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Arduino-based intelligent handling robot design

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Abstract: Design of a robot for autonomous reception, autonomous recognition of tasks and material handling based on Arduino control. The Arduino microcontroller is the core of the robot control, the mechanical structure design, motor drive, QR code scanning, colour recognition and other basic structures are implemented. The design, production, selection and optimisation of customised modules for tracking and tracing, DC servo motors and mechanical jaws, the control software programs and the logic for the recovery system are written in the very powerful C language for each module. After the first installation of the system was optimised, the robot was able to quickly and accurately identify the QR codes corresponding to the different handling tasks and was able to accurately handle and deliver materials of different colours according to the material handling sequence specified by the QR codes.

1. Introduction

Nowadays, with the continuous innovation of science and technology, the demand for intelligent robots in industry is increasing. The logistics handling industry has a series of problems such as the consumption of huge human resources and low efficiency [1], and intelligent logistics handling robot technology plays a pivotal role in the construction of smart factories [2]. With the help of "Promoting Smart Manufacturing" and thus the collaborative fieldwork on machine performance, the development of production-oriented enterprises and industry prospects are quickly released, and the technological development of industries is promoted from labour-intensive to comparative industrial transformation and upgrading. To solve the problems of slow visual recognition [3], tediousness of multi-degree-of-freedom robotic arm control [4] and single Bluetooth control method [5] for intelligent handling robots, this paper designs an intelligent robot based on the Arduino master version for fully automatic task reception, autonomous path planning, automatic task recognition and completion of handling. This vision-based fully automatic intelligent handling robot is widely used in traditional fields such as manufacturing, food service and the military, as well as in modern fields such as the machinery industry and the electronics industry, with a wide range of applications and a high market demand.

2. Overall design

The intelligent handling robot mainly consists of the main control module (Arduino Mega 2560 microcontroller), mechanical structure module (which contains the chassis-related mechanism and mechanical claw robot arm structure), motor drive module, two-dimensional code and colour recognition module, tracking and tracing module, servo motor module, DC power supply module, etc. Its overall framework structure is shown in Figure 1. The Arduino Mega 2560 microcontroller is the module control centre for the entire robot system, equivalent to a human brain, and is responsible for receiving and processing internal information from each module. The DC power supply module provides the voltage required for the entire system to work properly, the QR code and colour recognition module is responsible for scanning the QR code and reading the colour information of the distinguished materials, the tracing module collects the path information on the working area, the motor drive module and the robot arm claw module complete the accurate handling and placement of the materials.

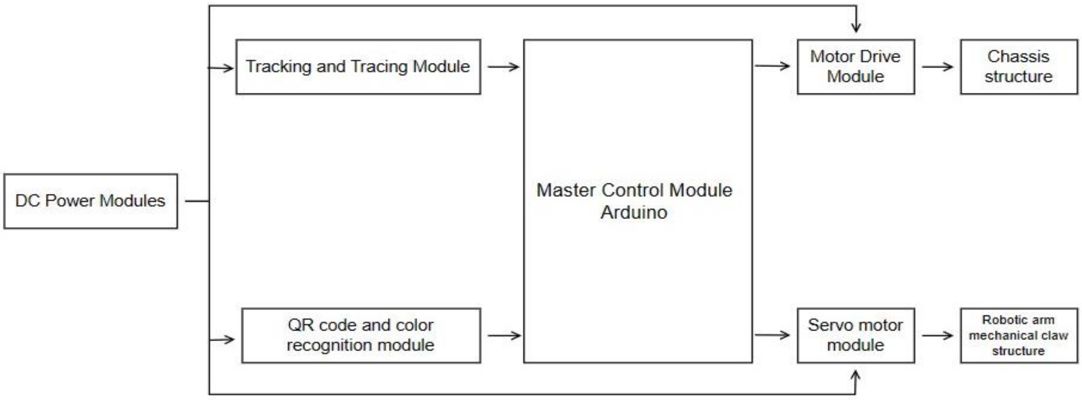

Figure 1: General framework.

3. Conception and realisation of the mechanical structure

The basic structure of the robot mechanical design covers two parts: the suspension structure of the robot and the basic gripper structure of the robotic arm mechanical design. The undercarriage structure carries the functional areas and the robotic arm mechanical gripper structure is responsible for the autonomous identification and gripping of the material, as shown in Figure 2.

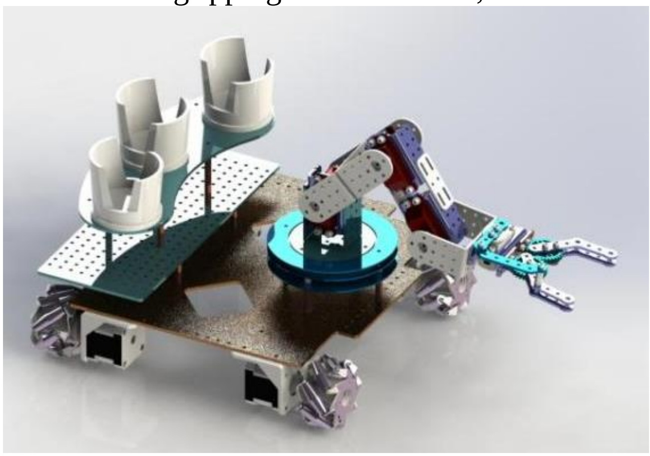

Figure 2: The robot as a whole.

3.1. Chassis construction

The base of the intelligent handling robot is made of 3mm aluminium plate. In order to facilitate the installation and position adjustment of the upper parts, the base is designed with a specific porous structure for the precise fixing of the double layer material carrying area, the servo head connection area, the sensor feedback area and the bottom motor drive area, as shown in Figure 3.

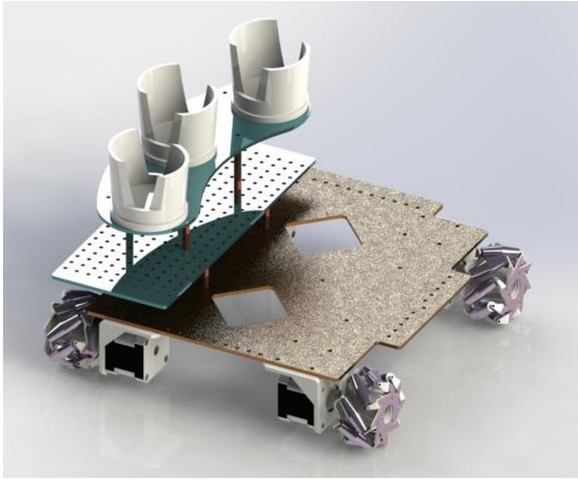

Figure 3: Chassis construction.

3.2. Robotic arm jaw structure

The arm consists of a servo head and a number of servo motors, with a total of four degrees of freedom, allowing flexible omnidirectional operation in space, with U-shaped plates of varying lengths between the servo motors for good connection and fixing of the arm.

The jaws are designed and machined using a 3D printer according to the handling target and are controlled on both sides by means of gear meshing. The jaws are connected to the multi-degree of freedom arm by means of a tiller, and the opening and closing of the jaws is controlled by the reciprocating rotation of the top servo motor, as shown in Figure 4.

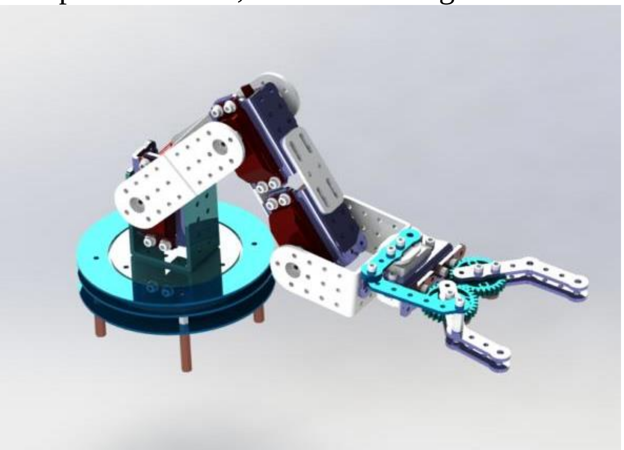

Figure 4: Structure of the robot arm's claw.

4. Design and implementation of the hardware system

The robot hardware system covers the main control module, motor drive module, tracking and tracing module, colour recognition and QR code scanning module, servo motor module and DC power supply module.

4.1. Master Control Module

The Arduino Mega 2560 is a microcontroller circuit based on the ATmega 2560 with 54 digital input/output network ports and 15 capable of being considered PWM outputs for mounting drive angle sensors and driving stepper motors.

4.2. Motor drive modules

The A4988 drives NEMA bipolar stepper motors and controls the stepper motor step mode with the aid of MS1, MS2 and MS3, with the default being full step mode.

DIR direction control pin, when this pin is low, it controls the motor to rotate clockwise; when it is high, and vice versa. RESET reset pin, active low, i.e. when this pin is low, the A4988 will be reset; when it is not connected to the level, it hangs, and the A4988 works normally at high level by default. When the SLEEP pin is connected low, the A4988 will enter a low-power sleep state and consume less power. During normal operation, with the ability to connect the SLEEP pin to the RESET pin, the A4988 will continue to maintain its normal power consumption state and will not enter a low power state, as shown in Table 1.

Table 1: Step mode logic relationships.

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

4.3. Tracking and tracing module

Three three-way greyscale sensors are used for positioning and tracing. The supply voltage is 3.3V~5V, the supply current is 8mA~12mA, the detection distance (based on the distance of the bottom of the probe from the ground) is 10~50mm, the best detection distance is 10~25mm, the output level changes from high to low when the corresponding probe shines to a higher grey value, the corresponding LED lights up.

The sensor adjustment method is when placed on the lighter colour the potentiometer voltage is adjusted until the signal light is on, then move horizontally to the darker colour area sensor corresponding to the signal light is off, as long as the two colours can be identified to output different signals.

The sensor outputs as a 1/0 digital signal and is simple to program and control, allowing the signal sensitivity to be adjusted according to the light of the venue etc. The voltage comparator has two voltage inputs, a reference voltage for the potentiometer input and a voltage for the receiver tube, which needs to be adjusted according to the voltage value of the receiver tube in the 2 colours.

4.4. QR code and colour recognition module

The QR code and colour recognition module covers the Raspberry Pi 3B and 60FPS camera in hardware and the task-oriented recognition algorithm according to Open CV in software. The Raspberry Pi 3B development board is a Linux-based microcontroller system with a 64-bit quadcore ARM Cortex-A53 for 2.5 A power supply, four USB 2.0 ports and 40 GPIO pins.

4.5. Servo motor modules

It consists of two 180° analogue servos, MG995 and MG996R. The angle can only be corrected by means of a continuous PWM signal. The servo control requires a 20ms time base pulse, the high part of the pulse corresponds to a range of 0.5ms to 2.5ms the angle control pulse part of the angle control is able to control the rotation angle when the servo is high. The corresponding control relationships are as follows:

0.5ms -------------------0 degrees.

1.0ms -----------------45 degrees.

1.5ms -----------------90 degrees.

2.0ms ---------------135 degrees.

2.5ms ---------------180 degrees.

4.6. DC Power Modules

The robot uses the ACE 2200mAh 3S 11.1V 30C lithium battery with a capacity of 2200mAh and a standard voltage of 3.7V*3=11.1V. When fully charged, the voltage can generally reach 12.6V, which can be used as a 12V power supply, as shown in Table 2.

Table 2: Parameters of some DC power supplies of a certain 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
5S	18.5	21.0	17.5
6S	22.2	25.2	21.0

5. Robot software programming implementation

5.1. General design of the robot program

The robot has adopted the idea of using modular programming and has written the control program for the whole machine in C language. The overall system software design flow of the robot is shown in the diagram. After the robot starts up, the system first performs the boot-up process to complete the Raspberry Pi self-start, then starts from the starting point, guides to the task QR code location with the help of the tracking and tracing module, scans the QR code to receive the task coloured material in the order of the processing tasks (i.e. different processing tasks), guided by the tracking module, it continues down to the material handling area and captures the material colour information with the help of the camera, which is decoded and analysed in the Raspberry Pi using the ZBar toolkit and transmitted to the Arduino main control board via serial communication. The robot arm is then driven by a servo motor to grab the material and place it in the robot's U-shaped material stacking area, then plan a path to the material placement area and, when the material is placed, travel to the end, as shown in Figure 5.

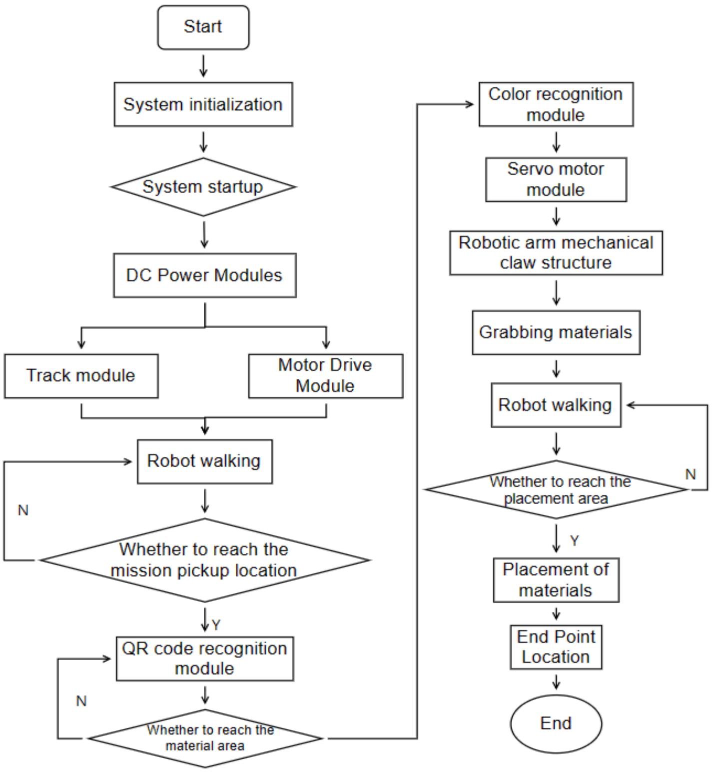

Figure 5: General design of the robot program.

5.2. Robotic vehicle tracking design

The robot uses three three-way digital grey sensors, placed on the left, right and front sides of the chassis, to detect the black line feedback low level, and vice versa for high level. The body sensors are mainly used for tracing, with low level feedback when a black line is detected. The neutral sensor on each side calculates the total number of black lines traced and reaches a specified stopping point when a specified number of lines is reached, which is used for the robot to reach the material placement area or turning point and stop moving forward for material handling and placement or turning.

Given a specific label t for a three-way sensor by means of the array pin[i], the high and low levels of the sensors with different labels at the same moment are summed up and calculated,and then calculate the specific state of the three-way sensor at the current time through the value=(digitalRead (pin[i])*t+value formula,and feed back the high and low level values of the sensor at a certain time with the hexadecimal sign number value, so as to judge the operation deviation status of the vehicle body and correct it autonomously.

5.3. Robot bottom motor design

The underlying stepper motor drive uses closed-loop PID control to meet higher accuracy requirements. Through repeated debugging of the kp, ki and kd parameters, the difference between each output speed and the previous output speed is calculated by substituting the feedback formula, and the PWM value of the feedback is input to the motor to correct the current speed until the stepper motor can respond quickly to reach the desired set speed.

5.4. Programming of robotic arm gripping with mechanical jaws

The MG995 and MG996R analogue servos are used to control the different angles of servo motor rotation given different duty cycles of PWM. Multiple servo motors rotate to form an action group, which in turn controls the all-round movement of the robot arm and the opening and closing of the mechanical jaws, allowing precise gripping and placing of materials in different positions.

5.5. Programming of QR codes and colour recognition

By using the official website Linux computer operating system to port the least squares method in the framework of the Open CV architecture.Open CV is a library of computer vision technology released under the relevant BSD license and can run on computers with Linux, Windows, Android and Mac OS operating systems. With the help of Open CV's library composite functions, the robot first creates the device needed to create the display image and the parameters of another function, then acquires the display image in the built-in camera, and finally creates and sets up the Zbar display image reader to acquire the information associated with the display image. The identified database data is converted from UTF8 file format to ASCII file format and the reference combination should be scanned and identified accordingly.

The relevant parameters for colour are: overall hue, colour saturation and display brightness. A specific approach of binarising the critical values of the colour words was taken to segment the black and white display image into colour words and object-oriented programming was carried out with the help of HSV 3D maps. The QR code and material information captured by the camera is transmitted to the master controller with the help of the serial communication of the Raspberry Pi 3B development kit, as shown in Figure 6.

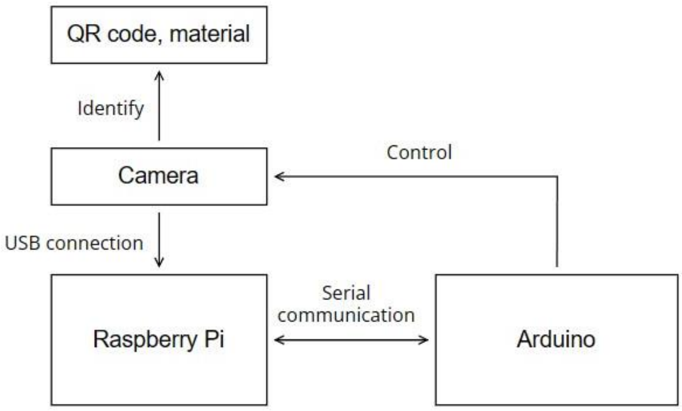

Figure 6: Block diagram of the program for QR code and colour recognition.

6. Experimental results

This intelligent handling robot realises the flexible movement and precise gripping of materials on the McNamee wheel chassis with a multi-degree-of-freedom flexible robot arm.

The robot is able to move flexibly and accurately grasp and place materials in the specified position, with high accuracy in the positioning movement of the vehicle and the grasping of the mechanical jaws of the robot arm, and little deviation in the vehicle's trajectory feedback. In the physical test, it only took 30s to identify and carry three different materials, which was a good completion of the specified task and the robot is shown in Figure 7.

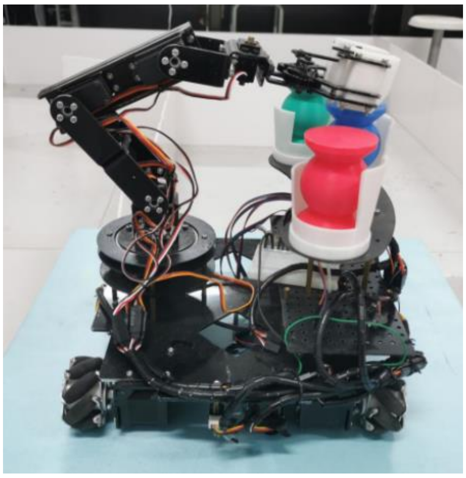

Figure 7: Physical view of the robot.

7. Conclusion

This paper presents and designs an intelligent handling robot based on Open CV recognition. The robot uses the Arduino Mega 2560 as the main control chip, with a lightweight and stable mechanical mechanism and a reasonable and scalable hardware and software design. The Arduino-based robot is capable of receiving tasks, planning paths, identifying and transporting target materials to specified locations.

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