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Design and Implementation of an Intelligent Sitting Pad for Posture Correction Based on STM32 and CAN Bus

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Abstract: This study presents an intelligent ergonomic seat cushion system utilizing STM32 microcontroller and CAN bus technology, designed to address health issues like scoliosis and myopia caused by prolonged poor posture. The device employs a film pressure sensor to monitor real-time hip pressure distribution, while integrating STM32F103C8T6 microcontroller with HX711 analog-to-digital converter for high-precision signal processing. A L298N driver motor controls a scissor-type lifting mechanism, enabling independent height adjustment on both sides. The closed-loop control system dynamically adjusts the cushion's posture based on pressure differences, encouraging users to correct their sitting posture autonomously. The structural design combines ergonomic principles with finite element analysis, using aluminum alloy and PETG materials to balance strength and comfort. Experimental results demonstrate the system's effective posture recognition and adaptive correction capabilities, showcasing excellent stability and promising application potential.
Keywords: smart seat cushion; pressure sensor; correct sitting posture.

1. Foreword

1.1 Background and Issues:

Modern society has witnessed the proliferation of sedentary work environments, such as prolonged computer use and extended classroom sessions. These activities often lead to poor posture, which can cause abnormal spinal growth patterns. Chronic poor sitting posture may result in spinal curvature (scoliosis) and common conditions like myopia. Two primary approaches exist for correcting posture: self-regulation through personal awareness, and external corrective measures to stabilize postural alignment.

The current mainstream orthotic seating solutions on the market primarily include ergonomic backrests, corrective belts, and lumbar support devices. Research indicates that even after prolonged refinement, these orthotic aids still provide limited correction effectiveness, often leading to dependency or discontinuation of use. This inspired our design of this ergonomic cushion. Incorrect sitting posture inevitably creates uneven pressure distribution across the cushion surface compared to normal sitting patterns. Through integrated sensors and embedded computing systems, the cushion dynamically adjusts internal elevation at various points, enabling the body to self-correct its posture in real-time.

This invention aims to assist in correcting bad sitting posture based on mechanical structure and intelligent system.

1.2 Research Content:

This study focuses on populations with higher susceptibility to scoliosis. Two product categories currently available on the market assist in spinal curvature prevention: ergonomic chairs and desks that maintain proper posture to reduce scoliosis risks, and posture monitoring devices/technologies. These systems utilize sensors to track spinal alignment changes and provide real-time alerts, effectively minimizing prolonged poor sitting postures. Examples include smart seat belts, spinal tracking sensors, and mobile apps that monitor sitting posture in real time, helping users maintain healthy habits. Building on these two categories, we propose integrating assistance with detection to achieve both monitoring and posture adjustment. Specifically for Asian populations, we analyze the distribution of gluteal pressure values and optimize sensor placement configurations. This approach ensures more accurate pressure detection, enables timely adjustments to cushion alignment and pillow tilt angles, and provides users with relaxation reminders to enhance lumbar muscle recovery. The resulting smart cushion integrates thin-film sensors with motors through CAN communication for precise posture management.

1.3 Method Overview:

This project is a pressure sensing electric lifting cushion system adapted to human body structure. The core information is as follows:

Mechanical Design: The system employs multiple scissor-type lifting platforms of varying sizes to form a curved, semi-enclosed lifting mechanism, enabling vertical movement, horizontal rotation, and tilting. The lower section features a detachable zipper for easy assembly/disassembly, while the thicker latex layer in the lower part securely holds sensors and the scissor base. Initially constructed with PLA material, the design allows for future upgrades to incorporate motorized torque adjustments.

The electronic control system, centered around the STM32F103C8T6 microcontroller, collects pressure signals through strain gauges and the HX711 sensor (with STM32 reading and converting the data). The L298N driver board manages the motor via pin control for forward/reverse rotation and PWM signals for speed regulation, forming a closed-loop control system.

2. Posture Analysis

To develop passive dynamic sitting exercises suitable for office environments, this study conducts an anatomical analysis of seated movements. The multifidus, longestus, and iliopsoas muscles play crucial roles in maintaining spinal stability and mobility. Prolonged sitting often leads to fatigue in these muscles, which may contribute to lower back pain and related discomfort [7]. Therefore, these muscles were selected for analysis. The multifidus originates from the lumbar lamina and spinous processes, inserting into the facet joints of lower vertebrae, transverse processes, and sacrum. With a cross-sectional area twice that of the longestus and iliopsoas muscles, the multifidus plays a vital role in spinal stability. Atrophy of the multifidus frequently triggers lower back pain [6][7]. The longestus originates from the sacrum, inserting into the transverse processes of lumbar vertebrae, the tips of all thoracic transverse processes, and the angles of the last 9-10 ribs. The iliopsoas originates from the dorsal surface of the sacrum and iliac crest, inserting into the angles of the lower 6th ribs, as shown in Figure 1. Both the longestus and iliopsoas are components of the erector spinae muscles, primarily responsible for generating large-amplitude lumbar movements [5]. Passive dynamic sitting exercises can induce pelvic tilts in lateral and anterior-posterior directions, helping users adjust these muscle groups and effectively preventing lower back pain and other sedentary-related issues [9][10]. However, anterior-posterior pelvic tilts may cause upper body instability and visual disturbances [8]. Therefore, this study focuses on lateral spinal flexion exercises, which help stretch tight muscles and strengthen weak ones [10][12]. At the same time, the upper body can be kept stable under the left and right spinal lateral flexion movements [7], which is suitable for office needs.

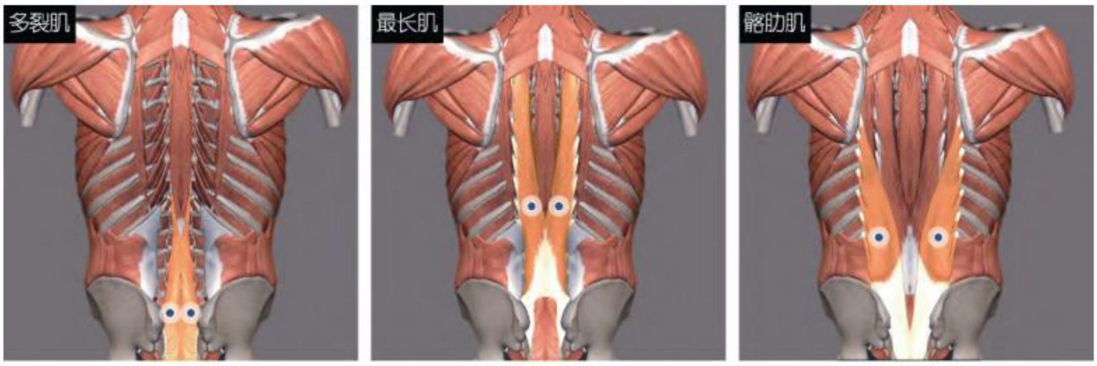

Figure 1: The pectoralis major, the longest muscle, and the iliopsoas muscle

3. Cushion Design

3.1 Pressure sensing cushion structure design

This project presents a multifunctional electric lifting platform comprising a base, electric push rod, scissor mechanism, top seat, toothed rotary mechanism, inclined base, inclined top seat, and support rod assembly. The toothed rotary mechanism is rotatably mounted at the center of the top seat, with its upper section connected to the bottom of the inclined base. The first end of the inclined top seat is hinged to the first end of the inclined base, while the product to be lifted is positioned atop the inclined top seat. The support rod assembly, installed above the inclined base, connects its functional end to the bottom of the second end of the inclined top seat. This application is adaptable for multiple scenarios: The electric push rod and scissor mechanism work together to lift heavy objects, the toothed rotary mechanism enables horizontal rotation of the load, and the coordinated action of the support rod assembly, inclined base, and inclined top seat allows tilting adjustments. During cushion structure design, finite element analysis software was employed to simulate stress distribution under various sitting postures, ensuring sensor placement maintains structural integrity while accurately collecting pressure data. Additionally, establishing a 3D assembly model of mechanical components and electrical control modules helps prevent spatial interference issues. The uppermost layer of the cushion is made of PETG material, chosen for its non-BPA content suitable for maternal and infant use, with a melting point range of 70-85°C [11] – within the operational temperature range.

Elevating Drive Module: Symmetrically mounted on both sides of the seat cushion are drive motors with a torque of 16kg/cm. The motor's output shaft drives a threaded push rod, which in turn moves the slider linearly. This slider actuates one end of the scissor mechanism, enabling independent height adjustment at both ends of the seat cushion to accommodate various posture requirements.

Structural strength assurance: The scissor mechanism, seat cushion top plate, base plate, and transmission slider are all made of aluminum alloy and CNC precision machining, which not only ensures the overall bearing capacity and stability of the structure, but also effectively controls the weight of the components and avoids redundant load of the system [2].

Battery life and power supply design: The system is equipped with a 12V/2500mAh lithium battery as the power supply unit, which takes into account the battery life and installation space, and can meet the needs of stable operation for a long time.

Pressure Detection Module: Featuring a 70kg-range pressure sensor as the core signal acquisition unit, this system operates within a temperature range of-20°C to 85°C with 0.1mV/V sensitivity and a total integrated error of 0.02%F.S. Its robust environmental adaptability and high detection accuracy are key advantages. When pressure is applied to the seat surface, the sensor converts mechanical signals into electrical signals, which are then transmitted to the HX711 analog-to-digital converter for conditioning and digital processing. The processed data drives motor operations, forming a closed-loop control system that integrates pressure acquisition, signal processing, and actuator execution [1][4].

Ergonomic design: The seat cushion surface features a 3D model created using SolidWorks software, tailored to the natural curves of the human buttock. Manufactured through 3D printing technology, this design ensures a snug fit that significantly enhances riding comfort.

Feasibility verification of key components: SolidWorks was employed to create 3D models of core transmission components including the guide shaft base plate, sliding connector, support rod, and shaft bracket (as shown in Figure 2). The software's built-in assembly interference check and structural feasibility analysis functions were utilized to validate the rationality of component assembly relationships and motion reliability [3], providing a design basis for physical prototype fabrication.

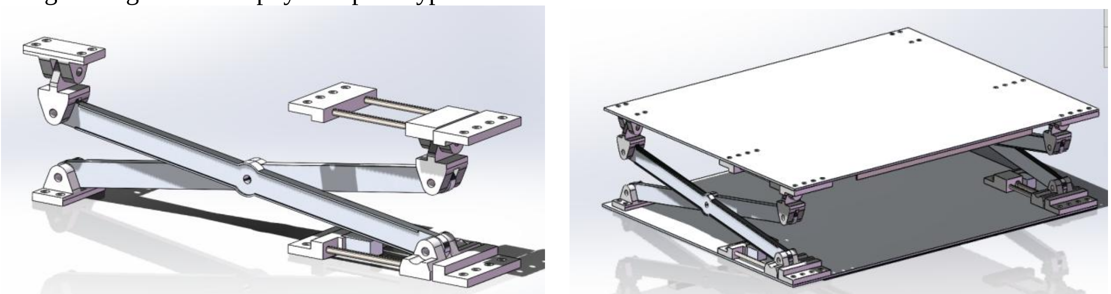

Figure 2: Modeling the inner frame of the cushion

Comfort optimization: The 16kg/cm torque motor delivers stable performance, ensuring smooth cushion movement during posture adjustments and preventing motion-induced discomfort. The ergonomically designed cushion surface combines 'stable adjustment' with 'supportive fit' for dual comfort assurance.

3.2 Pressure sensing cushion circuit control system

The pressure-sensitive cushion's electronic control system, centered around the STM32F103C8T6 microcontroller, establishes a closed-loop control system that covers everything from high-precision signal acquisition to motor drive. For signal acquisition, the system utilizes the dedicated HX711 24-bit analog-to-digital converter (ADC) chip to process the strain gauge's weak signals. The converter is shown in Figure 3.

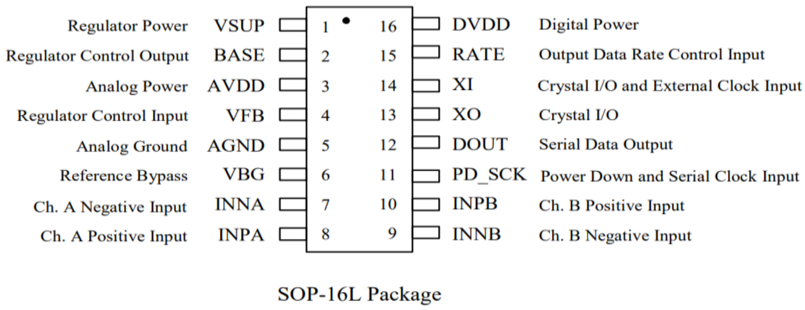

Figure 3 HX711 chip

For the specific connection, the four output pins of the 1000-3EB full-bridge strain gauge—two signal lines (positive/negative) and two power lines (positive/negative)—are directly connected to the "A channel" interface of the HX711 module: E+, E-, A+, A-. The signal undergoes 128x gain, while the HX711's internal voltage regulator ensures stable power supply to the bridge. Figure 5 shows the channel schematic.

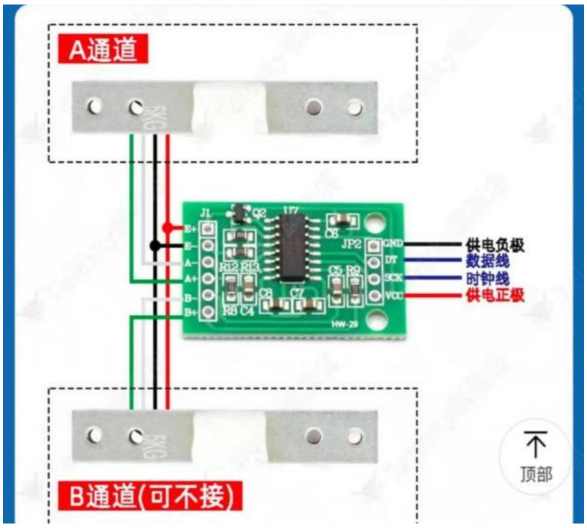

Figure 5 Channel diagram

The STM32 communicates with the HX711 via two GPIO lines (PD_SCK and DOUT) for synchronous serial data transfer. As shown in Figure 6, when the DOUT pin transitions from high to low, it signals the completion of an A/D conversion. The STM32 then generates 25 clock pulses, sequentially reading 24-bit data from the DOUT line during the rising edges of the first 24 pulses to form an initial count value. The operation Count = Count ^ 0x800000 in the code essentially calibrates the system using the HX711's binary complement output format. By inverting the most significant bit, this converts the data into a binary offset code that is easier for the microcontroller to process.

```
uint32_t ReadCount1(void)
{
  uint32_t Count = 0;
  uint8_t i = 0;
  HAL_Delay(10);
  HAL_GPIO_WritePin(SCK1_GPIO_Port, SCK1_Pin, GPIO_PIN_RESET);

  while(HAL_GPIO_ReadPin(DT1_GPIO_Port, DT1_Pin));//判断AD转换器是否准备好（DOUT应为低电平）
  for(i = 0; i <24; i++)//24
  {
    HAL_GPIO_WritePin(SCK1_GPIO_Port, SCK1_Pin, GPIO_PIN_SET);
    Count = Count << 1;
    if(HAL_GPIO_ReadPin(DT1_GPIO_Port, DT1_Pin))
    {
        Count ++;
    }
    HAL_GPIO_WritePin(SCK1_GPIO_Port, SCK1_Pin, GPIO_PIN_RESET);
  }

  HAL_GPIO_WritePin(SCK1_GPIO_Port, SCK1_Pin, GPIO_PIN_SET);
  Count = Count ^ 0x800000;
  HAL_GPIO_WritePin(SCK1_GPIO_Port, SCK1_Pin, GPIO_PIN_RESET);
  return Count;
}

uint32_t ReadCount2(void)
{
  uint32_t Count = 0;
  uint8_t i = 0;
  HAL_Delay(10);
  HAL_GPIO_WritePin(SCK2_GPIO_Port, SCK2_Pin, GPIO_PIN_RESET);

  while(HAL_GPIO_ReadPin(DT2_GPIO_Port, DT2_Pin));//判断AD转换器是否准备好（DOUT应为低电平）
  for(i = 0; i <24; i++)//24
  {
    HAL_GPIO_WritePin(SCK2_GPIO_Port, SCK2_Pin, GPIO_PIN_SET);
    Count = Count << 1;
    if(HAL_GPIO_ReadPin(DT2_GPIO_Port, DT2_Pin))
    {
        Count ++;
    }
    HAL_GPIO_WritePin(SCK2_GPIO_Port, SCK2_Pin, GPIO_PIN_RESET);
  }

  HAL_GPIO_WritePin(SCK2_GPIO_Port, SCK2_Pin, GPIO_PIN_SET);
  Count = Count ^ 0x800000;
  HAL_GPIO_WritePin(SCK2_GPIO_Port, SCK2_Pin, GPIO_PIN_RESET);
  return Count;
}
```

Figure 6: Program code

At the motor drive level, the system employs an L298N driver board. The STM32 controls the motor's forward/reverse rotation by setting the IN1 and IN2 pin levels: IN1=1 and IN2=0 for forward rotation. To achieve precise speed regulation, the system utilizes the STM32's hardware timer (TIM) to generate PWM signals. The PWM output is initiated by calling the HAL library function HAL_TIM_PWM_Start(&htim1, TIM_CHANNEL_1), with the duty cycle dynamically adjusted by writing to the capture/compare register TIM1->CCR1 = 800, thereby modifying the motor's rotational speed.

The system successfully converted strain gauge deformations into high-precision numerical values and implemented threshold-based motor control. However, during actual debugging, it was observed that although the HX711 sensor provides 24-bit high resolution, its signal is susceptible to mechanical vibrations and temperature drift, causing data fluctuations. By implementing dead zone settings in software, applying sliding average filtering to pressure values, and fine-tuning the PWM duty cycle, the system's stability and control smoothness were effectively improved. The program is illustrated in Figure 7.

```c
uint32_t average_jisuan(void)
{
 // 获取两个重量值
   static uint32_t last_average = 0; // 保存上一次的平均值
    uint32_t weight1 = WeightReal1();
    uint32_t weight2 = WeightReal2();
  uint32_t average = (weight1 + weight2) / 2;
  printf("weight1=%d\r\n",WeightReal1());
  printf("weight2=%d\r\n",WeightReal2());
  printf("average=%d\r\n", average);

  // 判断 weight1 是否与平均值的差值超过阈值
  if (abs((int)(weight1 - last_average)) > 3)
    {
      Motor1_Forward();
      printf("The motor_1 is forward\r\n");
       HAL_Delay (1000);
      Motor1_Reverse();
       printf("The motor_1 is reversed\r\n");
    }
  else if(abs((int)(weight1 - last_average)) < 1)
    {
      Motor1_Stop();
      printf("No drive motor_1 is needed\r\n");
    }


     // 判断 weight2 是否与平均值的差值超过阈值
   if (abs((int)(weight2 - last_average)) > 3) {

       Motor2_Forward();
      printf("The motor_2 is forward\r\n");
      HAL_Delay (1000);
     Motor2_Reverse();
        printf("The motor_2 is reversed\r\n");
    }
  else if( abs((int)(weight2 - last_average)) < 1)
    {
        Motor2_Stop();
      printf("No drive motor_2 is needed\r\n");
    }

    last_average = average;
  return 0;
```

Figure 7: Program code

In the main loop of the program, the critical debugging information—such as real-time AD values, calculated filtered pressure values, motor direction (forward/reverse), and stop status—gets printed by calling the HAL_UART_Transmit or redirecting the printf function, as shown in Figure 8, enabling timely access to control data.

```
forwardThe motor_2 is forwardweight1=7061weight2=7437
forwardThe motor_2 is forwardweight1=7062weight2=7437
forwardThe motor_2 is forwardweight1=7063weight2=7437
forwardThe motor_2 is forwardweight1=7063weight2=7437
forwardThe motor_2 is forwardweight1=7065weight2=7437
forwardThe motor_2 is forwardweight1=7066weight2=7437
forwardThe motor_2 is forwardweight1=7068weight2=7436
forwardThe motor_2 is forwardweight1=7063weight2=7441
```

Graph 8

Results and conclusions: The characteristics of the final 3D model and physical prototype are summarized, the rationality of its structure and the realization of its function are proved, and its application value in the field of sitting posture monitoring and correction is pointed out.

4. Pressure Sensing Cushion Exercise Method and Working Principle

4.1 Intelligent pressure sensing cushion posture adjustment principle

The intelligent pressure sensing seat cushion achieves dynamic correction of users' bad sitting posture through the closed-loop control logic of "pressure detection, signal processing and executive adjustment". The specific motion adjustment principle is as follows:

When a user sits down, improper posture (such as excessive weight on one side of the buttocks or leaning) causes uneven pressure distribution between the left and right buttocks on the seat cushion. The built-in pressure sensor detects this imbalance and converts it into an electrical signal. This signal is then transmitted to the HX711 analog-to-digital converter chip, where it undergoes signal conditioning and digital processing. The system accurately calculates the required height adjustment to balance the pressure and generates corresponding motor drive commands.

The control command activates the motors on both sides of the seat cushion. The motors' torque drives the threaded push rod to move linearly, which in turn pushes the slider for extension/retraction of the scissor mechanism. Specifically, when the pressure is higher on one side of the seat cushion, the scissor mechanism extends to lift it; conversely, when the pressure is lower on the other side, the mechanism retracts to lower the cushion.

When a height difference forms between the cushion's sides, users sitting on it will experience noticeable imbalance. This sensory feedback prompts them to consciously adjust their posture. The system continuously adjusts until the user sits upright with balanced pressure distribution across both hips, then stops automatically, achieving self-adaptive correction of poor sitting posture.

4.2 Intelligent pressure sensing seat cushion circuit control logic

The circuit control of the intelligent pressure sensing seat cushion is based on the proportional relationship of "pressure difference-height adjustment" to realize the adaptive control of sitting posture correction. The specific logic is as follows:

When a user sits with poor posture, the pressure distribution between their buttocks becomes uneven across the cushion's ends. The circuit system first collects real-time pressure data from both ends using pressure sensors, converts the pressure difference into corresponding electrical signals, and then applies the preset "pressure-to-lift-height" proportional logic function.

This function takes the pressure difference as the input variable, calculates the required lifting or lowering height at both ends of the seat cushion through the algorithm (the end with higher pressure value corresponds to the calculation of lifting height, and the end with lower pressure value corresponds to the calculation of lowering height), and generates accurate motor drive signal.

The motor activates the corresponding actions based on the drive signal, driving the mechanical structure to adjust the height at both ends. This adjustment process continues until the pressure distribution at both ends of the seat cushion reaches equilibrium. The circuit system then determines that the user's sitting posture has returned to a correct position, immediately halting the drive signal output. The adjustment process terminates, achieving closed-loop control for sitting posture correction.

5. Product Innovation Applications

This intelligent pressure sensing cushion system has a number of innovations in product design and application, which are embodied in the following aspects:

Multimodal fusion of sitting posture perception and regulation mechanism

The system integrates a high-precision thin-film pressure sensor, STM32 embedded controller, and electric scissor lift mechanism, achieving a fully closed-loop control system of "sensing, decision-making, and execution". Unlike traditional static orthotic devices, this system dynamically adjusts the seat cushion posture based on real-time pressure distribution, providing passive and sensor-free posture guidance to prevent user dependency or discomfort.

Ergonomic structural innovation

The seat features a zoned independent lifting mechanism, utilizing a hip pressure distribution model to precisely counteract poor sitting postures. The scissor mechanism combined with a swivel base enables both lateral tilting and horizontal rotation, expanding the range of posture adjustments to better accommodate dynamic sitting needs in office environments.

Embedded intelligent system with hardware and software collaboration

The system features a stable and reliable electronic control platform based on the STM32 core, integrated with the HX711 high-precision ADC and L298N motor driver. By implementing software strategies such as sliding average filtering, PWM speed regulation, and dead time control, the platform significantly enhances its anti-interference capability and control smoothness, while maintaining strong engineering feasibility and scalability.

It has a wide range of applications and good social promotion value

This product is not only suitable for sedentary groups such as students and office workers, but can also be extended to professional scenarios like drivers and rehabilitation training. Its modular design and detachable structure facilitate cleaning and maintenance. The selection of PETG and aluminum alloy materials ensures both safety and structural strength, offering promising industrialization prospects.

6. Epilogue

We have developed and implemented an intelligent pressure-sensing seat cushion system based on STM32 and CAN bus. By organically integrating mechanical structures, sensors, and embedded control systems, the system achieves real-time detection and dynamic correction of poor sitting postures. It features high-precision pressure sensing, multi-degree-of-freedom posture adjustment, and closed-loop control capabilities. The system demonstrates excellent feasibility and practicality in structural design, signal processing, and control logic.

Experimental results demonstrate that the system effectively responds to users' sitting posture changes, guiding them back to proper alignment through adjustable cushion height, delivering both excellent user experience and corrective efficacy. In future iterations, the system will integrate wireless communication modules (e.g., Bluetooth/Wi-Fi) with mobile apps to enable posture data recording and health alerts. This evolution will transform it into a smart health seat that combines monitoring, correction, and data analysis, providing effective technical support for spinal health management among sedentary populations.

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