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Arduino-based flexible electronic intelligent production and processing system

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Abstract

To design a flexible electronic processing system based on Arduino control that can realize automatic intelligent production. The working devices used in this system mainly include flexible film water transfer paper gripping device, conductive ink spraying device, embossing and forming device, flexible film deflection correction device and traction device. The system uses Arduino microcontroller as the control core, and controls the servo motor, stepper motor,vacuum pump, infrared sensor and analog gray sensor, etc. After reasonable parameter adjustment and program writing, each part moves according to a certain logical relationship, so as to realize the efficient integrated processing of flexible electronic devices.

Keywords

Flexible electronics, integrated processing, intelligent production.

1. Introduction

The rapid development of flexible electronics technology has promoted the rapid emergence of wearable electronics, electronic skin, implantable medical electronics, soft robots, and new flexible human-machine interfaces.[1] . With the increasing demand for flexible electronics, a variety of flexible electronics processing and preparation methods have emerged, but there are a series of urgent problems such as high preparation cost, cumbersome preparation process, long preparation time and labor-intensive[2] . In order to solve the above problems, this paper proposes an automatic production and processing system for flexible electronics, which integrates the originally complex and scattered preparation process rationally to realize the fully automatic processing of flexible electronics. It also uses information sensing technology and data processing technology to collect, transmit, process, store and display the working data of each motor and sensor in the system to realize real-time monitoring and regulation of the system operation status, thus realizing intelligent processing of flexible electronics. Workers only need to put the raw materials into the corresponding position of the system to get the finished flexible electronics, greatly improving the preparation efficiency, solving the traditional preparation process requires manual operation at each step of the problem, simplifying the preparation process. At the same time, the printing and processing method used in the system can create flexible electronic products that are closer to the application and more competitive in the market, which is an effective technical means to promote the industrialization of flexible electronics at this stage[3] .

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2. Overall design

The flexible electronic intelligent production processing system mainly consists of the main control module (Arduino Mega 2560 microcontroller), mechanical structure module (including flexible film roll mounting bracket, flexible film water transfer paper gripping and heating device, conductive ink spraying device, embossing forming device, traction device), motor drive module, flexible film deflection module, servo motor module, image recognition module, DC power supply module and system data acquisition and processing module, The Arduino microcontroller is the core control module of the processing system, equivalent to the human brain, which is responsible for controlling the movement of the motor in a certain logical sequence and processing the external information obtained by various sensing modules. The image recognition module detects whether the corresponding area on the flexible film has reached the set working area, so as to better control the start/stop of each actuator. The mechanical structure module connects the traction device with one end of the flexible film. During the operation of the flexible film, the flexible film water transfer paper gripping device, the conductive ink spraying device and the embossing device are used to complete the flexible film water transfer paper forming, conductive ink spraying and embossing operations respectively. The data acquisition and processing module presents the working status of the system in a visualized manner in real time. Each module cooperates with each other to realize efficient, integrated and intelligent processing of flexible electronic devices.

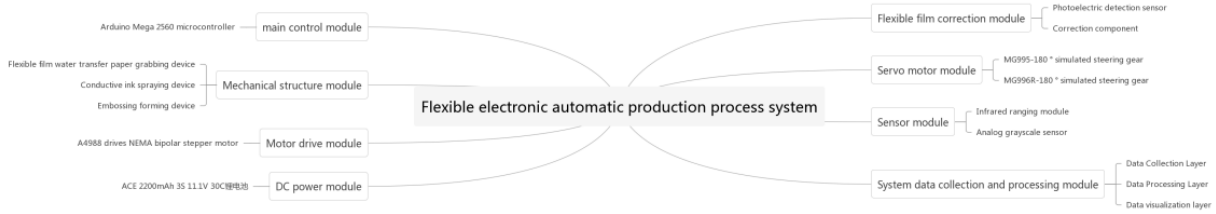

Figure 1 General framework

3. Mechanical structure design and implementation

The mechanical structure of this processing system consists of a flexible film water transfer paper gripping and heating device, a conductive ink coating device, an embossing and forming device, and a deflection device. All the devices used are assembled by 3D printing the 3D model to obtain the real object.

3.1. Flexible film water transfer paper gripping device

The function of the flexible film water transfer paper gripping device is to place the stacked water transfer base paper on the polyimide material that has been brushed with conductive ink by the suction cup robot, so the device has to realize two degrees of freedom of movement, respectively, the rotation of the base and the lifting along the vertical direction, so the servo motor that drives the overall device to do rotational movement and the ball screw mechanism that drives the suction cup device to do up and down movement of the robot to realize the function of the device. The servo motor, which drives the whole device to do rotational movement, and the ball screw mechanism, which drives the suction cup device to do up and down movement, are used to realize the function of the device.

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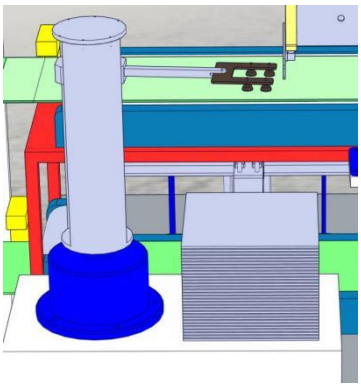

Figure 2 Flexible film water transfer paper gripping device

3.2. Conductive ink spraying device

The conductive ink spraying device is controlled by a ball screw mechanism driven by two stepper motors, and the conductive ink is sprayed onto the surface of the object to be sprayed through a spray gun or disc atomizer, using pressure or centrifugal force. Considering the problems of uneven spraying and high viscosity requirement of liquid when using the spraying method, drawing on the manual painting method, the sputtering head is placed before the scraper, which not only applies the conductive ink evenly on the material, but also plays the role of leveling the polyimide paper and can provide a better foundation for the next process.

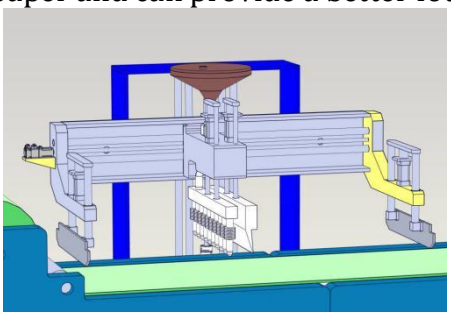

Figure 3 Conductive ink coating device

3.3. Embossing forming device

The embossing and forming device consists of a ball screw mechanism driven by a stepping motor. When the sensor detects that the material to be processed reaches the working position of the embossing roller, it starts to send a working signal to the motor to design the desired shape on the platen, and together with the motor screw controls the up and down movement of the stamping and forming module, and at the same time laminates the needle around the stamping die to increase the pressure, so as to press and cut down the graphics to be generated. The press is then pressed and cut out.

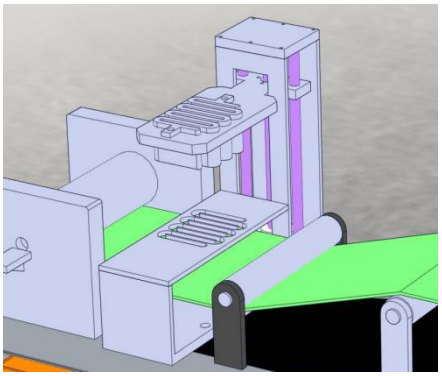

Figure 4 Embossing and forming device

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3.4. Flexible film deflection device

The flexible film deflection device consists of a photoelectric detection sensor and a deflection component, which mainly includes a base, a deflection roller support column, a deflection roller and a telescopic motor. In the process of flexible electrode preparation, a traction mechanism is used to pull the flexible film so that it can run along the working table, and then each process of the flexible electrode processing is completed on the flexible film in turn, and finally the flexible electrode is produced. After testing, it is found that the flexible film is very easy to be shifted when following the traction mechanism along the working table, so the position of the flexible film needs to be corrected in time to ensure that the flexible film always runs along the working table.

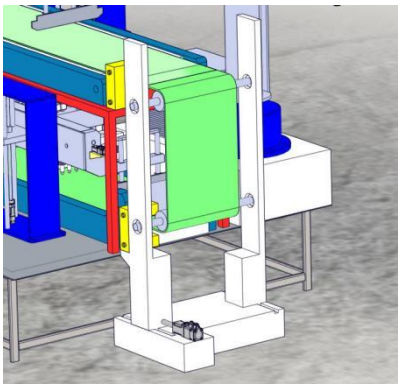

Figure 5 Flexible film deflection device

4. Design and implementation of hardware system

4.1. Master Control Module

The Arduino Mega 2560 is an ATmega2560-based microcontroller board with 54 digital input/output ports, 15 of which can be used as PWM outputs to drive servos and stepper motors.

4.2. Servo motor module

It is composed of two kinds of 180° analog servos, MG995 and MG996R, which have to continuously provide PWM signals to fix the angle. The control of the servos generally requires a 20ms time base pulse, and the high level part of this pulse corresponds to the angle control pulse part in the range of 0.5ms~2.5ms, and the rotation angle can be controlled by the high level duration of the servos, and the high level duration of 0.5 When the high level duration is 0.5ms, the corresponding angle is 0 degrees; when the high level duration is 1ms, the corresponding angle is 45 degrees, when the high level duration is 1.5ms, the corresponding angle is 90 degrees, and so on backward until 180 degrees.

4.3. DC power module

The processing system is powered by ACE 2200mAh 3S 11.1V 30C lithium battery with a capacity of 2200mAh and a standard voltage of 3.7V*3=11.1V, which can generally reach 12.6V after a full charge and can be used as a 12V power supply with a discharge multiplier of 30C, a charging cut-off voltage of 12.6V and a discharge cut-off voltage of 10.5V.

Table 1 Some DC power parameters of a brand

Battery Name	Standard voltage/V	Charge cut-off voltage/V	Discharge cut-off voltage/V
2S	7.4	8.4	7.0
3S	11.1	12.6	`10.5
4S	14.8	16.8	14.0

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5S	18.5	21.0	17.5
6S	22.2	25.2	21.0

4.4. Motor drive module

The A4988 drives a NEMA bipolar stepper motor, and controls the stepper motor's stepping mode through MS1, MS2, and MS3. The default is full stepper mode, and the DIR pin controls the motor to rotate clockwise when it is low; the reverse is true when it is high. SLEEP pin, when the connection level is low, the A4988 will enter the low power sleep state, i.e., consume the minimum power. During normal operation, the SLEEP pin can be connected to the RESET pin, and the A4988 will continue to maintain a normal power consumption state without entering a low power consumption state.

Table 2 Step mode logic relationship

MS1	MS2	MS3	STEPS
L	L	L	FULL
H	L	L	HALF
L	H	L	QUARTER
H	H	L	EIGHTH
H	H	H	SIXTEENTH

4.5. Infrared distance measurement module

The infrared distance sensor used in this system uses the principle that the infrared signal will reflect different intensity of light according to the distance when it meets an obstacle to detect the distance of the item to be processed from the position to be processed. The infrared distance sensor has a pair of infrared signal transmitting and receiving diodes, the transmitting tube transmits infrared signals of a specific frequency, the receiving tube receives infrared signals of this frequency, when the detection direction of infrared encounters an obstacle, the infrared signal is reflected back and received by the receiving tube, after processing, it is returned to the microcontroller through the digital sensor interface, the system can use the return signal of infrared to identify the surrounding environment The system can use the infrared return signal to identify the surrounding environment changes, so as to carry out the corresponding action.

5. Machining system working part software programming implementation

5.1. General design of the system program

In order to ensure the coordination of all parts of the system and to improve the overall efficiency of the operation, we adopted the following working model: the start and stop of the drive is fed back through the pva coating part, and the pva coating part, the water transfer paper grabbing and placing part, the silver paste coating part and the embossing part work in a logical sequence according to the written code. According to the above working mode, we use the modular programming method, the action code of each part is encapsulated, when needed, only need to call in the main function to achieve the expected action. The overall software design flow of the system is shown in the following figure:

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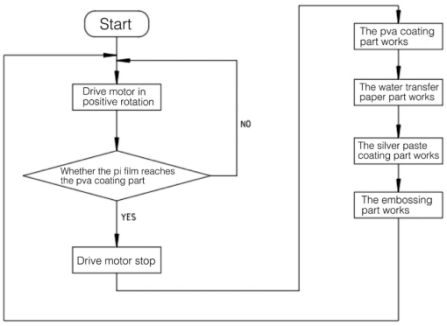

Figure 6 Overall system software design flow

5.2. Flexible film water transfer paper gripping device program design

When this part of the device starts to work, the suction cup is first raised to the highest place to prevent the suction cup from colliding with the conveyor belt during the movement of the servo, and then the servo drives the rotating shaft to rotate the specified angle to reach the top of the water transfer paper. At this time, the ball screw mechanism driven by stepping motor starts to move, so that the suction cup gradually descends, when the infrared distance measuring module detects that the suction cup reaches the specified position, the suction cup stops moving down, the vacuum pump slowly sucks air to suck the water transfer paper tightly on the suction cup, at this time, the suction cup starts to return to the original way, and moves the suction cup to the specified position above the conveyor belt according to the program, after reaching the specified position, the vacuum pump starts to deflate, the water transfer paper loses The water transfer paper loses the attraction of the suction cup and then falls on the conveyor belt, and the water transfer paper gripping work is completed.

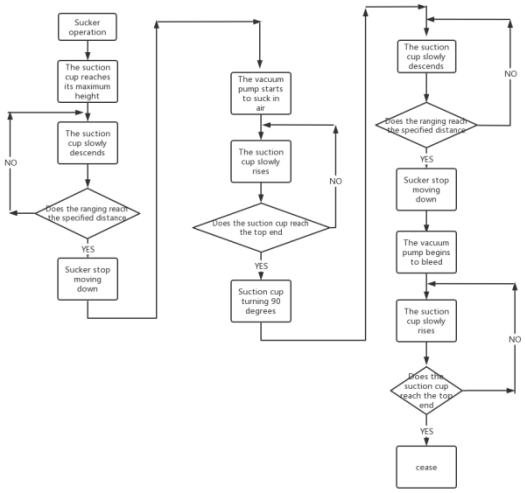

Figure. 7 Flow chart of flexible film water transfer paper gripping device program

5.3. Conductive ink spraying device program design

When this part of the device starts working, the ball screw mechanism of the stepper motor placed vertically raises the nozzle to the highest point first, and then the ball screw mechanism of the stepper motor placed horizontally moves the nozzle to the leftmost end and waits for the water transfer paper to be delivered. When the image recognition module detects that the water transfer paper reaches the specified position, the nozzle starts to descend gradually and controls the start and stop of the stepper motor through the data fed back by the infrared distance measurement module, that is, the start and stop of the nozzle. When the nozzle reaches the top of the water transfer paper, the solenoid valve that controls the opening and closing of the nozzle opens, and the conductive ink is evenly sprayed on the water transfer paper, and

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then returns to the starting position according to the original route, and the work of the conductive ink spraying is completed.

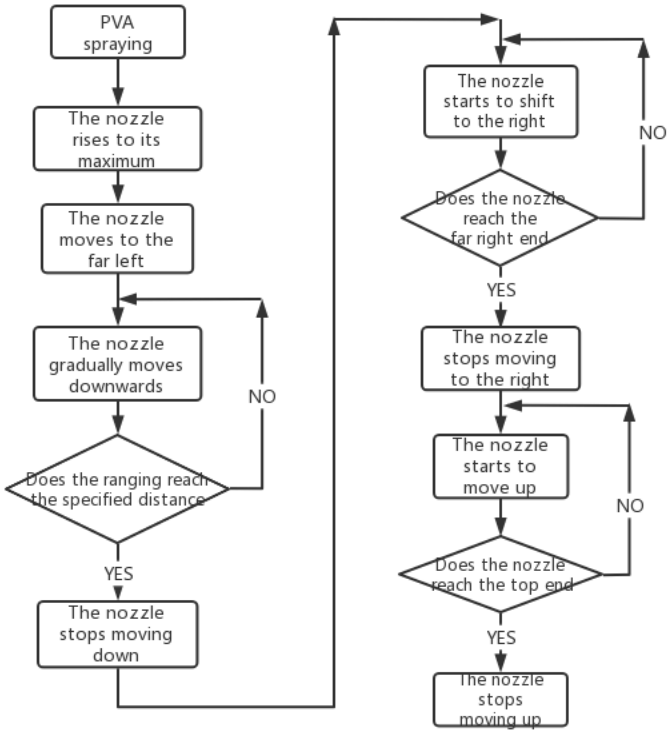

Figure 8 Flow chart of the program of the conductive ink coating device

6. Machining system detection part of the software programming to achieve

6.1. Design requirements and design ideas

Realize the real-time monitoring of the working status of the whole flexible electronic processing system, such as the temperature of the drying area, the speed and direction of the stepping motor, the rotation angle of the water transfer paper gripping device, the transmission distance of the flexible electronic devices and other data that are crucial to the monitoring of the processing status, and transmit the collected data to the data center through wireless transmission technology, and carry out secondary processing of the data in the data center to clean off the useless data The data is then stored in the database to obtain the data set of the whole processing system. Web development is carried out through computer-related technologies, and a user-friendly software system is developed based on the database data, and the data is displayed in front of the user in the form of graphical charts through visualization technology. It is divided into three main parts: data acquisition layer, data processing layer and data visualization layer.

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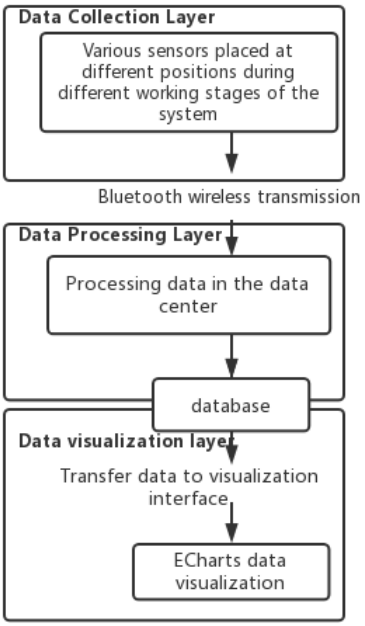

Figure 9 Specific design steps

6.2. Data acquisition layer design

Various types of sensors are placed in different positions of the flexible electronic automatic production and processing system for data acquisition at different working stages, and the data is transmitted to the data center via Bluetooth wireless transmission.

6.3. Data processing layer design

Not all the data collected directly from the processing system is valuable and can be used directly, and must be scientifically processed to filter out the worthless data before it can be used. The main application here is python data processing related technology. This is the specific content of the data processing of the ultrasonic distance measurement module in the water transfer paper gripping and placing mechanism.

Since the ball screw mechanism selected for the water transfer paper gripping device may have the problem of losing steps in the motor during the lifting process, the data transmitted to the data center will have wrong values, and it is necessary to write code to delete and fill the wrong values through the pandas library built on Numpy, so as to realize the accurate monitoring of the working status of the gripping mechanism.

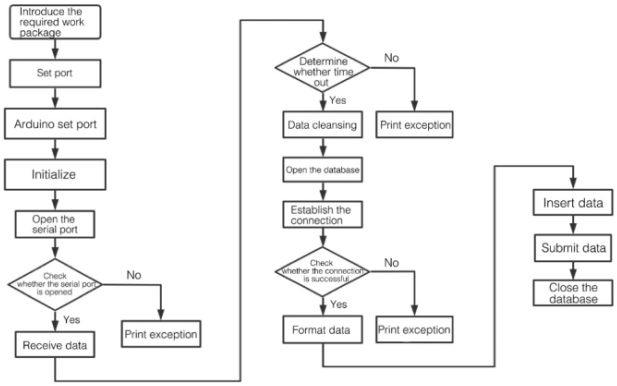

Figure 10 Data processing layer design

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6.4. Data visualization layer design

The application was developed within the Flask framework on the basis of the database established earlier. One of the main tasks is to visualize the data, so an easy-to-learn data visualization plugin ECharts is used to transform the data into graphical charts in a user-friendly way.

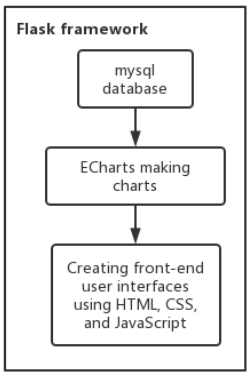

Figure 11 Data visualization layer design

7. Experimental effects

This intelligent automatic production and processing system for flexible electronics integrates the originally complex and scattered preparation process, thus realizing the integrated processing of flexible electronics. It also uses information sensing technology and data processing technology to collect, transmit, process, store and display the working data of each motor and sensor in the system to realize real-time monitoring and regulation of the system operation status, thus realizing the intelligent processing of flexible electronics. The disadvantage is that the ball screw structure used in the mechanical arm of the water transfer paper gripping device often causes the motor to lose steps due to excessive resistance during operation, making the device unable to run smoothly. The next step will be to modify the mechanical arm motion form and change the relative motion to improve the robustness of the system. The actual system is shown in Figure 12.

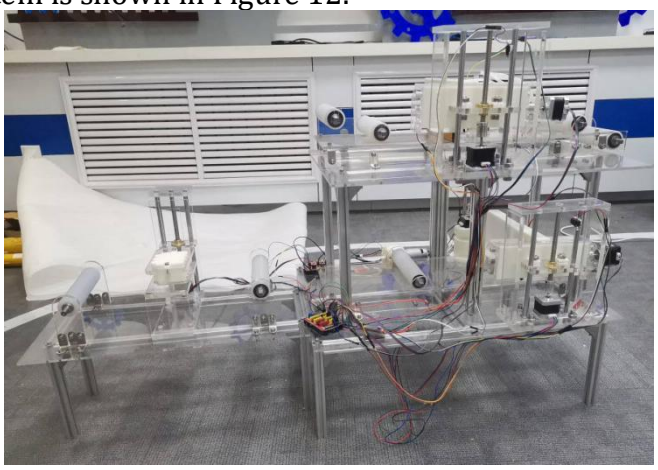

Figure 12 Physical diagram of the processing system

8. Summary

This paper proposes and designs an Arduino-based flexible electronic intelligent production and processing system, which uses Arduino Mega 2560 as the main control chip, with a

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lightweight and stable mechanical mechanism, reasonable hardware and software design, and strong scalability. At present, this Arduino-based flexible electronic intelligent production and processing system can realize the automation and intelligent production and processing of flexible electronic devices.

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