are based on the plantar pressure detection board, which makes the plantar pressure detection limited to indoor, unable to achieve real-time monitoring. In the other part of the study, the plantar pressure sensor is installed on the insole for detection. Because of the material of the sensor, it is not conducive to a large number of placement on the insole, which makes the collected data too little, resulting in low accuracy of gait detection algorithm. In addition, the power consumption of sensors and information transmission is high, which is not conducive to long-term wear. To solve these problems, this paper designs a plantar pressure acquisition and analysis system based on Flexiforce. Each foot is equipped with ten sensors at key points. Because of the small volume, bendable and low power consumption of Flexiforce, the plantar pressure acquisition system has many acquisition points and is easy to wear. In addition, ZigBee technology is used in wireless transmission module, which has low power consumption and strong endurance [2].

2. Design ideas

The internal structure of Flexiforce film pressure sensor is mainly composed of two parts of substrate. Its main material is polyester fiber film. By covering a special conductive material on the thin film layer,
adding a layer of pressure ink sensitive to pressure on the surface of the conductive material, and finally using the bonding material to press the two layers of substrate together to form a complete sensor. The silver edge displayed outside the pressure ink indicates the area sensitive to pressure. There are two outgoing wires around the sensitive area, which are input to the peripheral circuit. [3] The Flexiforce membrane pressure sensor in the circuit can be regarded as a variable resistance in the circuit. When there is no pressure load, the Flexiforce membrane pressure sensor shows a high resistance state. When there is pressure load, the resistance decreases.

The Flexiforce thin film sensor converts non-electrical signal data such as pressure and weight into electrical signals, then amplifies the weak electrical signals through the signal amplification circuit, and transmits the amplified signals to the STM32 microcontroller. [4]. STM32 single chip microcomputer will convert analog electrical signal into digital electrical signal through its ad peripheral, store and analyze the data, and finally send the original data and results to the upper computer.

3. System composition and working principle
The plantar pressure acquisition and analysis system designed in this paper is based on STM32F103 microprocessor. The system consists of power module, acquisition module, signal amplification module, STM32F103 minimum system, extended SRAM, wireless communication module. The system structure block diagram is shown in Figure 1.

The plantar pressure detection and analysis system is controlled by STM32F103 microprocessor. The specific working process is as follows: Ten pressure sensors are installed in the key parts of each foot, forefoot, heel and thumb. The pressure sensor installed on the sole of the foot senses and measures the pressure data. The sensor convert the pressure received into an electrical signal, amplify it to a suitable voltage through an amplification circuit, and convert it into a digital quantity through the A/D conversion module of the microprocessor [5]. The microprocessor on the left foot sends the collected data to the transmission module, which sends the data to the microprocessor on the right foot. The microprocessor on the right foot saves the data transmitted from the left foot and the pressure data collected from the right foot to the extended SARM for analysis. Finally, the analysis results and the collected original data are sent to the upper computer [6].
3.1. Power module
As the system is used for wearable devices, 3.7V lithium battery is used for power supply. STM32F103 minimum system and ZigBee communication module need 3.3V power supply, and signal amplification module needs + / - 5V power supply. So the power module consists of four parts: charging circuit, using TP4056 chip to charge lithium battery. 3.3V voltage stabilizing circuit adopts RT9193 chip to stabilize the 3.7V voltage of lithium battery into a stable 3.3V voltage. The 5V boost circuit uses PS7516 chip to boost 3.7V to a stable 5V voltage to supply power for the signal amplification module. The negative voltage conversion module uses ICL7660 chip to convert + 5V to - 5V stable voltage to supply power for the signal amplification module. The power module structure block diagram is shown in Figure 2.

![Figure 2. Power module structure block diagram](image)

3.2. Signal amplification module
Because the Flexiforce membrane pressure sensor used in this system has a weak output signal, a signal amplification module is needed to amplify the signal before the MCU collects the signal. According to the characteristics of Flexiforce thin film pressure sensor, the system adopts mcp6004 chip recommended by Flexiforce, which amplifies the pressure signal and transmits it to MCU [7]. Mcp6004 chip is a 1MHz low power operational amplifier designed by microchip Technology Company of the United States. There are four operational amplifiers in the chip [8]. The system uses the reverse proportion operation amplification circuit to amplify the weak electrical signal output by the sensor, and the specific circuit is shown in Figure 3.

![Figure 3. Signal amplification module circuit](image)

The same direction input terminal of the operational amplifier is grounded, and a sliding rheostat is connected in series between the reverse input terminal and the output terminal. One pin of the sensor is connected to - 5V, and another one is connected to the reverse input of the op amp. Considering the sensor as resistance Rs, according to the principle of virtual short and virtual break, it can be concluded that:
\[ V_{out} = -5 \times \left( \frac{R_f}{R_s} \right) \]

So whenever the sensor is stressed, the value of Rs will change, and the Vout will change accordingly. So long as the value of Vout is detected, it can be judged whether the sensor is under stress [9].

3.3. Extend SARM module

There are SRAM and flash in STM32 controller chip as memory and program storage space, it is necessary to expand the memory outside STM32 chip when the program is large and the memory and program space are insufficient. Because the system samples five times per second, there are 20 sensors on both feet, running the system for a long time, and the 64K ram of STM32 can't store all data, a 512k SRAM is added to the smallest system on the right foot. Due to the limitation of the number of pins. Only STM32F103ZE and higher-level MCUs can expand external SRAM. That's why STM32F103ZE MCU was chosen [10].

Stm32F1 series chips use FSMC peripherals to manage extended memory. FSMC is the abbreviation of flexible static memory controller, which is translated into flexible static memory controller. After FSMC connects external memory and initializes, it can read and write data directly through access address. Its storage unit is mapped to the internal addressing space of STM32. A pointer is defined in the program to represent these addresses, and then directly modify the contents of the storage unit through the pointer [11]. The FSMC peripheral will commands does not need program control.

4. System software design

STM32F103 is used for this system as the main control chip. The detected analog signal is converted into digital signal by A/D peripheral. In order to reduce the interference of the signal and make the measurement data more accurate, each acquisition point is set with five buffers, which are filtered by median average filtering method, and the results are stored and sent to the upper computer. The software flow chart is shown in Figure 4.

![Software flow chart](image)

**Figure 4.** Software flow chart
5. System performance analysis

In order to verify the stability and correctness of the system, the system is connected with the upper computer through ZigBee wireless module. Apply pressure to the sensor through the pressure gauge, observe the data received by the upper computer, and compare with the displayed value of the pressure gauge. The upper computer receives data as shown in Figure 5.

![Figure 5. Upper computer display data](image)

5.1. Steady rise pressure test

In the experiment, a three variable digital push-pull meter with a measuring range of 500N was used. In this experiment, the pressure is increased by 5N every fixed time interval. Considering the actual needs of the system, the maximum pressure on the foot when the human body is running will not exceed 100N, so the maximum force in this experiment is 100N. Through the data obtained in this experiment, check whether the system has step, mutation and other abnormalities, and judge whether the system is stable. The experimental results are shown in Figure 6:

![Figure 6. Results of steady pressure test](image)

It can be seen from the analysis of the root experiment results that the data of this experiment is stable and there is no step, mutation and other abnormalities. The value displayed by the software increases with the pressure of the manometer.

5.2. Zero pressure test experiment

Assume that no external force is applied to the membrane sensor. Let it stand for one minute, record the pressure value of the sensor during this period, and calculate the average and maximum pressure during this period. After testing, the maximum value displayed by the upper computer is 0.87N, and the average value is 0.19N. According to the instructions of the pressure sensor, the Flexiforce thin film pressure sensor has the characteristics of hysteresis and drift, which will cause 1% error in the maximum range. The error of the data obtained from this experiment meets this range.

5.3. Fixed pressure test

In order to test the stability of the system under constant force, a pressure gauge is used to apply external force to the system. In this experiment, 10N, 20N, 30N, 40N, 50N, 60N, 70N, 80N, 90N and 100N were...
used respectively. Record the data displayed by the upper computer and find the average value. Pressure value obtained in the table is expressed in \( x \pm s \), and the unit is N.

**Table 1.** Fixed pressure test results

| Experimental sequence | Applied pressure value/N | Pressure gained/N   |
|------------------------|---------------------------|---------------------|
| 1                      | 10                        | 10 \( \pm 0.245 \)  |
| 2                      | 20                        | 20 \( \pm 0.406 \)  |
| 3                      | 30                        | 30 \( \pm 0.527 \)  |
| 4                      | 40                        | 40 \( \pm 0.812 \)  |
| 5                      | 50                        | 50 \( \pm 1.034 \)  |
| 6                      | 60                        | 60 \( \pm 1.372 \)  |
| 7                      | 70                        | 70 \( \pm 1.474 \)  |
| 8                      | 80                        | 80 \( \pm 1.748 \)  |
| 9                      | 90                        | 90 \( \pm 1.801 \)  |

Experimental data shows that the system has good stability, and the measured data errors all meet the error range of 1% of the Flexiforce thin film pressure sensor [12].

**References**

[1] Jaehwan Ryu, Byeong-Hyeon Lee, Junho Maeng, Deok-Hwan Kim. sEMG-signal and IMU sensor-based gait sub-phase detection and prediction using a user-adaptive classifier [J]. Medical Engineering and Physics, 2019, 69.

[2] Lei Xu, Hui Zeng, Jun Zhao, Jungong Zhao, Jun Yin, Hua Chen, Yimin Chai, Yuqian Bao, Fang Liu, Weiping Jia. WITHDRAWN: Index of plantar pressure alters with prolonged diabetes duration [J]. Diabetes & Metabolic Syndrome: Clinical Research & Reviews, 2019.

[3] Animesh Hazari, Arun Maiya, Ioannis Agouris, Ashma Monteiro, Shivashankara. Prediction of peak plantar pressure for diabetic foot: The regresional model [J]. The Foot, 2019, 40.

[4] Serkan Taş, Alp Çetin. An investigation of the relationship between plantar pressure distribution and the morphologic and mechanic properties of the intrinsic foot muscles and plantar fascia [J]. Gait & Posture, 2019, 72.

[5] Hu Kun, Wang Zhiyong, Mei Shaohui, Ehgoetz Kaylena, Yao Tingting, Lewis Simon, Feng Dagan. Vision-based Freezing of Gait Detection with Anatomic Directed Graph Representation. [J]. IEEE journal of biomedical and health informatics, 2019.

[6] Behboodi Ahad, Zahradka Nicole, Wright Henry, Alesi James, Lee Samuel C K. Real-Time Detection of Seven Phases of Gait in Children with Cerebral Palsy Using Two Gyroscopes. [J]. Sensors (Basel, Switzerland), 2019, 19 (11).

[7] Hu Huacheng, Zheng Jianbin, Zhan Enqi, Yu Lie. Curve Similarity Model for Real-Time Gait Phase Detection Based on Ground Contact Forces. [J]. Sensors (Basel, Switzerland), 2019, 19 (14).

[8] Chomiak Taylor, Xian Wenbiao, Pei Zhong, Hu Bin. A novel single-sensor-based method for the detection of gait-cycle breakdown and freezing of gait in Parkinson's disease. [J]. Journal of neural transmission (Vienna, Austria: 1996), 2019, 126 (8).

[9] Zhiguan Huang, Yuhe Li, Long Jin, Hongwei Li. Evaluating flatfoot based on gait plantar pressure data in juveniles by a neural network method [J]. Footwear Science, 2019, 11 (sup1).

[10] Fatemeh Farhadi, Shane Johnson. Plantar pressure relief in pes cavus and pes planus: smart passive gait retraining using deformable insoles [J]. Footwear Science, 2019, 11 (sup1).

[11] Qichang Mei, Yaodong Gu, Vickie Shim, Justin Fernandez. Relating foot morphology and plantar pressure in shod and barefoot populations [J]. Footwear Science, 2019, 11 (sup1).

[12] J. Paulo, P. Peixoto, P. Amorim. Trajectory-based gait pattern shift detection for assistive robotics applications [J]. Intelligent Service Robotics, 2019, 12 (3).