Design and Implementation of a Handling Robot Based on Target Recognition

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Abstract: In this paper, aiming at robot target recognition and path planning, an algorithm of target recognition based on clustering analysis, which eliminates the traditional boundary extraction algorithm, decreases CPU time, and improves the real-time performance, is proposed, and a related hardware and software module design are implemented, including a claw grab mechanism, a drive control unit, visual unit, Mecanum four-wheeled mobile platform, universal driver, robot control app, etc. The robot can realize automatic operation and manual control by target recognition training calibration procedure, automatic operation program, and manual procedure. Test results show that the robot is working properly and achieves the desired goal.

1. Introduction
In recent years, robots for competition have developed rapidly and various games have grown significantly. Participating in challenging robotics competition can greatly stimulate the scientific interest of young people. The handling robot is a common type of robot in various types of competition robots. It usually follows a preset procedure to transfer a designated target to a predetermined position. This involves target acquisition and identification, path planning and various types of control servos. It is a complex and comprehensive system. Each part needs to coordinate work to ensure the completion of the task.

In [1], a mobile robot based on embedded system is studied. By using a CCD camera, the target can be detected and captured, and image processing techniques such as histogram, spatial resolution of the image, and adjacent pixels can be used. In [2], aiming at target recognition and tracking, an efficient algorithm is introduced to overcome the contradiction between the complexity of the algorithm, tracking accuracy, and real-time performance. Literature [3] proposes a high-speed visual system of table tennis robot design algorithm and a ball detection algorithm to improve the image processing speed up to 200 frames per second. Literature [4] studies the visual system for RoboCup to improve the accuracy and stability of the visual system. There is also research on the visual system of robots used for harvesting wild plants [5].

This paper proposes a target recognition method based on cluster analysis in point of the specific target recognition. The algorithm can greatly simplify the complex steps of the traditional target recognition one, and effectively improve the efficiency of target recognition. A robot device is achieved through the relevant software and hardware module design in the paper. The paper is organized as follows: The section II proposes a target recognition algorithm based on clustering analysis; the section III gives the overall framework of the robot and its hardware and software design; and finally the conclusion is given.
2. Target Recognition Based on Cluster Analysis

At present, there are many methods to identify the shape of a target, such as boundary feature method, Fourier shape descriptor method, geometric parameter method, shape invariant moment method, Finite Element Method (FEM) and so on. The traditional target boundary extraction methods use the shape feature to identify the target, so the boundary of the target needs to be extracted first, which belongs to the field of image segmentation. In general, the boundaries of the target and the background are intertwined. This can consume a lot of CPU time and affect the real-time performance of target recognition. This paper proposes a target recognition algorithm based on cluster analysis to identify the center position and shape of the workpiece. The algorithm eliminates the traditional boundary extraction algorithm and directly performs target recognition.

The robot vision recognition system designed in this paper is the target shape, color and distance recognition, so as to complete the robot's recognition and tracking for the shape and color of target. The target identification process is shown in Fig. 1.

The target in this design is a blue ball. According to the characteristics of the target, there are two tasks to be performed: one is to determine the color is blue, and another is to determine the shape as a sphere.

We can divide the entire area of the captured image into 16 sub-blocks, each of which presets a motion path for the robot. We first use "cluster analysis" to detect the initial target. Fig. 2(a) is the first frame of the collected image containing the blue ball. According to the collected RGB original image, it can be determined which pixel belongs to the blue based on the pixel value feature. Therefore, for the pixels of the same color, cluster can perform as formula (1):

\[ z = \frac{1}{N} \sum x_i \]  

Where \( z \) is the cluster center, \( x_i \) is the sample, and \( N \) is the number of samples of the cluster. Then, the distances between the most peripheral pixels and the cluster center are calculated. If these distance errors are smaller than a certain threshold, the cluster may be determined to be a circle.

The actual distance between the ball and the robot must be calibrated during the training phase so that the distance between the robot and the ball can be calculated based on the calculated cluster radius.

According to the analysis of Fig. 2(a), the corresponding servo drive mechanism is adjusted to obtain the next sampled frame image, as shown in Fig. 2(b). It can be seen that the orientation of the robot has been calibrated at this time. According to formula (1), cluster analysis is performed to obtain the corresponding cluster center and cluster radius, and then the robot's travel path is adjusted. By analogy in turn, the target is tracked continuously. Fig. 2(c) is the third frame of the collected image.

![Figure 1. Identification based on cluster analysis](image1)

![Figure 2. Image frame containing blue balls](image2)
3. Robot System Design

3.1 System Hardware
In order to complete the target recognition and corresponding drive, the overall block diagram design of this robot system is shown in Figure 3:

![Figure 3. System structure](image)

The robot is mainly composed of mechanical claw gripping mechanism, drive control unit, Mecanum four-wheeled mobile platform, visual unit, sensor unit and robot control app. The robot can shift back and forth. With the mechanical arm of lifting mechanism, it can grasp and release the specified objects with different heights flexibly. At the same time, the robot has accurate positioning capability. Using a gyro sensor and a rotary encoder, a rotational error less than 1 degree and a horizontal movement error less than 1 cm are achieved through the PID control algorithm. The functions of main module are as follows:

3.1.1 Drive control unit: Drive control unit of the robot system consists of two EXPANSION HUBs provided by REV Robotics – a company. EXPANSION HUB is powered by 12Vdc power supply. Two EXPANSION HUBs exchange control data with each other through RS485, and communicate with Xiaomi 4 on the robot side via Mini USB. Each EXPANSION HUB supports 4 motor control interfaces, 4 rotary encoder input interfaces, 6 servo control interfaces, 8 digital input interfaces and 4 IIC bus interfaces.

3.1.2 Mecanum four-wheeled mobile platform: The robot mobile platform adopts four Mecanum wheels. All four wheels are driving wheels and driven by AndyMark's 12V dc motor (NeveRest 40). The maximum RPM is 160 RPM. The motor comes with a rotary encoder for simple closed-loop control.

3.1.3 Mechanical claw grasping mechanism: The robot's grasping mechanism consists of lifting slide rail, lifting plate, lifting arm seat, mechanical claw and upper and lower limit switch. The lifting mechanism is driven by 12V dc motor (NeveRest 60) with maximum speed of 110 RPM. The motor controls uplift and fall of the grasping mechanism by rotating forward and backward, respectively. The mechanical claw is driven by two CYS-BLS9825 servos made by Supersonic, which includes helical gears with a maximum torque of 15kg·cm. and owns the advantages of overcurrent protection and long service life. The upper and lower limit switches are used to limit the extreme position of lifting and falling.

3.1.4 Visual unit: The robot's visual acquisition is obtained through the camera of the Xiaomi 4 mobile phone, which is used to monitor robot handling and identify moving target. The mobile phone placement platform can rotate 180 degrees left and right, and 60 degrees up and down, using motors and servos, respectively. The mobile platform is mounted on the robot frame structure above the lifting slide, which can provide the stereo image and close-up image of the environment and moving objects.
3.1.5 Sensor unit: The rotating center of the robot is equipped with a gyroscope sensor, which is used to precisely control the robot's rotation angular displacement, so that the lifting plate and mechanical claw of the robot can be used for the designated transport.

3.2 System Software

The system software includes the remote App running on the remote mobile phone and the robot control App running on the robot side phone. Both of these apps are programmed with Java and are compiled and debugged in Android Studio 3.01 development environment.

3.2.1 Target recognition training calibration procedure: The target recognition training calibration procedure can automatically establish a quantitative array of the actual distance between the ball and the robot and the cluster radius of the recognized ball. The program controls the mobile phone camera of the robot platform to collect the target image. The main method is to control the mobile platform rotation through accessed image area containing recognized target to locate recognized target at the center of the image area (Figure 4), calculate the radius of the cluster and the actual distance between the robot and the ball at this time, and record the result in the corresponding global array variable as the basis for automatic program execution. The actual distance between the robot and ball can be achieved by factors of robots and the initial position of ball, the rotary encoder values from the drive motors of robots Mecanum wheels and Mecanum wheel radius. In the execution of the identification training, the initial position of the robot and the ball is determined as 5m according to site conditions, and a set of calibration data is determined every 0.2m. The flow chart of calibration program for the target identification training is shown in Figure 5.

Figure 4. Target in the center of the image area.

Figure 5. Flow chart of calibration program
3.2.2 Automatic operation program: The robot can complete scheduled action automatically according to the program set in figure 6.

3.2.3 Manual procedure: The current popular augmented reality platform Vuforia 7 is directly used when considering the camera monitoring function in the process of manual programming. Manual control of robot movement can be realized when necessary.

![Flow chart of automatic mode](image-url)

**Figure 6.** Flow chart of automatic mode
3.2.4 Universal driver: Universal driver includes hardware initialization modules and Mecanum wheel control modules. When performing manual program, the operator sets platform forward (backward) speed, to the right (left) speed, rotating angular velocity through game handle, calculates driver voltage of the dc motor used in the four-wheel driving platform by calling the universal driven Mecanum wheel algorithm, and controls the corresponding motor angular velocity by voltage, as shown in Figure 7.

3.2.5 Robot control App: The robot side mobile phone establishes wireless communication with remote control phone through Wifi Direct connection. The robot control App mainly supports the following functions: receiving the command from the remote control mobile phone, sending the robot system running status and monitoring video data to the remote control mobile phone.

Remote App obtains robot system running status information, gives instructions to the robot to perform manual program, automatic program or target recognition training calibration procedure, sends game handle code and acquires mobile phone camera surveillance video data on the robot side.

Figure 8 shows the completed robot system. After testing, the robot is working properly to achieve the desired goal.

```plaintext
fl_value = (forward + clockwise + right); //left front wheel
fr_value = (forward - clockwise - right); //right front wheel
rl_value = (forward + clockwise - right); //left rear wheel
rr_value = (forward - clockwise + right); //right rear wheel
max_value = getMaxValue(fl_value, fr_value, rl_value, rr_value);
if (max_value > 3.0) {
    fl_value = fl_value / max_value;
    fr_value = fr_value / max_value;
    rl_value = rl_value / max_value;
    rr_value = rr_value / max_value;
}
```

Figure 7. Output voltage of each drive motor

Figure 8. Outline of robot system

Conclusion

With the continuous increase of labor costs in modern society, there are more and more replacement of people with robots to reduce costs and increase production efficiency. The recognition-based robot proposed in this paper can achieve the specified path planning and object moving. Future work can consider more complex target recognition algorithms to achieve more complex applications such as fruit picking and qualified product classification, so as to truly realize the replacement from human to machine to complete general repetitive tasks, thus allowing more people to engage in creative work.

References

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