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Design of Automatic Irrigation Robot Based on Tracking and Visual Recognition

Jiahui Li[1,*], Jindong Zhang[2], Zhiying Liu[3], Yan Liang[4], Zhongfa Yin[5], Fuda Wang[6]

[1]*School of Mechanical Engineering, Tianjin University of Technology and Education, Tianjin, China*
[2]*School of Automation and Electrical Engineering, Tianjin University of Technology and Education, Tianjin, China*
[3]*School of Mechanical Engineering, Tianjin University of Technology and Education, Tianjin, China*
[4]*School of Mechanical Engineering, Tianjin University of Technology and Education, Tianjin, China*
[5]*School of Automation and Electrical Engineering, Tianjin University of Technology and Education, Tianjin, China*
[6]*School of Automation and Electrical Engineering, Tianjin University of Technology and Education, Tianjin, China*
[*]*Corresponding author*

Abstract: *The purpose of this project is to design an automatic watering robot with tracing module and visual module, which is equipped with watering, spraying and supporting facilities. This product aims to solve the problems of difficult management of potted plants in flower lovers ' families or greenhouses, and high mortality caused by neglect of management of flowers due to human factors. The project takes STM32 single-chip microcomputer as the core, with tracing module and visual recognition module. The execution module adopts belt transmission, combined with Internet of things, path automatic planning, magnetic coupling resonance wireless charging and other technologies to realize the application of robot automatic irrigation and spraying by autonomous planning of road trajectory. The project has good promotion value in the flower market and smart home.*

Keywords: *tracking, control algorithm*

1. Introduction

With the acceleration of social and economic development, people's living standards and housing conditions have been greatly improved. More and more people have put forward new requirements for living environment and quality of life. For example, urban white-collar workers like to plant some potted plants at home. Potted plants can not only play a beautiful and clean role indoors, but also purify the air, cultivate sentiment, enrich life, and relax the mood of long-term intense work.

However, for most office workers, it is not easy to raise green plants. The traditional irrigation method is artificially irrigated manually according to experience, which cannot accurately control the timing of irrigation, and cannot control the amount of irrigation. In the fast-paced life, busy work almost let them have no time to take care of their own planting potted plants, or because of the business cannot water and fertilize the green plant potted plants dry and death, studies have shown that the family of green plants potted plants 80 % of the causes of death are man-made. In recent years, the development of smart home products is in full swing. Smart home can comprehensively manage various family systems, and ultimately provide a comfortable, safe, convenient and efficient personalized home space[1].

2. Innovation Characteristics of Works

2.1. Distributed Architecture

Each functional module is involved in the whole system as a relatively independent unit. The main control unit and the measurement and control intervention processing, attitude control system, track control system, data transmission, payload control and other functional subsystems are independent of each other as agents and connected by the bus. The structure design is shown in Figure 1.

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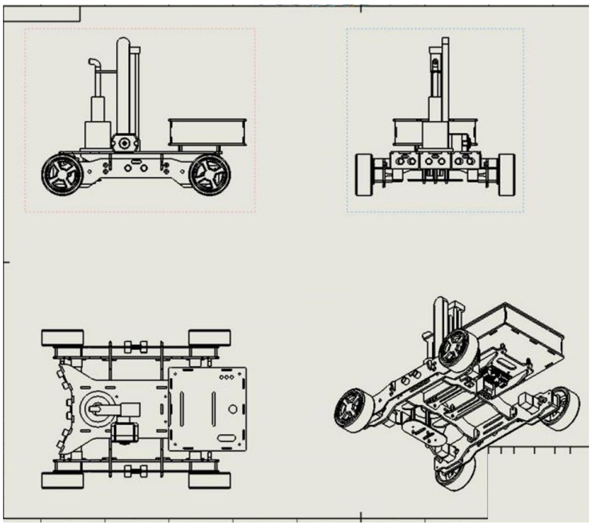

Figure 1: Structural design drawing

2.2. Wireless Charging

When the power consumption of the robot reaches the minimum preset value, it will automatically alarm and automatically go to the nearest wireless charging point for orderly charging after completing the current task. At the same time, wireless charging transmits power through a non-contact magnetic field, which greatly reduces the occurrence of security risks and avoids unnecessary hardware loss.

2.3. Fail-Safe Operation

The robot is equipped with ultrasonic sensors around it, which can accurately and timely detect sudden faults on the path, and bypass the faults after processing by the controller to ensure driving safety. The manipulator is equipped with a limited switch to ensure that the manipulator can stop in time after reaching the maximum working range and avoid damage. In addition, beyond the maximum working range of the manipulator, there is also a pair of optical fiber sensors to ensure that in the working engineering of the manipulator, the injury accident is caused by the inadvertent entry of the personnel into the working range of the manipulator[2].

2.4. The Combination of Tracing and Vision

When the robot can identify the ' label ' artificially pasted in front of it in front of different plants, to irrigate the corresponding water volume and apply multiple types of fertilizers or spray the corresponding drugs, it can work in green areas with diverse varieties and has strong compatibility.

2.5. Using Belt Drive

Even for potted green plants placed in several layers of shelves, the range of motion of the robot's actuator will not be limited and can adapt to different working environments.

2.6. Low Working Environment Requirements

The robot chassis has the advantage of small body volume and can perform precise operation in a narrow working area.

3. The Overall System Design of The Robot

The design and research of robot control system. The control system refers to the intelligent and efficient human-computer interaction control system for robots, including sensor design and human-computer interaction system design. Sensor is one of the key components for robots to realize autonomous navigation and sense the environment. It is necessary to select suitable sensors for design, such as lidar, camera, inertial sensor, etc., and obtain high-quality sensing data through signal

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processing and algorithm optimization. The overall structure frame diagram is shown in Figure 2.

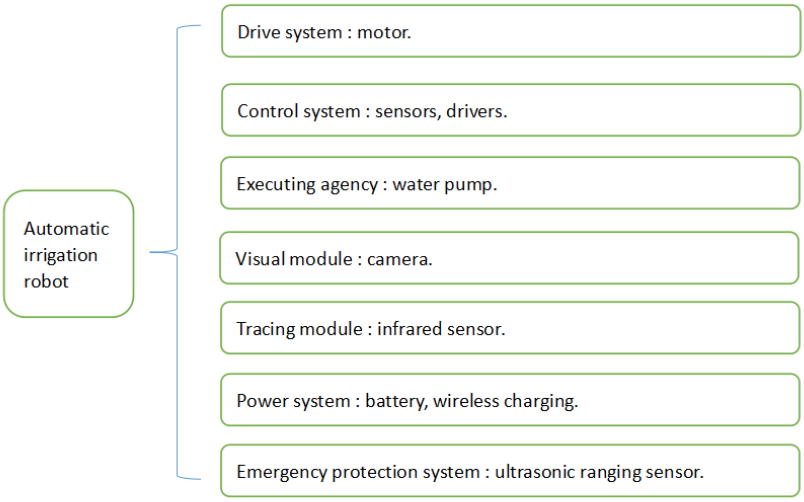


Figure 2: Overall structure frame diagram

3.1. Design and Research of Robot Drive Module

The robot chassis carries a large volume of water tank and lifting mechanism, so the load is large. Because the robot has the flexibility of forward, steering, stop and emergency stop at the same time, according to the good speed regulation and start-up of DC motor, the torque is large, so DC motor drive is selected. PWM wave speed regulation system can be used, steering adopts differential control, and two L298 N motor drive modules are used to drive DC motor[3].

3.2. Design of Robot Tracking Module and Road Trajectory Module

The cruise path is set with black track adhesive paper to ensure that the irrigation robot passes in front of each pot.

3.3. Design of Robot Vision Module

The vision module is a hardware component used in the field of machine vision. It collects image signals through devices such as cameras or photoelectric sensors, and converts them into digital signals. Then it performs data analysis and processing through corresponding algorithms and processors, and finally realizes the recognition, classification and tracking of target objects, scenes or events.

3.4. Design and Research of Robot Execution Module

In order to irrigate potted green plants placed on shelves of different heights, a motor with a transmission belt is used to drive the workbench with a nozzle to a certain height, and a water pump is installed in the water tank. When the signal is detected, the switch is turned on and the irrigation is completed.

3.5. Design of Wireless Charging System

A charging base with anti-skid bottom and fixed manipulator is designed to enable the robot to align the charger accurately and ensure the charging efficiency. Moreover, the charging base needs to take into account the size and weight of the tracing robot, as well as the installation position of the wireless charging module.

3.6. Design and Research of Robot Emergency Protection Module

On the basis of the tracing route, the ultrasonic ranging sensor module is installed. When encountering people or obstacles, the single-chip microcomputer control module will receive the feedback signal of the ultrasonic ranging sensor, trigger the buzzer buzzer and LED flashing alarm, and stop the motor to prevent damage to the robot body due to collision[4].

4. Robot Hardware Selection Introduction

4.1. Motor Selection

The water storage capacity of the water tank is about 2.5 liters. The plastic wheel with a diameter of 0.1 m is selected. The overall weight of the automatic irrigation robot is about 3.5-4 kg, and the walking speed is about 0.12 m / s. The friction coefficient between the plastic wheel and the ground is, and the maximum load speed of the motor is:

$$\omega_{\max} = \frac{60v}{\pi D} = \frac{60\times0.12}{3.14\times0.10} = 22.93r/min \quad (1)$$

The minimum load torque of a single motor is:

$$T_{\min} = \frac{\mu mg}{2}\times\frac{D}{2} = \frac{0.2\times4\times9.8}{2}\times\frac{0.1}{2} = 0.196N\cdot m \quad (2)$$

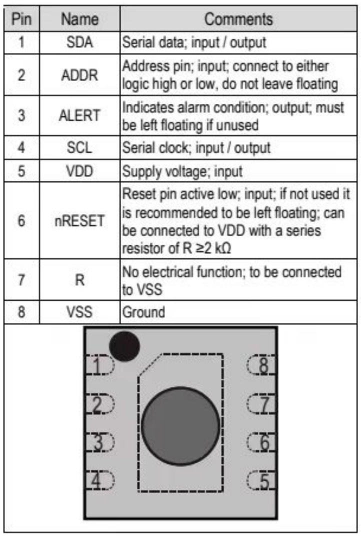
According to the maximum load speed and minimum load torque above the motor, the walking motor chooses low speed and large torque miniature DC deceleration motor, rated voltage 12V, no-load speed 40 r/min, load speed 35 r/min, load current 0.2A, load torque 0.5 N·m, and output power 2W.

The overall weight of the platform is about 200-300g, with a diameter of 0.05m and a lifting mechanism is selected, and the maximum load torque of the motor is $T_{\min} = 0.0075N\cdot m$ .The rated voltage is 12V, no-load speed is 35 r/min, load speed is 28 r/min, load current is 0.1A, load torque is 0.245 N·m, and output power is 0.8w.

4.2. Pump Selection

The maximum elevation of the nozzle is 1.5m, so the 385 micro pump with working voltage DC12V, working current 0.5-0.7A, flow rate 1.5-2 L/min, suction range of two meters and head range of three meters is selected.

4.3. Humidity Sensor Selection



Pin	Name	Comments
1	SDA	Serial data; input / output
2	ADDR	Address pin; input; connect to either logic high or low, do not leave floating
3	ALERT	Indicates alarm condition; output; must be left floating if unused
4	SCL	Serial clock; input / output
5	VDD	Supply voltage; input
6	nRESET	Reset pin active low; input; if not used it is recommended to be left floating; can be connected to VDD with a series resistor of R ≥2 kΩ
7	R	No electrical function; to be connected to VSS
8	VSS	Ground

Figure 3: Sensirion SHTC3 pin diagram

SensirionSHTC3 humidity sensor is selected. This compact humidity sensor adopts capacitive technology and has the characteristics of high precision, fast response and low power consumption. It is suitable for scenarios such as IoT terminal devices, smart homes, and handheld devices.

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SensirionSHTC3 pin is shown in Figure 3.

4.4. Water Level Sensor Selection

The TE Connectivity D5K water level sensor is selected. This digital small water level sensor uses pressure sensor technology and can calculate the liquid level height by measuring the liquid static pressure. It also has a variety of output modes, high precision and low power consumption. It is suitable for liquid level monitoring, flow control and other scenarios, which is very suitable for the application of this robot.

4.5. Visual Module Selection

This camera has accurate image acquisition, accurate control and positioning, high operating efficiency, and can identify different kinds of plants at high speed and accurately.

4.6. Tracing Module Selection

The tracing module uses TCRT5000 infrared reflection sensor (working voltage 3.3-5V, detection reflection distance 1mm-25mm). The car is equipped with four infrared sensors to collect data at any time. When the detection is black line, the return value is 1; when the detection is a white line, the return value is 0. Only when the return values of the two sensors on the same side are both 1, the robot travels according to the trajectory, as shown in Figure 4.

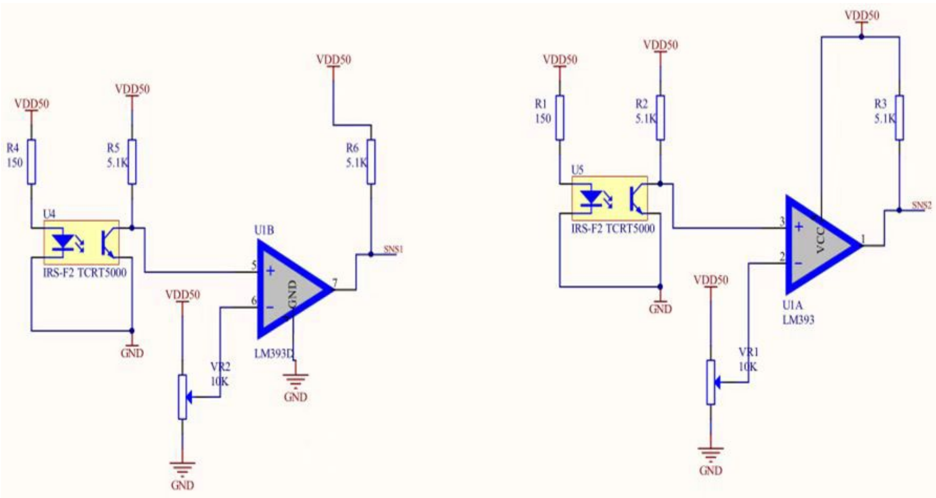

Figure 4: Electrical schematic diagram of infrared sensor

4.7. Selection of Touch Screen

Panasonic JT-B1 series touch screen is selected. This series of touch screen adopts capacitive multi-touch technology, which has the characteristics of light weight, waterproof and dustproof. It is suitable for outdoor environment and field service, and has high durability and reliability.

4.8. Selection of Ultrasonic Ranging Sensor

The HC-SR04 ultrasonic ranging sensor is selected. This small ultrasonic ranging sensor adopts non-contact technology, which can achieve a ranging range of 2cm to 400cm, with high precision, fast response and low power consumption. It is suitable for robot navigation, smart home, automated warehousing and other scenarios. The schematic diagram of HC-SR04 is shown in Figure 5.

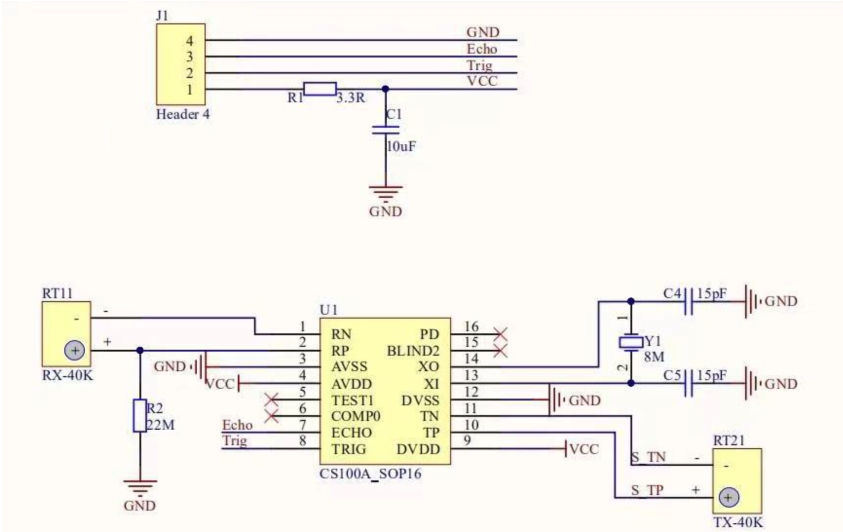

Figure 5: HC-SR04 schematic diagram

4.9. Selection of Wireless Charging Module

Anker PowerWave Pad wireless charger is selected. This wireless charger supports a charging power of up to 10 W, which allows the car to charge after receiving a certain range of wireless signals. It also has the characteristics of multi-layer security protection, efficient heat dissipation and portability, which is suitable for charging small mobile devices.

5. Robot Software System Design

5.1. Selection of Operation System

The operating system is FreeRTOS. FreeRTOS is selected as the operating system of the robot software system mainly because it has good real-time and predictability. FreeRTOS is a lightweight real-time operating system for embedded devices. It has multi-tasking, time slice rotation, memory management, IPC (inter-process communication) and other common operating system functions, which can help the robot software system to better manage hardware resources and program execution. At the same time, the task scheduling algorithm of FreeRTOS is very flexible and can support a variety of real-time requirements. For example, for control tasks that require high real-time performance, a preemptive scheduling algorithm can be used; for low-priority background tasks, collaborative scheduling algorithms can be used to reduce system overhead. In addition, FreeRTOS supports multiple processor architectures and compilers with good portability and scalability. This makes the robot software system more convenient when it needs to be upgraded and extended. In summary, FreeRTOS is selected as the operating system of the robot software system because it has good real-time, predictability and scalability, and is very suitable for embedded device applications.

5.2. The Design of Software Architecture

Using MVC architecture, the main reasons are as follows:

5.2.1. Separating concerns

MVC places business logic, user interface and data model in different layers, so that each part has clear responsibilities and functions, and is easier to maintain and update.

5.2.2. Improving scalability

MVC allows each part to be independently extended or replaced without affecting the entire system. For example, when you need to add a new user interface or data storage, just add a new view or model.

5.2.3. Achieving loose coupling

MVC uses a message passing mechanism to achieve interaction between different layers, thus avoiding tight coupling. This makes the system easier to test, maintain and modify. Improve code structure. MVC separates business logic from the user interface, making the code structure clearer and making the code easier to read and understand. Improve reusability. MVC separates business logic and data model, and provides a common model to process data for reuse in different applications. This allows developers to create new applications faster because they can reuse the code and models they have written.

5.3. Design of sensor driver

The sensor driver is a module in the robot software system that is responsible for reading data from the sensor, parsing data, and sending data. The following is the driver development process of HC-SR04 ultrasonic ranging sensor:

5.3.1. Initializing GPIO Port

The pins used to connect the ultrasonic module need to be initialized, including setting the pin as input or output, and setting the pin level. Part of the code is shown in Figure 6.

```
int fuzzy_light(int light)
{
    int val = 0;
    if(light <= 50) val = 1;
    else if(light > 50 && light <= 100) val = (100 - light) / 50;
    else if(light > 100) val = 0;

    return val;
}


int fuzzy_distance(int distance)
{
    int val = 0;
    if(distance <= 20) val = 0;
    else if(distance > 20 && distance <= 30) val = (distance - 20) / 10;
    else if(distance > 30 && distance <= 60) val = 1;
    else if(distance > 60 && distance <= 70) val = (70 - distance) / 10;
    else if(distance > 70) val = 0;

    return val;
}


int fuzzy_direction(int light_val, int distance_val)
{
    int dir = 0;
    if(light_val >= 0.5 && distance_val >= 0.5) dir = 0;
    else if(light_val >= 0.5 && distance_val < 0.5) dir = -1;
```

Figure 6: Control algorithm code

5.3.2. Sending Trigger Signal

A positive pulse with a high level duration of at least 10 us is sent to the ultrasonic module to trigger the ultrasonic emission.

5.3.3. Receiving Echo Signal

After the ultrasonic wave reaches the obstacle, it will be reflected and received by the ultrasonic receiver. At this time, a response echo signal will be generated, and the duration of the echo signal will be determined by reading the pin level change.

5.3.4. Calculating the Ranging Value

Since the propagation speed of the ultrasonic wave in the air is known, the distance of the target object can be calculated according to the duration of the echo signal.

5.3.5. Outputting processing results

The processed data is output to other modules for further processing or display.

5.4. Writing of Control Algorithm

In order to enable the robot to track and visually identify, and automatically perform tasks based on this information, it is necessary to write corresponding control algorithms. Part of the code is shown in

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Figure 7.

```
int fuzzy_light(int light)
{
    int val = 0;
    if(light <= 50) val = 1;
    else if(light > 50 && light <= 100) val = (100 - light) / 50;
    else if(light > 100) val = 0;

    return val;
}


int fuzzy_distance(int distance)
{
    int val = 0;
    if(distance <= 20) val = 0;
    else if(distance > 20 && distance <= 30) val = (distance - 20) / 10;
    else if(distance > 30 && distance <= 60) val = 1;
    else if(distance > 60 && distance <= 70) val = (70 - distance) / 10;
    else if(distance > 70) val = 0;

    return val;
}


int fuzzy_direction(int light_val, int distance_val)
{
    int dir = 0;
    if(light_val >= 0.5 && distance_val >= 0.5) dir = 0;
    else if(light_val >= 0.5 && distance_val < 0.5) dir = -1;
```

Figure 7: Control algorithm code

6. Conclusions

In this era of rapid development of science and technology, integrated control technology is constantly updated. The logistics sorting system based on four-axis robot can further optimize the system function with the update of integrated technology. The design of this system breaks the traditional working form of green plant pot irrigation. The system can continuously and automatically trace and irrigate for a long time. It not only effectively solves the shortcomings of traditional manual operation but also reflects the application of production automation technology. Not only the automatic car and the mechanical mechanism are perfectly combined to realize the automatic tracing irrigation control; at the same time, it also integrates track planning, automatic identification and other technologies, so that the system can carry out irrigation work more safely and accurately. Selecting suitable water consumption and nutrient solution for different plants can achieve a variety of work objectives to meet different needs. Such as the precise delivery of special plant drugs. The whole system is known for its dexterity and convenience, which can meet various narrow working paths and ranges, and has a wide range of application fields and promotion space in smart home.

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