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Intelligent Active Correction Seat Based on Neural Network Sitting Posture Recognition

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Abstract: Aiming at the problem of waist strain caused by people sitting for a long time and improper sitting posture at work, an intelligent correction seat for improving sitting posture is independently developed based on stm32 single chip microcomputer. The seat measures the sitting posture data through pressure sensors and ultrasonic sensors, and establishes a sitting posture model through neural network for sitting posture recognition. This seat solves the problem of difficult to correct bad sitting posture and reduces the incidence of lumbar diseases. Convolutional neural network for deep learning can meet the needs of fast and accurate identification and correction. This solution has the advantages of low cost, high precision, fast feedback, and wide range.

1. Introduction

With the growing demand for productivity, more and more workers need to work in a sitting position for a long time, and a large number of workers are prone to sedentary hazards such as back, waist and cervical spine diseases due to sedentary conditions[1,2]. At the same time, this problem is particularly prominent among young people. In this case, the problem of sitting posture needs to be solved urgently, and the auxiliary machinery for sitting posture correction has become a development trend.

Most of the current research is mostly on sitting posture detection and prompting correctors[3] .At present, the methods of sitting posture detection at home and abroad mainly include: methods based on flexible pressure sensor arrays, methods based on video image technology, various wearable sensors (such as three-dimensional acceleration sensors, etc.), and methods based on multiple lidar sensors[4-6]. However, the single use of a single sensor often leads to the problem that it cannot adapt to multiple application scenarios, and there will be significant data differences, and some solutions will have problems such as high cost and narrow application.

Considering its advantages comprehensively, it is decided to set the plan as an intelligent correction seat that can intelligently correct sitting posture through joint monitoring of multi-sensors. The user's sitting posture can be collected through distributed pressure sensors and ultrasonic sensors, a sitting posture model can be established, and the user's sitting posture can be identified through a convolutional neural network, which can improve the ability to deal with different scenarios while controlling costs. In this paper, the realization of the function of the device will be explained from the aspects of hardware scheme, system design, and analysis of experimental test results.

2. Hardware Design Scheme

On the basis of the general seat mechanical structure, STM32F103ZET6 is added as the main control chip. Eight strain gauges are distributed on the seat cushion to collect the pressure of the human body's buttocks[7,8]. Six strain gauges are distributed on the upper part of the back to collect the pressure on the back of the human body, and two ultrasonic sensors are distributed on the lower part to collect the distance between the back of the human body and the back of the seat. The system sends the collected data to the main control board through electrical signals, and after processing, it is transmitted to the PC through Bluetooth. The voice module and the display module remind the user of improper sitting posture, and intelligently correct the user through the mechanical structure[9]. The power module continuously supplies power to the system during the process (Figure 1).

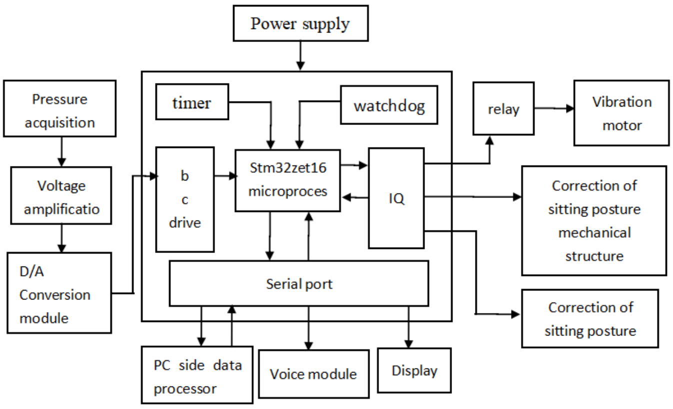

Figure 1 Hardware structure block diagram

2.1 Data collection

Using BF350 high-precision resistance strain gauge, according to the resistance strain effect, that is, when the metal wire is subjected to stress, the resistance value changes correspondingly with the size of the mechanical deformation. The theoretical formula is as follows:

$$R = p * (L / S) \tag{1}$$

When it is stretched by external force, the resistance increases; when it is compressed by force, the resistance decreases. The conversion relationship between resistance value and strain condition is:

$$\Delta R / R = K_o \tag{2}$$

As a result, the pressure change on the sensor can be detected by the voltage change.

The LM358 weak signal amplifier is used to amplify the DC weak signal, and then through the 12-bit low-power analog-to-digital conversion module of the stm32 chip, the real-time pressure values of 12 pressure sensors are continuously collected at the same time, and the data is processed.

2.2 Sensor distribution

When a person is in a normal sitting position, the pressure on the ischium is the greatest, and then distributes forward along the two thighs, and the pressure gradually spreads around. According to ergonomics, 8 pressure strain gauges are divided into three groups in the seat cushion part and placed in the main pressure area, as shown in the left picture of Figure 2. Among them, 1, 2 and 3, 4 are placed on the hip and femoral side to collect the posterior hip pressure; 5-8 four sensors are used to measure the pressure of the thigh. The back pressure is mainly distributed on the left and right sides, so the 6 pressure strain gauges are divided into two groups in the back part, as shown in the right picture of Figure 2, 1, 3, 5 are placed on the left side, and the left back Pressure; 2, 4, and 6 were placed on the right side, and the right back pressure was collected. At the same time, in the process of correcting the sitting posture, the sensor detects the posture in real time, which is convenient for more accurate correction.

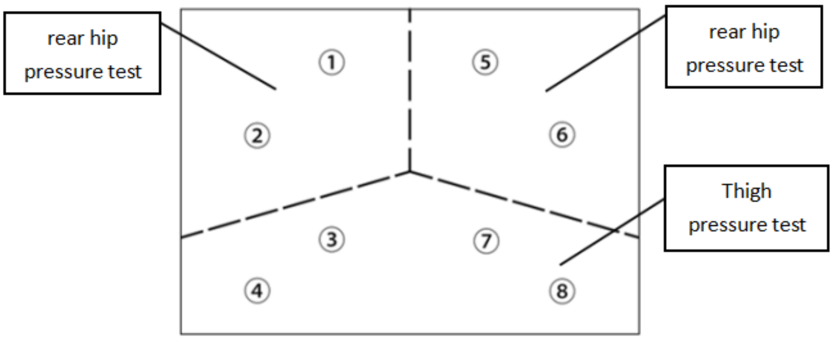

Figure 2 Layout of seat cushion strain gauge and back cushion strain gauge

3. Software Design Scheme

A closed-loop detection and correction system algorithm is designed. The process is shown in Figure 3. At the beginning of the system, the pressure is detected occasionally in the low-power mode, and when a human body is detected, the data is uploaded to the host computer. Compare the sitting posture model of the human body established by the neural convolutional network, obtain the sitting posture deviation of the human body, and then calculate the best correction scheme to enter the low-power mode after correcting the sitting posture to normal, and wait for five minutes to repeat the operation.

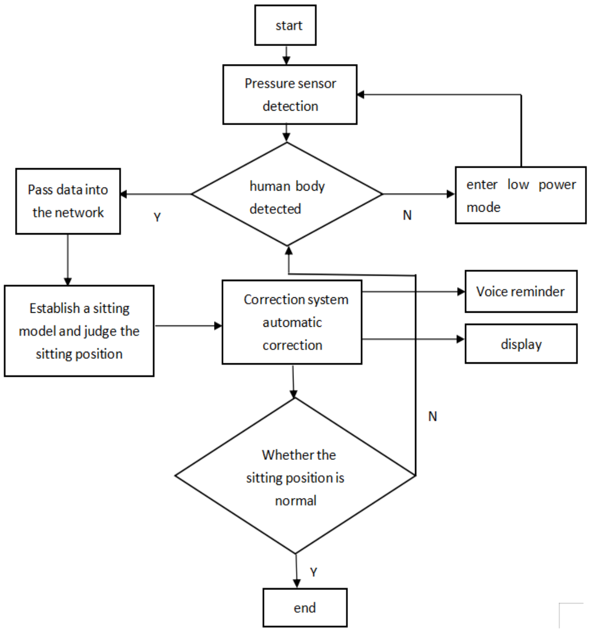

Figure 3 System Design Scheme

Seated human body model analysis. Because the data collected by the pressure sensor on the seat cushion is relatively complex and needs to meet the needs of different users, in order to achieve the best correction effect of the seat, we choose to build a human sitting posture data model to realize the use of the user's height and weight. The data derives the function of the pressure distribution of the cushion when sitting upright. The model can be used as a data reference when the correction function is implemented. In order to ensure the accuracy of the established model while simplifying the calculation, we choose to divide the sitting human body into three parts: upper body (hip joint and above), thigh and calf. Since the ratio of the weight and length of these three parts of the human body to the total body weight and height is basically fixed, the values obtained by the pressure sensor and the ultrasonic sensor can be pushed from the weight and height of the human body.

We adopt a simplified human sitting posture model, consisting of upper body, thigh and calf, as shown in Figure 1 below. The lengths of the calf, thigh, and upper body are set as l_1, l_2, l_3, respectively; the mass is respectively m_1, m_2, m_3; and the centroid is G_1, G_2, G_3, respectively. θ is the angle between the upper body and the horizontal plane of the hip joint, and is the vertical distance between the line connecting the knee joint and the hip joint and the front edge of the seat surface.

The ratio of each part to the height and weight of the human body is based on the average Japanese height ratio. As shown in Figure 4 below.

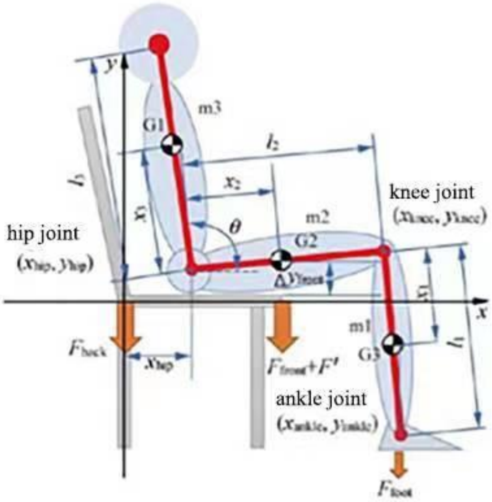

Figure 4 Disposal diagram under the sitting position

Table 1 The proportion of various parts of the human body in the whole body

body parts	quality	length	center of gravity
trunk	m_3=0.65m	l_3=0.49l	x_3=0.41l_1
thigh	m_2=0.21m	l_2=0.25l	x_2=0.42l_2
calf	m_1=0.14m	l_1=0.26l	x_1=0.48l_3

In experiments and observations, we found that the pressure distribution of sitting postures of people with different weights and heights is quite different, and different sitting postures will also have a greater impact on the pressure value of the cushion. Therefore, the pressure distribution of the seat cushion can not only reflect the height and weight of the user, but also reflect the sitting posture of the user. This provides a theoretical basis for our sitting analysis. In order to obtain the reference model of the ideal standard sitting posture, we use the sitting posture of the upper body and the lower legs perpendicular to the ground to establish a simplified mathematical relationship model of the human body. At this point, the center of mass of the upper body is located at the hip joint, the center of mass of the calf is located at the knee, and the gravity effect of the calf is offset by the ground reaction force. Therefore, the moment balance between the upper body F_{back} and the thigh F_{front} is obtained as follows:

$$(F^{'} + F_{front}) l_{sheet} = m_3 g x_{hip} + m_2 g (x_{hip} + x_2) \tag{3}$$

$$F_{front} l_{sheet} = m_2 g (l_{sheet} - x_{hip} - x_2) + m_3 g (l_{sheet} - x_{hip}) \tag{4}$$

In formula (4), F' is the force between the seat and the thigh muscles. Therefore, a force $F^{'}$ is introduced to make the model more realistic. After multiple data measurements, it is known that when the front end of the thigh is close to the front edge of the seat, the $F^{'}$ value increases, and the angle between the thigh and the seat surface increases; when the front end of the thigh is the front edge of the seat, $F^{'}$ decreases, and the thigh The seat surface angle is reduced. And the value of $F^{'}$ is related to the vertical distance Δy_{front} between the line connecting the knee joint and the hip joint and the front edge of the seat surface. The relationship between $F^{'}$ and can be approximately calculated as,

$$F^{'} = k \Delta y_{front} \tag{5}$$

Among them, *k* is the action force coefficient to compensate for the interaction force of the thigh and the surface of the seat.

From the relationship between the human thigh and the seat in Figure 1, it can be known that Δy_{front} is related to $l_{sheep}, x_{hip}, x_{sheep}, y_{knee}, y_{hin}$. When the position of the hip joint and knee joint is measured by the ultrasonic sensor, Δy_{front} can be calculated as:

$$\Delta y_{front} = \frac{l_{sheep} - x_{hip}}{x_{sheep} - x_{hip}} (y_{knee} - y_{hip}) \tag{6}$$

In order to obtain the coefficient k, we collected the data recorded by the test subjects of different heights and different weights in the standard sitting posture, and put the data into the above formula (1), and compared with the actual height and weight data, when k is 3000, the obtained data matches the reality more accurately. which is:

$$F^{'} = 3000 \Delta y_{front} \tag{7}$$

If the user is heavier and has higher body fat, it will result in a thicker-than-normal hip thickness, resulting in a smaller distance measurement; conversely, when the user is thinner, the hip thickness will be lower than normal. Therefore, it is necessary to introduce compensation length x_{offset} to correct the obtained data. Since BMI can well reflect the level of fat and thinness, the adjustment amount calculated by BMI is used. Because the adjustment directions of the fatter and thinner people are different, a piecewise function is used to describe the compensation length x_{offset},

$$x_{offset} = \begin{cases} 0.4(\frac{l^2}{m} - 24), BMI > 24 \\ -0.15(19 - \frac{l^2}{m}), BMI < 19 \end{cases} \tag{8}$$

$$BMI = \frac{l^2}{m} \tag{9}$$

4. Experimental Test and Results Analysis

Select one person to test randomly to detect the pressure distribution of cushions and back pads when sitting, left -leaning, and right -leaning, as well as the pressure distribution of cushion pressure when leaning and backward leaning. The collected data is uploaded through the Bluetooth module, and the pressure distribution table under different sitting positions as shown in Table 2 and Table 3 is obtained.

Table 2 Cushion Pressure Gauge

Normal	
Serial number	Voltage value/V
1	2.453
2	2.674
3	1.642
4	1.122
5	2.515
6	2.682
7	1.628
8	1.215
Lean Left	
Serial number	Voltage value/V
1	2.654
2	2.883
3	1.873
4	1.398
5	2.361
6	2.375
7	1.534
8	0.955
Lean Forward	
Serial number	Voltage value/V
1	1.553
2	2.259
3	1.842
4	1.315
5	1.617
6	2.221
7	1.733
8	1.354
Lean Back	
Serial number	Voltage value/V
1	2.603
2	2.75
3	1.275

4	0.588
5	2.628
6	2.741
7	1.227
8	0.643

Lean

Serial number	Voltage value/V
1	2.21
2	2.533
3	1.372
4	0.858
5	2.661
6	2.793
7	1.837
8	1.436

Table 3 Back pad pressure gauge

Normal

Serial number	Voltage value/V
1	0.654
2	0.622
3	0.421
4	0.443
5	0.213
6	0.221

Lean Left

Serial number	Voltage value/V
1	0.823
2	0.332
3	0.532
4	0.278
5	0.317
6	0.093

Lean

Serial number	Voltage value/V
1	0.324
2	0.902
3	0.311
4	0.583
5	0.101
6	0.311

According to the observation data, when the various data are balanced, the user is sitting upright. When one side of each data is high, the user is in a state of corresponding roll. The human sitting posture model is established through the data, and the convolutional neural network is used to judge the user's sitting posture problem, and the optimal correction scheme is calculated for correction acceptablely.

5. Conclusion

This paper proposes a multi-sensor intelligent sitting posture correction seat based on neural convolutional network that can be mechanically corrected. Judge the sitting posture problem, output the final sitting posture correction plan, and correct the user's sitting posture through various reminders and mechanical correction methods.

Different from the simple data collection analysis or manual adjustment of other solutions, this solution has a complete sitting posture correction process and includes many innovative functions, which can greatly improve people's problems caused by prolonged sitting and improper sitting posture, prevent or reduce waist strain, spondylosis, etc. exacerbation of the problem.

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