Manipulator Massage System Based on STM32 Control

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Abstract. With the computer gradually become an essential part of People's Daily life. Long periods of sitting can lead to headaches, dizziness and cervical discomfort. In this paper, a manipulator massage system based on STM32F103 chip is designed to promote the intellectualization and automation of human cervical vertebra massage. Based on the study of human neck and shoulder massage points and massage techniques, the mechanical structure of the manipulator is designed, and SolidWorks is used to design the 3D model.

1. Introduction
With the rapid development of era, the computer has become necessary in our life, in the case of using the computer for a long time, the body back and shoulder muscles is in a state of tension for a long time, easy to cause local vasoconstriction, poor blood supply, accumulation of metabolites in local, creating local muscle, tendon, articular inflammation and pain.

Cervical spine and shoulder are the areas where the source of disease is easy to accumulate, and are also the vulnerable parts of the body. The neck and shoulders are switches for the brain, through which blood is injected into the head and face. Toxins build up in the neck and shoulders, squeezing blood vessels and preventing blood from reaching the head or face successfully, leading to dizziness, headaches, fatigue, and over time, stiffness and difficulty in moving the neck and shoulders.

There are more than 40 points [1-3] commonly used in human body massage, and each point has its corresponding different functions, so the selection of massage points is different. Each person can choose different massage points according to his own needs, and the massage technique is based on traditional Chinese medicine massage [4,5].

Therefore, automatic technology to realize intelligent human cervical vertebra massage can greatly relieve the physical pain of sedentary people, and regulate people’s physiological functions to relieve physical discomfort.

2. Overall System Design
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2.1. Manipulator Massage System is Mainly Composed of Three Parts

2.1.1. Sensor Data System. This part mainly carries on the comprehensive determination for the position and state of the human body arm and shoulder arm. The basic information of the determination includes the distance between the manipulator and the arm shoulder arm and the pressing force of the manipulator.
2.1.2. Information Display Terminal System. The information display terminal system USES TFTLCD display screen to conduct man-machine interaction and change the pressing force and position of the manipulator.

2.1.3. Mechanical Design Part. The mechanical design part is mainly to design the motion mode of massage manipulator, and solidWorks is used to design the 3D model.

3. Hardware System Design

3.1. Demand Analysis
Through investigation and analysis, the three main functions of this system need to be realized, as follows:
1) Measure the pressure of the manipulator at each moment, and control the pressing force;
2) The control system works smoothly and has good stability;
3) The system should have high reliability and flexibility;

3.2. Mechanical Structure Design

3.2.1. The Operation Mode Design of the Rail Seat of the Shoulder Arm. The rail seat of shoulder arm mainly needs to realize the positioning of the human shoulder arm, because different people's shoulder height and shoulder width are different, in order to achieve accurate positioning, the rail seat of shoulder arm needs to realize the up-down, left-right movement of the two degrees of freedom fine-tuning operation, to ensure that the arm massage manipulator can accurately massage to the specified position. The external structure of the rail seat of the shoulder arm mechanical design is shown in the Figure 1 below.

3.2.2. Shoulder Arm Rail Seat Left and Right Movement Fine-Tuning Design. The left and right movement of the rail seat on the massage chair is controlled by controlling the size of the airbag. The airbag inflating pushing belt pushes the rail seat of the shoulder arm to move close to the human body, as shown in the Figure 2 below.

3.2.3. Design of Fine-Tuning Way of Rail Seat of Shoulder Arm Moving Up and Down. The up-down movement of the rail seat on the massage chair adopts the elevator structure. The height of the lifting platform can be controlled by controlling the rotation of the stepper motor at the bottom, so that the rail seat of the shoulder can be lifted to the shoulder height of the human body. The specific process is shown in Figure 3.

![Figure 1](image-url)
3.3. The Operation Mode Design of Small Manipulator for Arm Massage

3.3.1. Massage Manipulator Finger Design. According to the design requirements, the arm massage manipulator itself needs to complete at least 2 degrees of freedom movement. For this reason, two stepping motors are used to control the forward and backward movement of the machine and the clamping action respectively. The starting end of the finger is matched with the gear to open and close the finger, and the gear is driven by the stepping motor. The specific schematic diagram is shown in Figure 4.

3.3.2. The Small Arm Massage Manipulator is Designed in the Orbit Seat of the Shoulder Arm. According to the design requirements of the arm massage manipulator, the motion is drawn up as follows. The operation mode of the arm massage small manipulator in the rail seat of the shoulder arm adopts the scheme of guide rail lifting. The rise and fall of the left and right two sliders are controlled by two stepping motors in the rail seat of the shoulder arm, and then the rise and fall of the manipulator platform is controlled, as shown in Figure 5.

To sum up, according to the designed mechanical mechanism, SolidWorks software was used for 3D simulation design, and the following three-dimensional model was designed, as shown in Figure 6.
4. Software System Design

4.1. Control System Main Program Design
The system carries out manual interaction through TFTLCD display screen, receives the pressing force and pressing position that need to be accepted, and transmits the information to the STM32F103C8T6 microcontroller. After the microcontroller receives the signal, it carries out a series of controls on the manipulator system, and controls the pressing force through the pressure sensor on the mechanical hand.

4.2. Algorithm Design of Interactive System
In order to reduce the complexity of the massage manipulator designed in this scheme, the system USES the main controller STM32F103 and the TFT touch screen to create a set of human-computer interaction programs to provide a complete human-computer interaction operation interface. The designed human-computer interaction operation flow chart is shown in Figure 7.

The following flow chart of the detailed explanation: when the control system through the detection system detects began using massage manipulator, TFT screen natural light machine and display the boot animation, signal hint user massage chair, then TFT touch screen display function keys, the user can choose corresponding adjustment massage massage strength and the main position. During the massage, the touch screen repeatedly detects the value of the pause key. If the customer presses the pause key, the TFT screen will return to the pause control bit command of the MCU to interrupt service, and the touch screen will return to the functional selection section. The TFT screen will stop working until the user leaves the seat.
4.3. Motor Control Algorithm Design

This manipulator system uses stepper motor to control the position of the manipulator, the manipulator to reach the specified position and control the clamping degree of the manipulator.

In the control of stepping motor, its rotation speed is controlled by single-stage PID. The target value of the controller is the target speed input by the control system. The current speed is the output value (motor speed) of the encoder connected to the stepping motor, and the output value is the pulse signal transmitted to the motor drive.

In stepping motor control, its displacement is controlled by position cascade PID. The cascade PID controller is based on the velocity loop PID, and constructs a position type PID outer loop. The target value of the position-type PID controller is the target position input by the control system. By reading the current position fed back by the encoder connected with the stepping motor, the position loop PID controller calculates the expected speed and feeds it into the velocity loop PID controller to adjust the frequency of the output pulse as the current expected speed. The flow chart is shown in Figure 8.

The control system will be assigned to the timer dedicated to the motor control system, and the timer terminal cycle will be initialized for 10ms. When the timer interruption takes effect, the system will check the current system mode and target value, send the target value into the PID controller, and finally pulse output. The flow chart is shown in Figure 9.
4.4. Massage Intensity Control Algorithm

According to the experimental verification of relevant literature, the massage force of 15N is suitable for the elderly, children, and those with poor physique. 20N is a medium requirement, suitable for most people; 25N is suitable for people with high demands. Since this paper is designed for the human arm and shoulder massage, usually the shoulder massage is slightly stronger than the arm massage. Therefore, based on the literature, the maximum arm massage intensity in this paper is set to be 20N; The maximum strength of shoulder massage is 25N.

In the process of use, the intensity of massage has a great impact on user experience, so it should be strictly controlled. On the basis of the theoretical calculation, in the process of research and development, the team measured in massage many times normal arms wide users, fingers tightening control degree of the position of the motor and the relationship of the corresponding strength, used mathematical software to simulate a approximate curve, fuzzy calculation when mechanical fingers need to impose a certain size on users arm strength, the location of the step motor required movement. During the movement of the stepping motor, the control system will read the pressure sensor on the fingertip of the mechanical finger at any time, compare its value with the expected value, and adjust the motion state. In the adjustment process, in order to prevent discomfort caused to users by sudden pressure changes, the system will take a number of intermediate values between the expected displacement value and the current displacement value to smooth the transition pressure changes. The flow chart is shown in Figure 10.
5. Conclusions
This paper based on the human neck and shoulder massage and the design of the manipulator massage system, through the motion analysis and design of the massage manipulator, put into practical application, the motion process analysis of the manipulator and the expected design is consistent, verified the rationality of the design of the massage manipulator.

In addition, the project can be further improved. According to the current mechanical design, this project can only complete the task of two degrees of freedom temporarily, unable to massage to all the positions of the human body. In the future, new transmission modes and control algorithms can be designed to make the manipulator more accurate and comprehensive for massage operation.

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Figure 10. Massage dynamics algorithm.