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Designing an Intelligent Handling Robot for Performing Tasks Using QR Codes

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Abstract. With the increasing demand in intelligent manufacturing, an evolving prospective is anticipated for intelligent handling robots. Therefore, the present study aims at developing an intelligent handling robot which is capable of acquiring and fulfilling certain tasks from QR codes, such as handing objects with different shapes and colors. To this end, multiple photoelectric tubes were placed during the process. Subsequently, after ADC data acquisition for multiple times, channels were configured on a STM 32 board. Moreover, a photocell was connected with a single chip microcomputer. Accordingly, the values were obtained by photoelectric pair tubes. To identify QR codes, a camera module was installed. Furthermore, DC motors with encoders and a mechanical arm with steering gears were used as the source of power for the wheels and as the means of grabbing objects, respectively. At the same time, a universal algorithm was written to plan the robot's walking routes.

Keywords. Intelligent handling robot; DC motor; Photoelectric tubes; Steering gear; Universal algorithm.

1. Background of intelligent handling robot design

Since the development of the first industrial robot in the early 1960s, this area of knowledge has progressively become interesting. Accordingly, research on such areas as robot grasping [1-2], sensor [3-4], robot arm [5-6], etc., are gradually emerging. After more than 50 years of development, robots have entered all aspects of our lives. As an irreplaceable and important equipment in the advanced manufacturing industry, industrial robots are considered as a main branch of robotics. Consequently, they have become an important area for research and development in the field of robotics. In line with this, more and more interest has been given to research on planning and controlling industrial robots' motion trajectory. Hence, industrial robots have become an important symbol in measuring a country's manufacturing level and scientific and technological status.

Handling robots are an important branch of industrial robots. They are characterized by the ability to complete a variety of expected tasks through being programed. Moreover, in terms of structure and performance, they have the advantages of both humans and machines. In particular, they reflect human intelligence and adaptability. Moreover, the development of a country's national economy is also expected to be widely affected by the accuracy of manipulator operation and the ability of the robots to complete operations in various environments.

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Robots are required to urgently mechanize, i.e. automate, handling and transportation processes such as loading and unloading. Handling robots can save cost and loading and unloading labor. Accordingly, individual loading and unloading robots are not only allowed to work independently in certain countries, their online interaction with each other form a logistics network in handling the distribution of goods which greatly improve work efficiency. As a consequence, considering China's modern industrial development, research on the control and development of such robots has become an inevitable trend.

As an important branch of industrial robots, intelligent handling robots have ushered in a booming development with the advancement of artificial intelligence technology. An intelligent handling robot is a machine system which can fully simulates human perception, thinking and emotion. As a result, it can replace humans in various fields. Moreover, an increase in the volume of order and distribution demand, intelligent handling robots have gradually become automated. [7]. So, they are expected to be able to accurately identify the objects to be handled as well as to precisely plan the handling path.

Moreover, having the advantages of both humans and machines in construction and performance, such robots can distinctively accomplish all kinds of expected tasks through programming. More particularly, they reveal human intelligence and adaptability. Furthermore, the accuracy of the manipulator operations and ability to complete the operations in various environments have turned the robots into promising tools in the development of national economy in various fields.

The advent of China's industrial robots goes back to the 1980s. Later, competitive research institutions and enterprises working on industrial robots were established after more than 20 years. As a consequence, industrial robots have been developed in such areas as arc welding, electric welding, assembly, handling, injection molding, stamping, and painting. In recent years, China's annual sales of industrial robots and products related to automatic production lines have exceeded 1 billion Yuan. Currently, the domestic market has an annual demand for about 3000 units, the annual sales of which reach more than 2 billion Yuan. Based on statistics, as many as ten thousand industrial robots presently exist in Chinese markets. This number accounts for 0.56 % of the total number of industrial robots in the world, of which, while approximately 30 % are entirely domestic industrial robots (the first three industrial robot enterprises with relatively large industrial scale), the rest are imported from more than 20 countries such as Japan, the United States, Sweden, Germany, and Italy.

Robots can offer huge economic benefits in terms of reducing human efforts [8]. To be more exact, they are responsible for meeting the urgent needs of the mechanization, i.e., automation, of handling and transportation processes, such as loading and unloading. A handling robot can save handling and unloading labor as well as costs. Therefore, individual handling robots are not only allowed to work independently in certain countries, but they also interact with each other online. Accordingly, a logistic network is formed for handling distribution and the dispatch of cargo, which has greatly improved work efficiency. Hence, research on and development of handling robots are among the inevitable trends of China's modern industrial development.

Most of the existing intelligent handling robots are not able to autonomously acquire handling tasks and realize cargo identification [9]. To resolve this problem, the present study aims at developing an intelligent robot which is capable of obtaining tasks from QR codes, i.e., carrying objects of different shapes and colors. To this end, a DC motor with an encoder and a robotic arm with a servo are used to generate power for the wheels and to grab the objects, respectively. Moreover, a universal algorithm is written to plan the walking route of the robot in completing the task.

2. The whole structure design

Accuracy and speed have always been important indicators for measuring the highest performance in transportation competitions. Better results requires the design of a perfect structure. In the first stage, we extensively reviewed the literature and worked on 3-D modeling. Fig. 1 displays the structure of the developed system. Intelligent handling robots are mainly constituted from hardware and software. The former is based on the STM 32 single-chip microcomputer system and integrates such modules as motor, camera, manipulator, and tracking modules. To perform the tasks, the latter, i.e., the software, includes such programs as line patrol, location, obstacle avoidance, and visual recognition programs, etc.

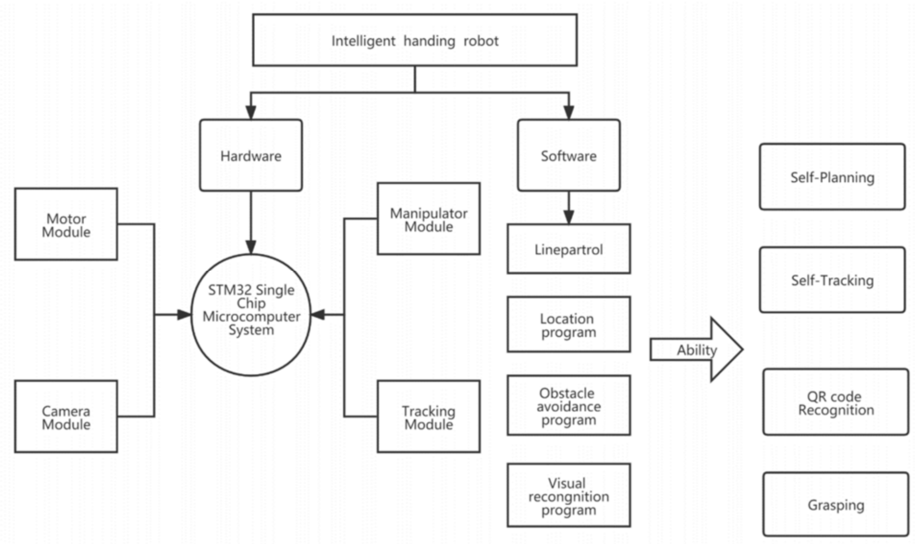

Figure 1. System structure

2.1 Task analysis

The intelligent robot receives the tasks (carrying objects of different shapes and colors) from the TWO-DIMENSIONAL code. Subsequently, it uses a DC motor with an encoder and a mechanical arm with a steering gear for generating the power of the wheel and grabbing the objects, respectively. At the same time, a general algorithm is written to plan the robot's walking path in completing the task. Based on the task analysis, the robot is expected to have certain abilities including self-tracking, self-planning, recognizing QR codes, and grabbing objects. To perform self-tracking and planning functions, the 8-channel photoelectric sensors should be placed on the front and rear sides of the base plate, with the four 8-channels in the middle for tracking. The other four channels are designed to help the robot to locate itself. Moreover, the QR code is recognized by the camera installed on the robot. The mechanical arm is also used to capture the objects. To identify two-dimensional codes, the camera is mounted on the rear part of the vehicle. Aluminum plates are synchronously fixed on the car floor. Once an initial model and the processing phase are developed, a robotic arm is built to perform the task. Therefore, the performance of the robot can be greatly improved by a solid and reliable robot hand. The arms are attached to the aluminum board using the steering wheel. Photoelectric sensors are also symmetrically positioned and must be traced for accuracy. The camera is the key to identify the QR codes. So, if not being positioned properly, the camera will negatively affect the function of other hardware. Therefore, the appropriate place, position and height of the camera is of high significance for accurately identifying the QR codes and the obtained information.

With the rapid development of robotics, robot arms emerged at the right moment. They have demonstrated outstanding capabilities and have turned into a key technology in the construction, support and providing service for various industries such as healthcare. They are also extensively used in a wide range of areas including operating rooms, automated cooking, spaceships, and intelligent robotic grasping.

2.2 Coordinated design of hardware and software

The hardware part of the handling robot must include a body, a development board, a steering gear, a voltage stabilizing board, a bottom board, a battery, a camera, etc. On the other hand, the software part should work in coordination with the hardware to complete the whole process and accomplish various tasks.

The actual use and condition of the task determines the location of the hardware to be installed. To provide power and support the robot, four wheels were properly installed on the floor of the vehicle. Moreover, a development board, a voltage stabilizing board, and a battery were arranged at the center of the vehicle's bottom plate. The voltage stabilizing plate has two functions. First, it stabilizes the voltage of the battery to the voltage required by the car hardware. Second, it supplies the power to the steering gear, development board, etc. To identify the QR codes, the camera was installed at the rear part of the vehicle's body. In addition, using copper pillars, an aluminum plate was fixed on the bottom plate of the car, on which the mechanical arm was fixed with a steering gear. Furthermore, in order to ensure the accuracy of tracking, photoelectric sensors were placed symmetrically around the body.

With regards to the software, each hardware was programmed to ensure its effective cooperation with other hardware. Finally, to accomplish the task, the program was downloaded into the development board. In the process of robot identification, the operator was able to click the mouse facing the device to display the information interface. On the one hand, while this function directly provide a view of the device information in the 3D view, it can also enhance the interaction between the operator and the model in the view, on the other. Accordingly, the device ID identifies an object and corresponds to the device information in the device details function. The device thumbnail is also used to view the overall appearance of the device model. Moreover, the 360-degree rotation of the device model provides the operator to gain an intuitive understanding of the device.

3. System hardware design

3.1 Bottom plate design

The main function of the bottom plate is to track and judge the various positions where the car is located. The 8-channel photoelectric sensors were placed in the right side at the front and back of the bottom plate. A photoelectric sensor is an important prerequisite for tracking, which recognizes the black and white areas according to the value returned by ADC. Moreover, while four DC motors were respectively installed on the appropriate position of the bottom plate, a development board, a voltage stabilizing board, and a battery were arranged at the center of the vehicle's bottom plate. Figure 2 displays the general construction of the vehicle floor. The center of the bottom plate is also shown in Figure 3.

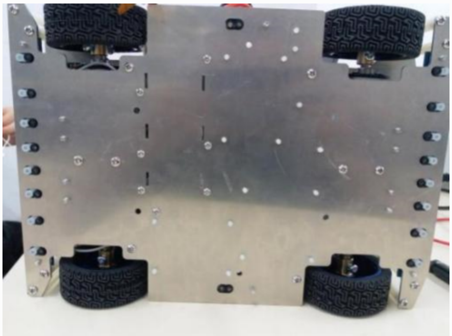

Figure 2. Structure of the bottom plate

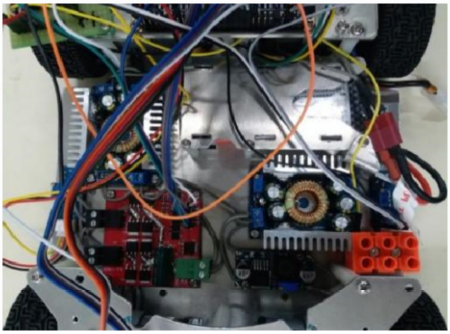

Figure 3. Center of the bottom plate

3.2 Mechanical arm design

Being a typical form of an industrial robot [10], a manipulator, i.e., commonly known as a mechanical arm, is an important structure for grasping objects. Therefore, a stable and reliable mechanical arm can remarkably improve the working efficiency of the robot. First, a model was built in the early stage. Subsequently, after examining it in the later stage, a mechanical arm capable of completing the task was constructed (Figure 4).

3.3 Camera placement

The camera is the key to identify the QR codes. So, if not being positioned properly, the camera will negatively affect the function of other hardware. Therefore, the appropriate place, position and height of the camera is of high significance for accurately identifying the QR codes and the obtained information (Fig. 5). Figure 6 displays the details of the camera.

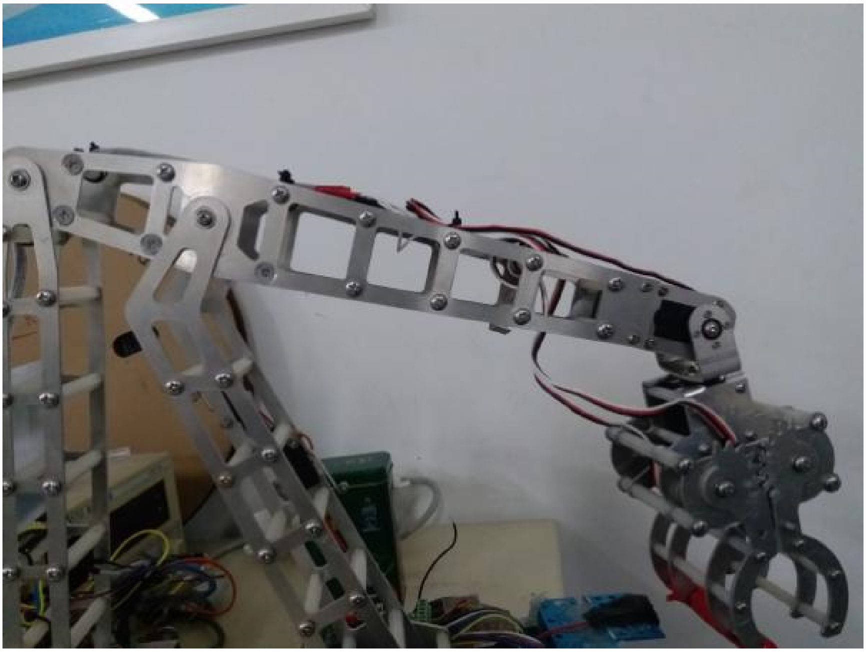

Figure 4. Mechanical arm structure

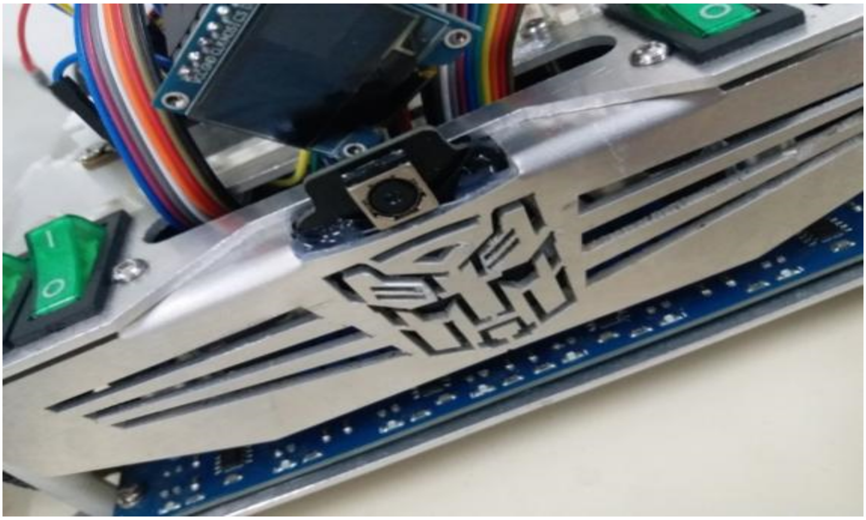

Figure 5. Camera placement

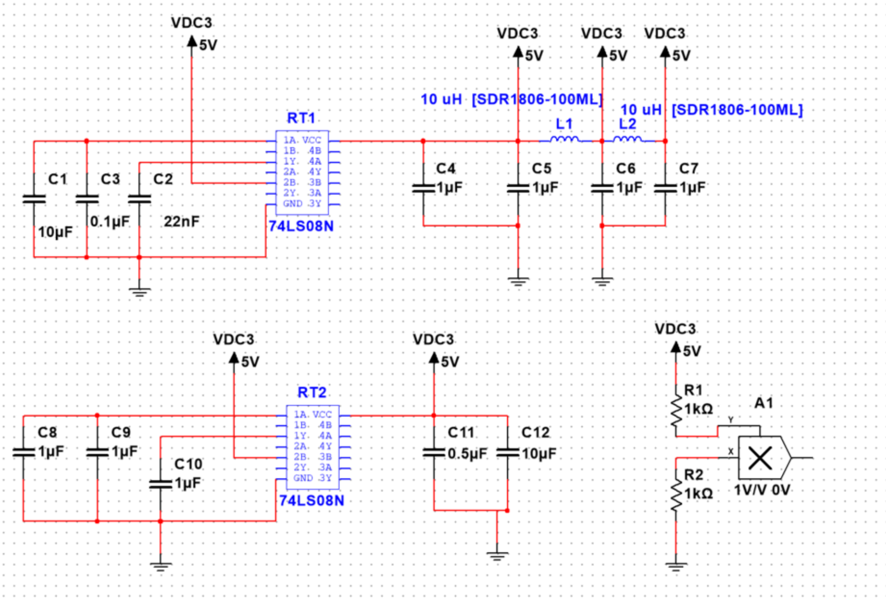

Figure 6. Camera diagram

3.4 The hardware design

The overall design of the automatic charging device is divided into two parts, namely, the plug and the socket. While the former is installed on the robot, the latter is installed on the ground. Moreover, while the protruding part of the plug's main body is made of nylon, the bottom is equipped with two copper sheets as electrodes. The copper sheets are further connected to the power supply. The front end is equipped with an inclined plane, which makes it convenient for the robot to slide into the socket when walking in the charging area. The plug body is encompassed in a frame made of an aluminum alloy. In addition, the plug body is placed around a certain gap, which makes it easy to slide the plug up and down. When the robot walks along the track and moves to the charging area, the radio frequency card reader installed on the body of the robot reads the post on the surface of the radio frequency card. Then, by entering the charging area, the robot stops. Subsequently, the push rod motor drives the plug main body to extend. When the extension reaches its half, the limit switch installed in the middle of the plug main body is touched, which causes the push rod motor to stop working. Since the movement of the robot is not accurately centered along the magnetic rail, a certain deviation to the left and right is expected. Accordingly, the slide of the socket with the transverse guide rail is tolerated to a certain range, so that the position of the jack to the left and right and the robot on the plug are consistent. The rotation of the robot changes the feedback value of the photoelectric sensor from black to white and then back to black again. To determine the angle of rotation, the development board reads the positive and negative jump. Next, after the delivery of the block, the robot needs to turn around to return to the center before moving to the next position. Accordingly, a photoelectric sensor needs to be set up at the tail of the robot when it turns to the line. However, due to the interference of the position of the blocks with each other as well as the special arrangement of the block in the second step, a mechanism needs to be designed through which the robot can grab the blocks.

Accordingly, a mechanical arm structure is used to grab, release and transport the object blocks to the specified position. To ensure the stability of the system, the input and output of the SCM control circuit are isolated using photoelectric coupling. The input signal IO, the single-chip input IO port, the IO output and output level signal are completely isolated. In order to output switching quantity with high current and low frequency, a relay output circuit is adopted. Moreover, to increase the anti-interference performance, a photoelectric coupler is used in the first stage of relay driving circuit. Subsequently, the control signal is amplified using a high-power triode. The power supply supplies power to the bracket. To control the camera, the holder is simultaneously equipped with multiple relay switch circuits. Moreover, the power supply unit accounts for supplying the voltage of the ground automatic inspection device of the whole power station. The quality of power supply design will directly affect the stability of the inspection device. The inspection device utilizes a lithium battery power supply. This is to say that while only the servo motor directly adopts a lithium battery power supply, other devices use low voltage power supply.

4. System development and debugging

The initial problem of developing the robot was the design of the bottom plate, i.e., the position of the 8-channel photoelectric sensors to carry out the tasks of tracing and turning [11]. Ultimately, the photoelectric sensors were put at the front and back parts of the bottom plate. While the middle four of the 8-channel were used for tracing, the other four channels assisted the robot in positioning its own position.

Followed by DC motors debugging, generating power for the robot is crucial [12]. During the process, it was found that the supply of the same voltage to the DC motors led to the different rotation speeds of the DC motors. Accordingly, pulse waves with different duty ratios were used to fine-tune the motor speeds.

The debugging of the steering gears was also an essential step [13]. Since the steering gears are installed on the mechanical arm, long-term pressure causes wear and tear to the gears. This problem was resolved by adjusting the PWM values of the steering gears several times and carrying out numerous tests.

The operation of the camera is extremely complicated. The inappropriate configuration of the camera in the program or the wrong design of the program logic prevent the camera to complete the expected task [14]. After extensively reviewing the literature and examining the program carefully at a later stage, the camera was eventually configured in such a way that it was able to quickly and correctly identify QR codes.

5. Conclusion

To improve the intelligence of intelligent handling robots, robots capable of obtaining tasks from QR codes and accomplishing them are designed and developed [15]. The intelligent handling robot is able to conduct automatic handling tasks and perform such functions as target object monitoring, grasping, and handling.

The robot takes the STM 32 single chip microcomputer system as the core. It also integrates the tracking module, manipulator module, and other functional modules into a whole. Moreover, PWM, PID, and other control ideas are used to program and perform various functions of the handling robot [16]. Fortunately, the whole system is simple, easy to design and runs stably and reliably.

By the continuous development of science and technology, higher standards are set for intelligent handling robots. Hence, as a future research, the algorithm is recommended to be further improved to enhance the capabilities of intelligent handling robots.

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