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Control System of Orthodontic Archwire Bending Robot based on LabVIEW and ATmega2560

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Abstract

The bending control in archwire-bending process is critical to the orthodontic archwire bending robot. In order to improve the manual bending efficiency and increase forming precision of angle and displacement of orthodontic archwire, the control system of the orthodontic archwire bending robot is designed in this paper. Software and Hardware are design of the orthodontic archwire bending Robot based on LabVIEW and ATmega2560. This system has special characteristic of simplicity of operator, high running speed, high automated level and high reliability.

Keywords*: orthodontic archwire bending robot, control system, LabVIEW, ATmega2560, human-computer interaction interface*

1. Introduction

Malocclusion is one of the three major oral diseases, According to statistics, there are over 70 percents of people accepted the orthodontic treatment in the United States. But for our country, the treatment of malocclusion becomes an urgent need. Currently, the archwire is bended by doctors with archwire forming device, not only the efficiency is low, but also is difficult to ensure the forming quality. For above reasons, the doctor urgently needs an orthodontic archwire bending control system to adjust angle and displacement of archwire. In the field of orthodontic archwire bending system, the majority of research is abroad, Suresmile software of Orametrix company can transmit the jaw information to the robot effectively. German researchers H Fischer-Brandies proposed the BAS system, which is composed of an electronic oral endoscope, computer and bending archwire structure. OrthoCAD software developed by the Cadent company in United States can achieve the entire treatment process in the case of virtualization. Zhou Chuantao developed a system of measurement and analysis based on VC++. For the orthodontic archwire bending control system, state of the art about the related research is relatively small. Therefore, this paper puts forward the control system based on LabVIEW and ATmega2560 MCU of application power. The cost of control system is low and the reliability is high, also it realizes the automatic bending. The control system is convenient and flexible, it not only improves the running efficiency, but also ensures the accuracy of the system.

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2. Structure and Control Scheme of Orthodontic Archwire Bending Robot

2.1. Structure of Orthodontic Archwire Bending Robot

The structure of orthodontic archwire bending robot is as shown in Figure 1, it is consist of base, motion platform, archwire rotation motor and bending motor, archwire support structure, archwire bending structure, belt wheel transmission structure. Screw motion platform supports the whole robot system and transfers kinds of movements. The archwire can be fixed on the fixture of the bending motor, and the bending structure drives archwire to the desired angle; The archwire structure prevent the archwire local bending phenomenon in the process of bending, keep the archwire fixed; Bending die is driven by torque make the archwire winding die forming.

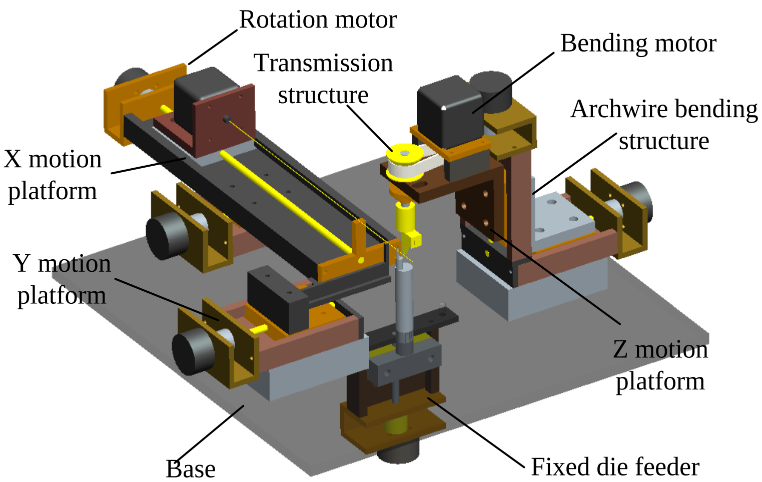

Figure 1. Structure of Orthodontic Archwire Bending Robot

2.2. Control Scheme

Control system of orthodontic archwire bending robot is to realize the movement of three stepping motor of X, Y, Z axis, an archwire rotation motor, an archwire bending motor and other auxiliary devices, mainly including LabVIEW, ATmega2560, stepping motor drivers. LabVIEW is the core of the control system. User inputs data to LabVIEW, and to control stepping motor through ATmega2560, ramps expansion board and stepping motor drivers, so as to realize the relevant bending motion. The motion platform of the X axis is used to feed archwire or send back archwire, and the archwire rotation motor plays a part in fixation and driving the archwire rotated 360 degrees; The motion platform of the Y axis can drive the bending die along Y axis, with altered the relative position between the bending die and the archwire processing part; The motion platform of the Z axis can drive the bending die along the Z axis. The bending motor drives the structure of belt wheel into bending archwire. The flow chat of control system is as shown in Figure 2.

3. Hardware Design

Considering the stability, maneuverability and development cycle of the robot control system, the ATmega2560 8 bit MCU of Atmel company is chosen. This MCU is widely used in industrial control, automation control, medical equipment and other fields. ATmega2560 has 56 I/O interfaces, including 14 PWM interfaces, 16 analog input interfaces, 4 UART interfaces, 6 external interrupts, 4 serial port communication, 3.3V and 5V power interface used in the large number of I/O interfaces design and PWM demand. PWM signal can be directly connected with the external device, which makes the peripheral circuit simplified greatly.

3.1. Simplification Communication

RS232 is used as communication interface between controller and PC, due to the electrical level is not compatible, so it needs ATMEGA16U2-MU serial port for level conversion, and sends the commands to the ATmega2560, the circuit diagram of ATmega2560 is as shown in Figure 3.

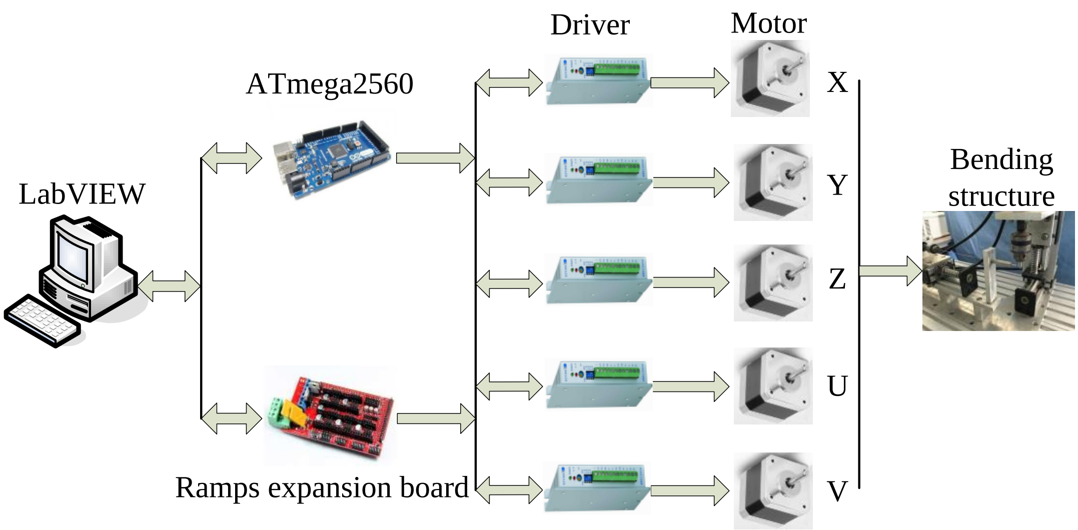

Figure 2. Flow Chat of Control System

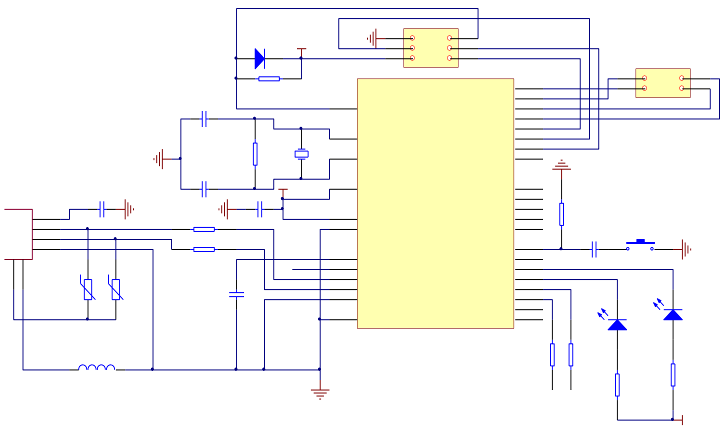

Figure 3. Circuit Diagram of Atmega2560

3.2. Ramps Expansion Board

Ramps(RepRap Arduino Mega Pololu Shield) as an expansion board of Arduino Mega is to connect Arduino Mega platform, not only plays a role in the connection, but also provides an adequate expansion space. The design of Ramps board is to connect the Arduino Mega Series MCU and stepping motor driver board. The bottom of the board is connected with the Mega Arduino Mega2560 main board through I/O port, and the top is connected with a stepping motor drive board to work. Ramps circuit diagram is as shown in Figure 4.

4. Software Design

System software uses LabVIEW to carry on overall design of modularization and layering. According to the functional requirements to divide the module, is to ensure the independence between modules. According to the idea of module design, the human-computer interaction module, the data operation module, the three-dimensional space display module, the Ethernet communication module and bending control module are designed. The data operation module transmits the parameters, initial values, and control points data to the data processing module, then the result is displayed in the three-dimensional module; The stepping motor is controlled through the Ethernet communication module; in the bending control module, the program is sent to the SCM and the relevant motion is executed. Composition of motion control system is as shown in Figure 5.

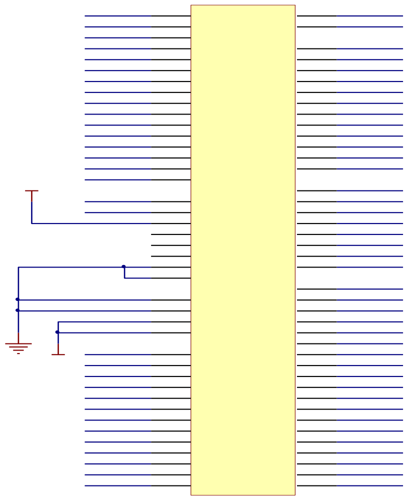

Figure 4. Circuit Diagram of Ramps Board

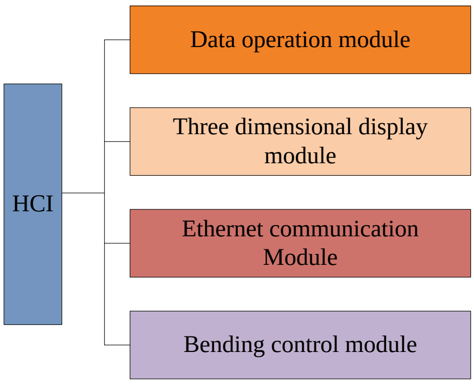

Figure 5. Composition of Motion Control System

4.1. Human-Computer Interaction Interface Module

The human-computer interaction interface of the module as the data input, adjust the displacement and angle of the control point, with intuitive, flexible, easy accessibility, and other advantages. The human-computer interaction interface is as shown in Figure 6.

4.2. Data Operation Module

The three-dimensional mathematical model of archwire is operating and modeling simulation with MATLAB, and saved in .m format, after the installation of Mathscript RT modules, the MATLAB program can be run directly in the LabVIEW, which makes the algorithm transplant easier. There are two ways to achieve the call, one is to select program>>structure>>Mathscript node in the program block diagram of the function panel; two is to select the mathematical>>script and formula>>Mathscript node in the panel.

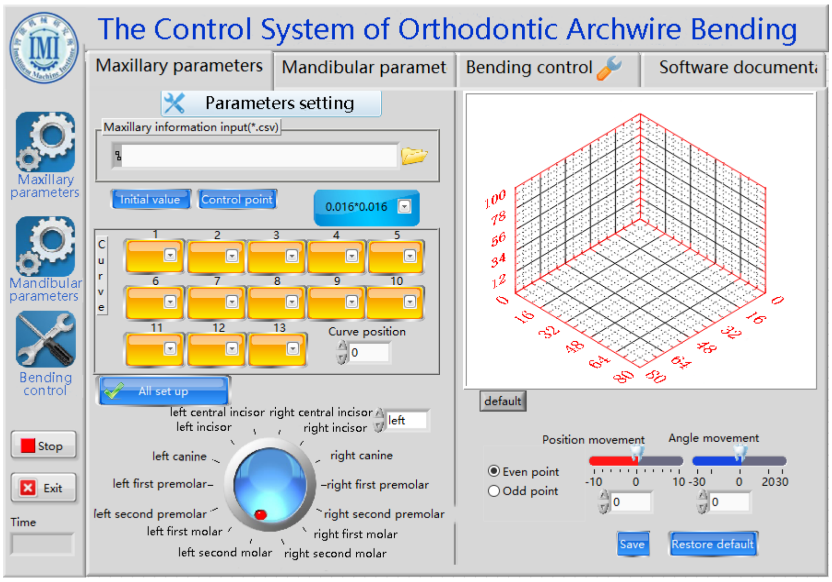

Figure 6. Human-Computer Interaction Interface

4.3. Three Dimensional Display Module

The three-dimensional coordinate information processed by the operation module is displayed in the module, and then the two adjacent points are connected in a straight line, so as to form a three-dimensional model of the archwire. Oral parameters of a patient, for example, the three-dimensional module shows the effect is as shown in Figure 7.

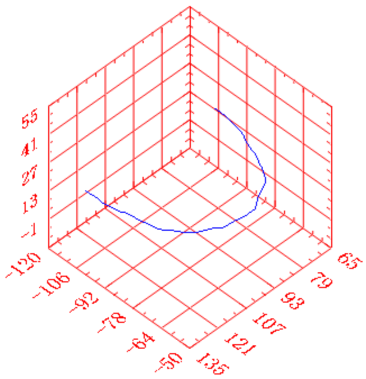

Figure 7. Three Dimensional Display Module

4.4. Ethernet Communication Module

VISA is used as the bottom function module in LabVIEW, which can connect different standard I/O devices. We can find the corresponding module to the serial port VI in the serial option of Instrument I/O, and then complete the PC communication in the diagram of the program, we must first complete the serial initialization in the program design, set baud rate 9600b/s, 8 data bits, 1 stop bit, 1 stop bit, then set the parameter of VISA Write and VISA Read and accomplish the communication with MCU.

4.4. Bending Control Module

The bending control module is the most important part of the motion control system, which dominates the motion state of the whole robot motion platform in the process of bending archwire, the bending control module is as shown in Figure 8. Mainly divided into the following 4 steps:

（1）Data input. Deal with the large amount of data generated by the operation module effectively, accurately identify the key coordinate information of the process, and translate it into the corresponding motion control commands.

（2）Algorithm generation. Plan the whole process of the robot motion platform, while the program is stored in the system cache.

（3）Processing start. Download the motor program of step (2) to the microcontroller, the robot start processing.

（4）File save. Save the program to PC and it is convenient to access.

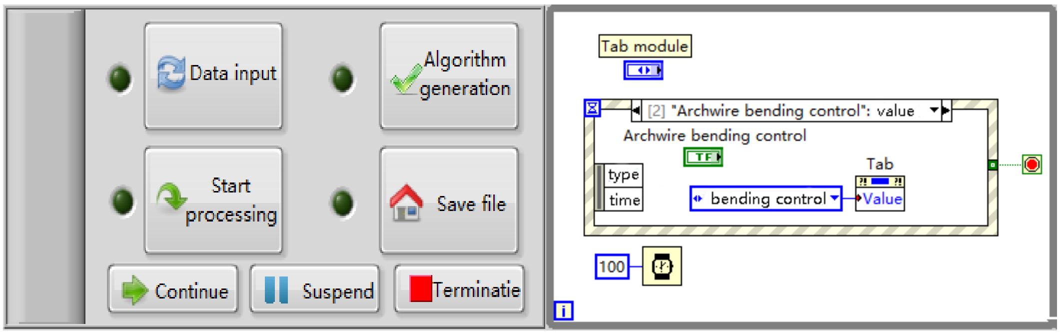

Figure 8. Bending Control Module

5. Experimental Verification

The bending experiment is made through the control system, is to verify whether the results can meet the requirements or not. The bending experiment is as shown in Figure 9. In order to make the experiment more representative, this paper selects 28 nodes information of a patient's upper jaw to carry out experimental research, Table 5-1 is shown below thispaper, and measuring the actual coordinates of the archwire with the three coordinate measuring instrument, then we compared the actual coordinates with the original coordinates and calculate the error between the original coordinates and the actual coordinates. The experimental comparison is as shown in Figure 10. The error is as shown in Figure 11. The result meets the requirements of orthodontic treatment.

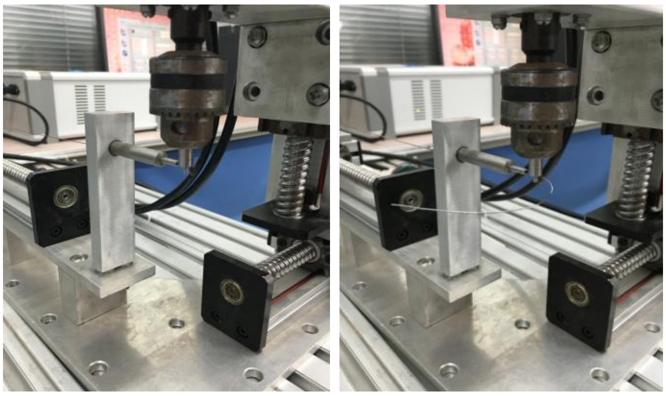

Figure 9. Bending Experiment

Table 5-1. Desired and Experimental Coordinates Value

Serial Number	Desired (x, y)	Experiment (x, y)	Serial Number	Desired (x, y)	Experiment (x, y)
1	(8.00,30.63)	(7.54,31.23)	15	(40.62,80.00)	(41.03,81.02)
2	(8.10,30.97)	(7.79,32.56)	16	(44.33,80.00)	(44.57,80.75)
3	(8.70,41.19)	(8.27,41.94)	17	(49.39,77.94)	(48.59,77.63)
4	(8.99,45.43)	(8.79,46.37)	18	(51.70,76.76)	(51.24,76.11)
5	(10.47,53.52)	(9.93,54.21)	19	(57.28,72.58)	(56.23,72.14)
6	(11.38,56.79)	(11.12,57.07)	20	(59.52,70.10)	(59.32,70.97)
7	(13.56,63.27)	(12.97,64.32)	21	(62.84,64.08)	(62.33,64.87)
8	(14.79,66.17)	(14.03,67.07)	22	(63.95,61.15)	(64.25,59.37)
9	(17.49,70.84)	(16.88,71.24)	23	(66.31,54.46)	(66.21,54.22)
10	(20.19,73.55)	(19.77,74.02)	24	(67.00,50.97)	(67.21,49.53)
11	(23.96,76.52)	(23.01,77.12)	25	(68.13,43.87)	(68.14,43.27)
12	(26.60,77.91)	(25.94,78.03)	26	(68.69,39.51)	(68.54,40.01)
13	(32.78,80.00)	(31.54,80.27)	27	(69.33,34.25)	(69.23,35.11)
14	(36.49,80.00)	(36.17,80.92)	28	(69.34,30.87)	(69.34,30.87)

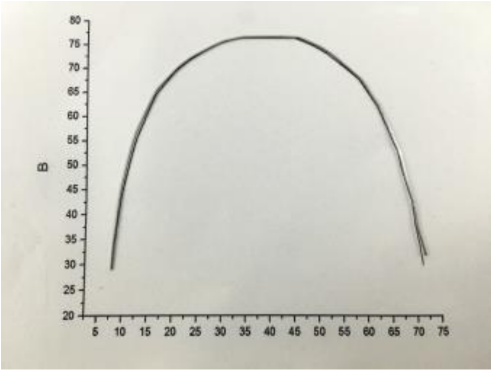

Figure 10. Experimental Comparison

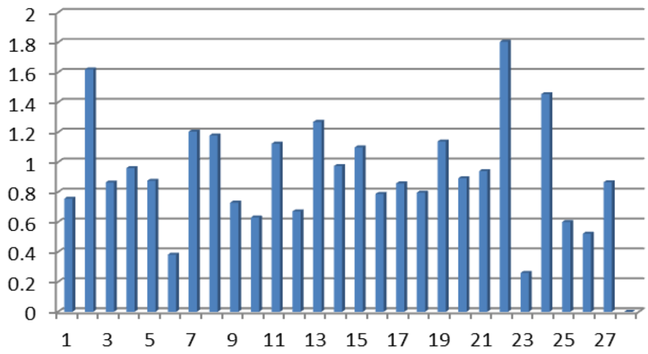

Figure 11. Error Histogram

6. Conclusion

The orthodontic archwire bending robot can simplify the process through the control system. The displacement and the angle of archwire can be adjusted through human-computer interaction interface. The bending control system is designed based on LabVIEW and ATmega2560. This can increase the bending efficiency, at the same time can reduce labor force, decrease costs and easy maintenance, and realize the intelligent and visualization in the control process.

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