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Design and Algorithm Research of a Weight Sorting Transport Robot

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In warehousing logistics, most regions still use manual sorting with low efficiency and high cost. Especially in some special work areas, such as high temperatures, severe electronic radiation, urgent need for small robots to replace manual labor. This design uses PID control algorithm to independently determine the weight of the goods, wait for receiving goods at a designated location, move forward at a constant speed, and transport its weight to the designated position and unload it. Constant speed can make the trolley travel more smoothly and load and unload goods more smoothly.

Keywords: STC, Weight sorting transportation, PID, Adaptive algorithm

1 Introduction

1.1 Design ideas

At present, many domestic enterprises are studying the sorting system[1], mainly to achieve effective sorting of goods. the sorting system has the disadvantages of large floor area and high overall cost [2]. Therefore, the shaped picking robot is one of the current research directions [3]. The main methods are as follows:

- Visual tracking is adopted for moving path, different signs are posted on the ground for self-positioning [4], the robot is installed with gyroscope to adjust its direction, and the vehicle body is installed with high torque steering gear to unload goods [5].
- Magnetic stripes are installed on the ground to design the travel route. The robot uses magnetic navigation sensors to induce magnetic stripes.The robot installs travel switches to detect the position of the car body. The car body installs other instruments or manually unloads goods.
- In this design, the pressure sensor is used to realize the weight measurement function,and the microcontroller is used as the main control chip, which can automatically measure the weight of goods and sort and transport them to the designated location; Tracking adopts motor and RFID radio frequency module, which can solve vehicle body jitter well [6].
- When arriving at the designated place, unloading is carried out. The vehicle body is designed and installed with unloading motor controlled by relay. The software adopts intelligent control algorithm to achieve the goal of constant speed of the car [7].
- The robot uses pressure sensors to achieve weight measurement function, and uses a microcontroller as the main control chip, which can automatically measure the weight of goods and sort and transport them to designated positions, The tracking system adopts an electric motor and RFID radio frequency module, which can effectively solve the vibration of the vehicle body, When arriving at the designated location, unloading operations need to be carried out. A unloading motor controlled by a relay is designed and installed on the vehicle body, and the software adopts intelligent control algorithms to achieve the goal of the car traveling at a uniform speed.

1.2 Method

The design of the weight sorting transport robot can be divided into weight measurement part, travel part, route detection part, information display part, unloading part, position detection part, power supply and power supply voltage stabilization part and main control part [8][9].

1.2.1 Weight measuring part

Load cell is a device that converts pressure signal into measurable electrical signal for output.

The cantilever force sensor attaches the strain gauge to the two ends of the elastic element near the surface. Four strain gauges form a full bridge differential bridge circuit, which has higher output voltage sensitivity and smaller nonlinear error.

Thin film pressure sensors are also a new type of sensor. They use vacuum coating technology to evaporate a layer of metal material of about 300 nm on an elastic substrate to form a thin film, which forms a resistance sensitive gate on the elastic substrate. After high-temperature and corrosion treatment, a thin film is formed, with relatively small mechanical hysteresis phenomena such as ceramics and quartz, and higher stability. [19-22]

1.2.2 Robot moving part

DC reduction motor: As the robot cannot travel too fast and needs to move with loads, it is necessary to select a reducer motor with low speed and large torque. Four 37GB-385 DC reducer motors are selected in this design.

The main parameters are as below:

- Voltage: 12 V
- Reduction ratio: 1:40
- No load speed: 200±10% rpm,
- Load speed: 150±10% rpm
- Load torque: 3.5 Kg×cm

DC motor drive board: In order to make the robot move along the specified route, the main controller needs to control the motor through the DC motor drive board. XY-15AS DC motor drive board is selected. The main parameters are as below:

- PWM FM: 0~100 KHz
- PWM Min effective pulse width: 200 ns

1.2.3 Route tracing module

The route detection needs two parts, one is the route sign arranged on the site in advance, the other is the route sign recognition module carried on the robot body. The BFD-1000 five way black and white line tracing module and black line are used for route tracing detection, and the input voltage range is 3.0-5.5 V.

1.2.4 Unloading part

Reduction motor: due to the advantages of low cost and easy control of the reduction motor, the DC double shaft reduction motor is used to drive the baffle plate to rotate and push the goods for unloading. Considering the weight of the goods to be pushed, a 1:48 straight double shaft reduction motor is selected. The main parameters are as below:

- No load current: 250 mA
- No load speed: 250±10% rpm
- Voltage: 3-12 V

1.2.5 Route detection part

Route detection requires two parts of cooperation, one is the route signs arranged in advance on the site, and the other is the route sign recognition module installed on the robot body. This module can usually adopt a black and white line tracing method, which is composed of an infrared recording sensor for obstacle avoidance and a touch sensor. It can solve the problem of multi machine collaborative work. The sensor parameters are as follows:

- Detection distance: 0.5-60mm
- Input voltage: 1.5V-6.0V

According to the design requirements,this design uses the BFD-1000 five way black and white line tracing module and black line (black tape or black paint with a minimum width of 1cm) for route tracing detection, other tracking modules can also be selected based on measurement requirements and budget.

1.2.6 Position detection part

Card reading module: the robot detects information through the position signs on the site and the signs on the robot body. MFRC522 RFID module is adopted in this design. The card reading distance is far and the operation is stable. The reading and writing module can be connected to the CPU motherboard through the SPI interface. The card reading module and S50 non-contact IC card can achieve the position detection function. The main parameters are as below:

- Voltage: 3.3 V
- FM: 13.56 MHz
- Peak current: <30 mA
- Temperature: -20~ +80
- Humidity: 5% -95%

Contactless IC card: since the selected operating FM of the card reading module is 13.56MHz, the card is only used to identify the location area, and the unique serial number of the card is used in the program, so S50 contactless IC card with the same operating FM is used, and the main parameters are as below:

- FM: 13.56 MHz
- Communication rate: 106 kB/s
- Reading and writing distance: <10 cm
- 32-bit unique serial number
- No power supply, built-in antenna
- Temperature: -20~ +50

1.3 Robot moving part

1.3.1 DC motor drive power circuit

The voltage source voltage is 12 V, the DC motor is driven through the power connection, Fig. 1 divided into left and right motor drives connected to the DC motor for control.

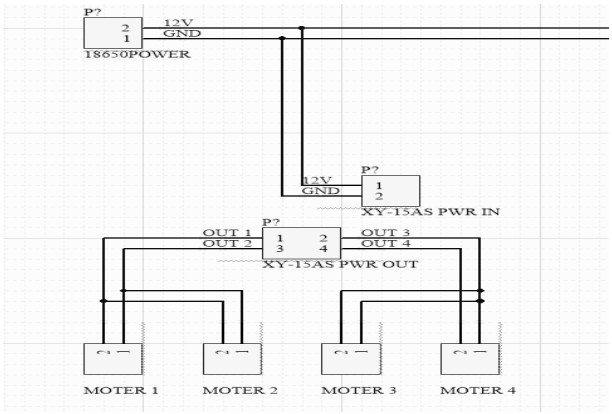

Fig. 1 *DC motor drive circuit diagram*

1.3.2 Unloading motor power circuit

12 V voltage is introduced from the power supply to the relay, and then connected to the unloading motor through the normally open contact point. The circuit diagram is as follows Fig. 2:

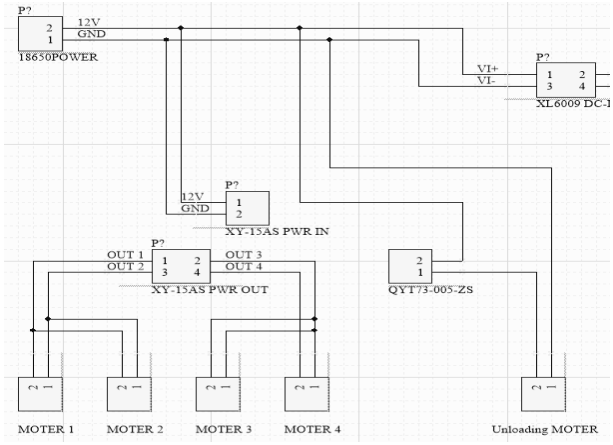

Fig. 2 *Unloading motor power circuit diagram*

1.3.3 Card reading part

The sorting point and different loading points need to use RFID radio frequency module and IC tag to distinguish. The radio frequency module communicates with the master microcontroller through SPI interface [10]. The circuit diagram is as follows Fig. 3:

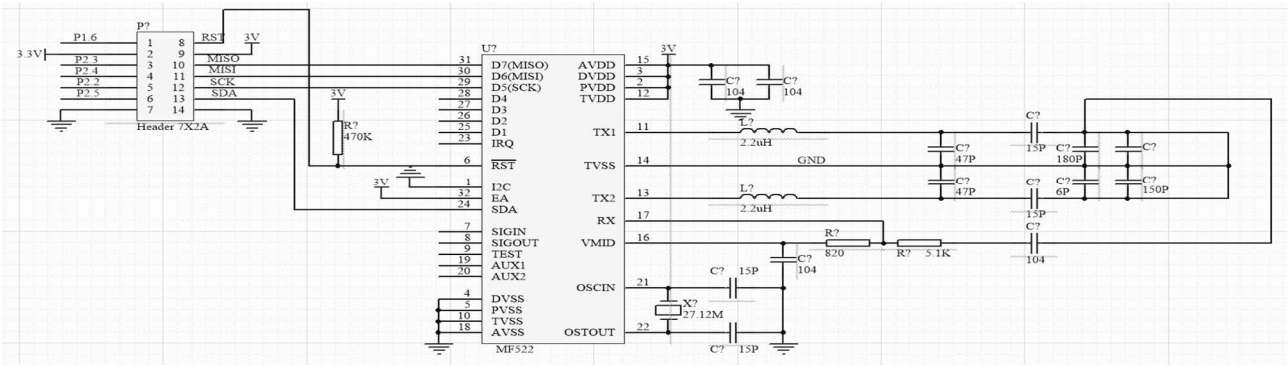

Fig. 3 *Circuit diagram of card reading part*

Other parts of the design, such as weight measurement, control, tracking, travel determination, control and other circuit wiring design will not be listed one by one.

1.4 MCU part

Most MCU can complete basic control functions and can be flexibly selected according to functional and budget requirements. This design selection is the STC15 series high-speed enhanced microcontroller, which has a high-precision clock and a highly reliable reset circuit inside the chip. When setting the Min system timing, external crystal oscillators and external reset circuits can be omitted,the main parameters are as below:

- BT: 4096 bytes RAM data storage
- EEPROM: Over 100000 erasures
- Timer/Counter: 7 timers/counters,of which 5 16 bits can be reinstalled.
- Programmable clock output function:clock division output for internal system clock or external pin clock input.
- High speed four serial ports/UART: Four completely independent high-speed asynchronous serial communication ports, which can be used as 9 sets of serial ports for time-sharing switching.
- High speed ADC: 8-channel 10 bit, with a speed of up to 300000 times/second, 8-channel PWM, which be used as 8-channel D/A.

- Comparator: It can be used as a 1-channel ADC, can perform electrical detection.
- It supports comparison between external pin CMP+and external pin CMP, can generate interrupts, and also supports comparison between external pin+and internal reference voltage.
- PWM: 6-channel 15 bit dedicated high-precision, combined with 2 channels of CCP, can be used to achieve D/A.

1.5 Power supply section

Satisfying the power supply needs of all modules, with stable power output,all are good power modules. Under some special conditions, considering the weight of the power supply or the stability of voltage and current, special power supply can be used. In this design, the deceleration motor requires a voltage of 12 V, with a Max load current of 1.2 A. Therefore, ordinary power supply is sufficient, and a 12 V lithium. battery pack can also meet the requirements.

2 Materials and Methods

2.1 PID automatic control algorithm

In the process of traveling, the speed of the car will change with the increase or decrease of the weight. In order to keep the car moving at a constant speed, we can intelligently adjust the traveling speed through algorithms to achieve the goal of keeping the car moving at a constant speed.

PID algorithm is based on the input deviation value, and operates according to the functional relationship of proportion, integral and differential.The operation results control the output[11]. The block diagram of the PID algorithm is as follows Fig. 4:

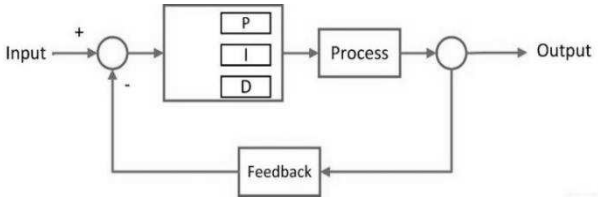

Fig. 4 *PID algorithm*

Control output:

$$U(t) = K_p(e(t) + \frac{1}{T_t}\int_0^t e(t)dt + T_D\frac{de(t)}{dt}) \quad (1)$$

The formula for converting to discrete PID is as follows:

$$U(k) = K_p(e(k) + K_i\sum_{i-o} e(i) + K_d(e(k) - e(k-1)) \quad (2)$$

2.2 Main flowchart as follows:

Route detection flowchart as follows Fig. 5, Information display flowchart as follows Fig. 6.

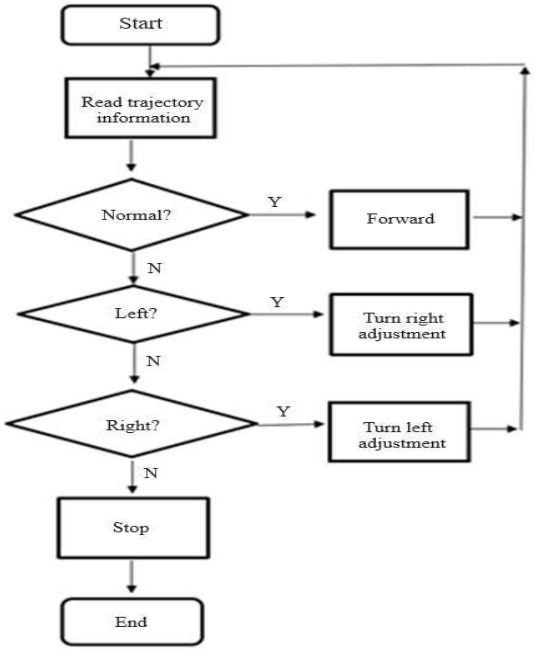

Fig. 5 *Route detection flowchart*

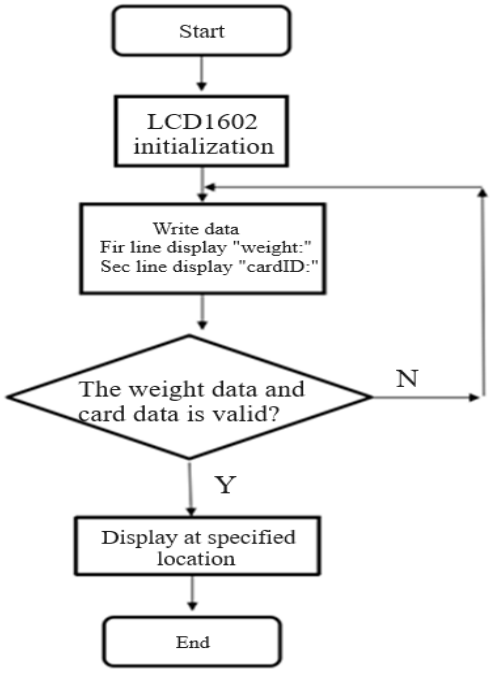

Fig. 6 *Information display flowchartas*

According to the PID algorithm,the overall design flowchart is as follows Fig. 7:

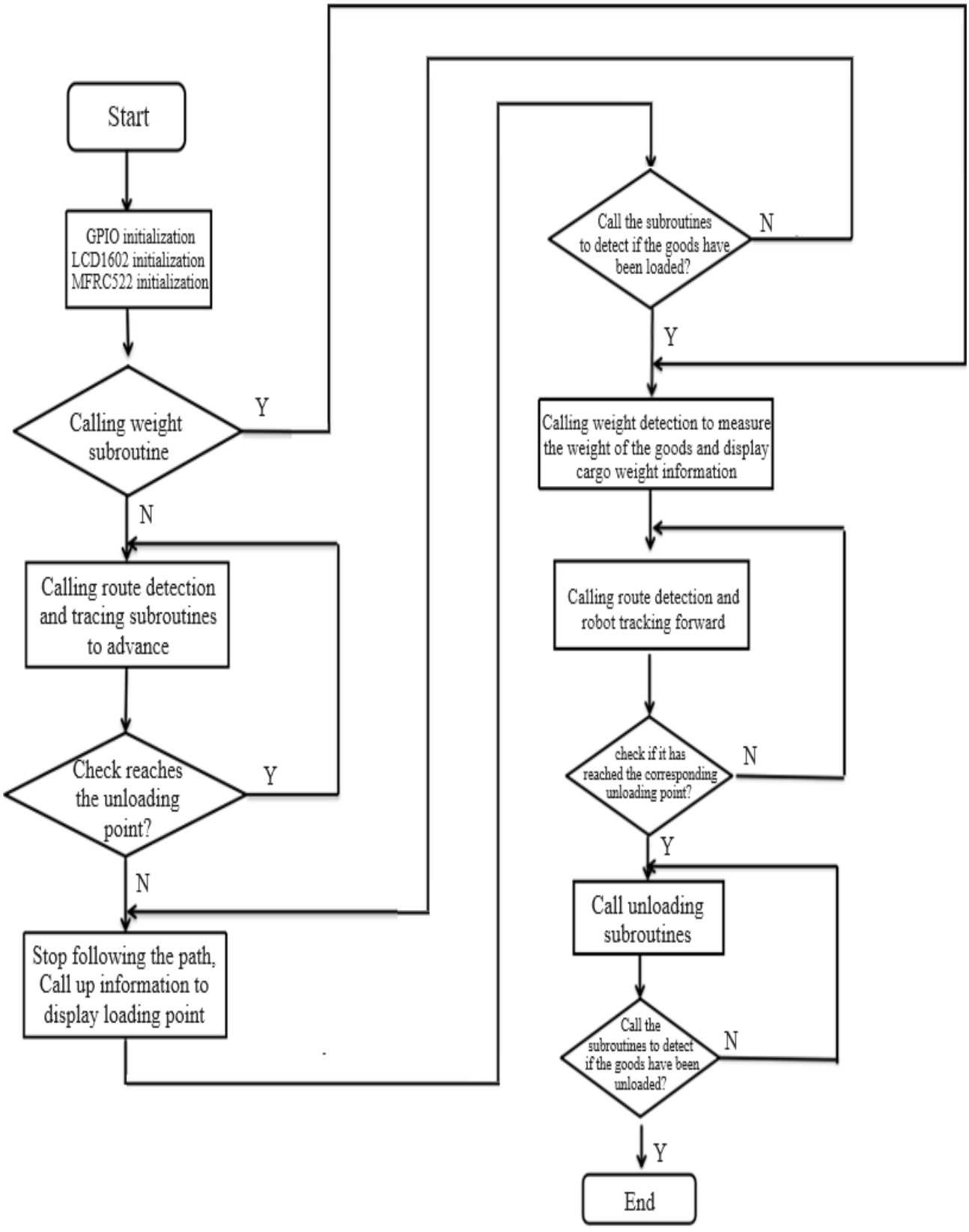

Fig. 7 *The overall design flowchart*

2.3 Main program code

Through the proportional control of the current moment and the differential control of the current moment and the previous moment, smooth adjustment can be made to make the robot transport trolley run at a uniform speed. The code is as follows:

Tab. 1 *Main program code*

```
typedef struct PID {
 double SetPoint;
 double Proportion;
 double Integral;
 double Derivative;
 double LastError;
 double PrevError;
 double SumError;
} PID;

double PIDCalc( PID *pp, double NextPoint)
{
 double dError, Error;
 Error = pp->SetPoint - NextPoint;
 pp->SumError += Error;
 dError = pp->LastError - pp->PrevError;
 pp->PrevError = pp->LastError;
 pp->LastError = Error;
 return (pp->Proportion * Error  + pp->Integral * pp->SumError  + pp->Derivative * dError );
}

void PIDInit (PID *pp)
{
 memset ( pp,0,sizeof(PID));
}

double sensor (void)
{
 return 100.0;
}

void actuator(double rDelta) {}

void main(void)
{
 PID sPID;
 double rOut;
double rIn;
 PIDInit ( &sPID );
 sPID.Proportion = 0.5;
 sPID.Integral = 0.5;
 sPID.Derivative = 0.0;
 sPID.SetPoint = 100.0;
 for (;;) {
 rIn = sensor ();
 rOut = PIDCalc ( &sPID,rIn );
 actuator ( rOut ); }
 }
```

Due to the limitation of the processing speed of the single chip microcomputer and the ram resource[12], all parameters can be used as integers for fixed-point number operations,which can improve the operation speed[13]. According to the different requirements of the control accuracy, when the accuracy requirements are high, the shift is reserved for compensation.

3 Discussion of results

3.1 Commissioning and operation

After the hardware debugging is completed[14], the project is established through software Keil, the corresponding functional programs are compiled according to different needs[15]. Then, they are burned to the microcontroller through Keil and burning software STC-ISP, and then the functions are realized[16].

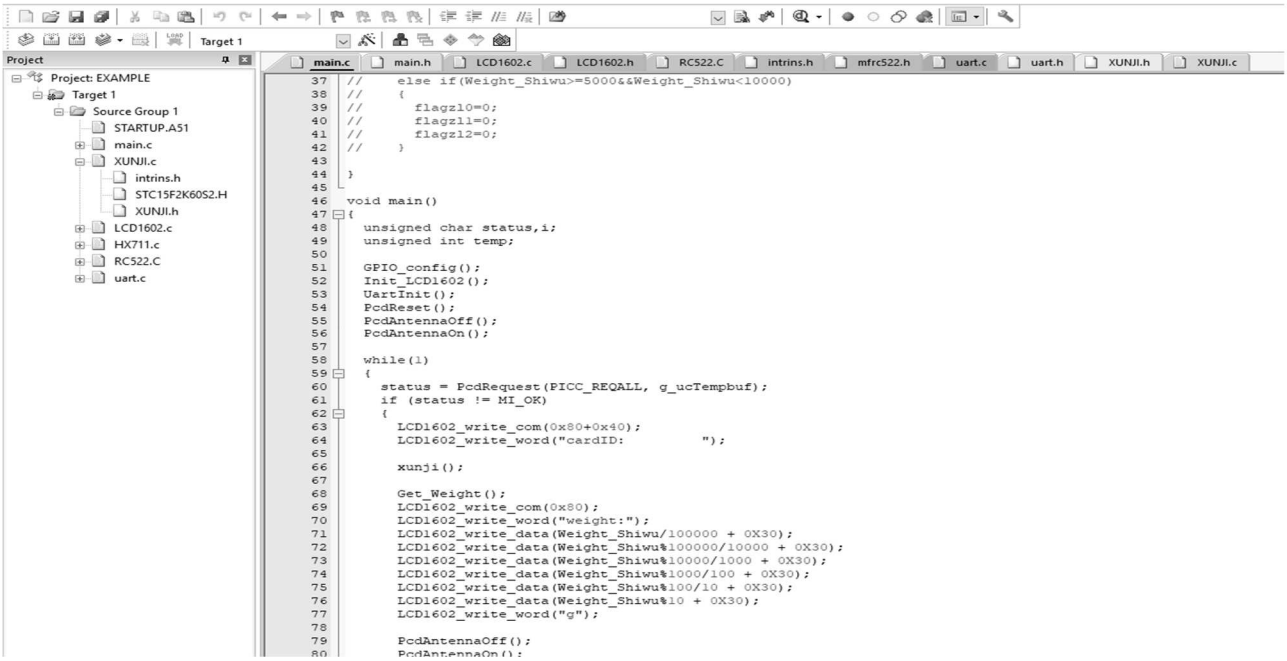

Fig. 8 *Software and hardware debugging*

3.2 Program debuggin

After debugging,perform functional verification, taking 300g weight-goods sorting as an example [17].

Suppose that the robot can sort and transport 0-300g and more than 300g, black line tracks are laid on the ground [18], and different IC cards are laid at three locations to be used as loading points, unloading point A (<300g), and unloading point B (>300g). Two objects are prepared, weighing 200g, 2000g, and 5500g respectively. After many tests, Table 2 shows the following data [20]:

Tab. 2 *Verification results of different goods weights*

Tests	Action of the first pass of checkpoint A	Action of the first pass of checkpoint B	Action of the first pass of checkpoint B	Action of the second pass of checkpoint A
No goods	Stop waiting	No behavior	No behavior	No behavior
When the robot moves to checkpoint A, place 200g goods	Stop waiting for goods,Drive after receiving goods, Display goods weight information	Stop moving, unload the goods, Walk on	Walk on	Stop moving, waiting for goods
When the robot moves to checkpoint A, place 2000g goods	ditto	Walk on	Stop moving, The goods cannot be pushed down when unloading	Stop moving, waiting for goods
When the robot moves to checkpoint A, place 2000g goods	ditto	Walk on	Stop moving, Walk on after unloading the goods	Stop moving, waiting for goods
When the robot moves to checkpoint A, place 5500g goods	Stop waiting for goods, Drive after receiving goods, Display goods weight information, Warning exceeds the range,and attention shall be paid to sorting	Walk on	Stop moving, Walk on after unloading the goods	Stop moving, waiting for goods

After the final assembly test, the designed robot size is about 16cm × 20cm × 30cm, the weight range of goods sorting is 0-5kg, which can start up to detect the load status, complete the unfinished transportation process by itself, and go to the designated loading point to wait for loading.

4 Conclusions

The design solves the problems of large floor area and high overall cost of the current overall sorting system, by using PID control algorithm, the trolley can move forward to the designated place at a uniform speed, complete the unloading operation by itself and return to the loading point for the next round of transportation, we will continue to study the control algorithm in the future.

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