Research on Embedded Navigation System of Agricultural Robot Based on ARM

XiaoJian Wang, Xujie Hou*, Wenhuan Niu, Shaoyan Jiang

(College of Mechanical and Electrical Engineering of Weifang Vocational College, Shandong Weifang 262737, China)

1016060817@qq.com, 2016230091@sdwfvc.cn

Abstract: This paper takes agricultural robot as the research object, combines machine vision and embedded technology, proposes an embedded agricultural robot image processing and path navigation algorithm based on machine vision, and successfully transplants the image processing and path navigation algorithm to the embedded environment based on ARM9.

1. Introduction
With the continuous development and improvement of the computer industry, modern agricultural equipment is developing in the direction of automation, information and artificial intelligence[1]. The mobility of robot means that the robot can complete the task independently without human intervention, which can not only save the cost, ensure the personal safety of personnel, but also improve the efficiency of agricultural production and the quality of agricultural products. Therefore, it is of great significance to study the autonomous navigation system of agricultural robot[2].

2. Overall Design Scheme of the System
This article is selected in the agricultural greenhouse environment, the ARM9-based embedded control agricultural robot obtains external image information through its own camera module, and completes self-positioning, and processes the image information through the OpenCV function library to obtain complete path information so as to complete the path planning.

Implementation plan:(1) According to the analysis of the placement position of the CMOS camera module, its internal parameters are obtained, and the pose calculation of the agricultural robot is performed.(2) In the PC environment, the OpenCV vision library is used to simulate and verify the image processing algorithm to obtain the walking path of the robot.(3) The algorithm is transplanted to the embedded development environment.(4) Send the navigation control parameters to the main controller of the agricultural robot.(5) Conduct field tests on agricultural robots in a greenhouse environment, and collect relevant information.

3. System Hardware Design
The whole system is composed of image acquisition module, decision control module, driving module and so on.

3.1. Image Acquisition Module
The image acquisition module is mainly used to obtain information about the environment around the robot and perform pre-processing of the image[3]. After screening, the image acquisition module selects
the OV7740 camera, as shown in Figure 1.

![CMOS OV7740 Camera](image1)

**Fig. 1 CMOS OV7740 Camera**

The camera module converts the collected image information into digital signals and saves them in the SDRAM of the development board, and performs certain image preprocessing, so that the decision-making control module can perform further image processing on the image.

3.2. **Decision Control Module**

The decision control module is mainly responsible for robot image data processing, running path trajectory planning, decision calculation, and sending control commands to the servo motor. It is the core part of the whole system, which directly affects the robot's work efficiency and performance. This module selects the JZ2440 development board, as shown in Figure 2. The development board is equipped with Samsung's S3C2440 processor, the core is 920T, and some general-purpose peripheral electronic devices are expanded. The camera module interface is used to connect the CMOS camera module. The Ethernet interface connects the development board and the virtual machine Linux system through the network cable, which is used for data exchange between them. The COM interface of USB to serial port is through micro_ USB connects embedded development board and PC for data communication. The PC uses the OPENJTAG/JLINK tool to download and debug the system and applications through the USB DEVICE interface of the ARM chip on the development board. The front of the development board is equipped with a 4.3-inch LCD screen and a JTAG interface for programming U-BOOT and debugging.

![JZ2440 development board](image2)

**Fig. 2 JZ2440 development board**

3.3. **Drive Module**

The drive module mainly converts the image-processed data into the voltage and current required by the actuator to move and completes the movement control of the robot by the development board. The servo motor of the robot receives the relevant control commands from the control module, and adjusts the magnitude and direction of the current to the motor according to the periodic different control signals of PWM output, so as to control the speed and direction of the robot.

4. **Software Design**

Before transplanting the software platform, we need to verify the image processing algorithm and path planning on the computer and choose OpenCV to meet the cross-platform use. OpenCV has a wealth of related functions applied to computer vision and image analysis and processing, which ensures its wide
application. The main OpenCV libraries used in this paper are / core, / calib3d, / HuiGUI, / features2d, / impro, etc.

The specific structure of OpenCV is shown in Figure 3.

Fig.3 OpenCV structure diagram

5. Vision System Three-Dimensional Space Planning

5.1. Camera calibration model
This experiment uses standard floor tiles (0.5m × 0.5m) to carry out related experiments. Figure 4 is the schematic diagram of camera module calibration. The camera module is placed at Oc, from which we can see the position of camera coordinate system relative to the world coordinate system.

In order to obtain the internal parameters of the camera module, we carried out the following experiments.

(1) Establish the world coordinate system. The origin of the world coordinate system Ow is the position where the front-end camera module of the agricultural robot contacts the ground vertically. The forward direction of the robot is the positive direction of Y_w, and the positive direction of Z_w is vertical upward, passing through the lens of the camera module. The X_w axis is perpendicular to the O_wX_wY_w plane and points to the right side of the agricultural robot.

(2) Establish the camera coordinate system. Take the center of the camera module lens as the coordinate origin, the optical axis of the camera as the Z_c axis, Y_c is the direction in which the camera module is installed and perpendicular to the plane of the development board display, and points to the development board, and the X_c axis is perpendicular to the Y_w, O_wZ_wplane and is in line with the world coordinates The Xw of the system points in the same direction.

(3) Measure the height of the camera module from the ground h = h3, the measured height of the camera module from the ground is about 0.8m, and the angle between the camera module and Z_w is 0= 135°.

(4) Select 9 fixed points on the ground as reference points and adjust the camera module to make it possible to clearly see the reference points on the ground. Acquire images, and at the same time reduce or eliminate the influence of distortion generated in the process of image acquisition through the correlation function in OpenCV and read the pixel coordinates of the reference point in the image. The
position coordinates of the reference point in the world coordinate system are obtained by measurement.

---

6. Overall system implementation

The specific implementation steps of the application are as follows:

1. Start the camera module, the device file of the camera module in the system is /dev/video0, by using `fd = open("/dev/video0", O_RDWR)`, open the device in a readable and writable mode, where `fd` is the return after opening the device. The file descriptor of the file descriptor is readable and writable. At the same time, make an error judgment and return an error if the camera device cannot be opened.

2. Obtain the relevant information in the structure `struct video_capability` of the camera module through the `ioctl(fd, VIDEOCGCAP, &capability)` function, which can be output through the `printf` function. Read the relevant information in the `video_picture` structure of the camera through `ioctl(fd, VIDEOCGPICT, &picture)` to obtain image information, including the length, height, number of pixels, etc.

3. Initialize the relevant equipment and map a memory through the `mmap` function to store the image information collected by the camera module. After obtaining the image information, perform corresponding processing on the image to obtain the path information and perform obstacle avoidance at the same time.[5]

After the application program is transplanted to the JZ2440 development board, select the sample image, and after image processing, the application program will output the image information collected by the camera and the planned path information to the display screen, and view the image processing result. The result is shown in Figure 7.

During the experiment, the experiment was carried out at different speeds (0.5m/s, 1m/s), from the camera module to obtain the external information to the image processing to finally obtain the navigation path information, when the speed is 0.5m/s, the robot processes the image. The time consumed is 157ms, and when the speed is 1m/s, the time consumed by the robot is 189ms. In order to determine the accuracy of the data, three repeated tests were carried out at each speed, and the group with the largest and smallest deviations between the actual displacement path and the navigation path of the robot was selected at this speed and compared. The test tracking results are as follows:
5

(a) The speed is 0.5m/s

(b) The speed is 1m/s

Fig. 8 Displacement deviation chart

When the speed is 0.5m/s, the actual displacement offset trend is close to the predicted displacement trend, and the difference between the maximum actual displacement offset and the minimum actual displacement offset is within 10cm, the lateral displacement deviation is 10cm and 7cm, and the average displacement deviations are 3.5cm and 2.27cm. The robot has less fluctuation during the movement. When the speed is 1m/s, the actual displacement deviation trend and the predicted displacement deviation trend are quite different, and the fluctuation of the actual displacement deviation and the predicted displacement deviation are both large, the maximum actual displacement deviation and the minimum actual displacement deviation The difference between the offset and the predicted displacement is between 10cm and 20cm, the lateral displacement deviation is 17cm, 11cm, and the average displacement deviation is 5.89cm, 4.64cm, so when the running speed is 1m/s, the position of the robot during movement The offset fluctuates greatly. Since the camera placement angle and height cannot fully meet the ideal conditions, the error is inevitable. It can be considered that the navigation information obtained within the error range is effective. Compared with the speed of 1m/s, the robot deviates at 0.5m/s The amount and fluctuation are small, so the effect is better when the robot speed is 0.5m/s.

7. Conclusions
In this context, this article closely follows the development trend of machine vision-based robot automatic navigation and embedded technology, combines machine vision and embedded technology, and proposes an embedded agricultural robot image processing and path based on machine vision Navigation algorithm, and successfully transplanted image processing and route navigation algorithm to ARM9-based embedded environment.
References

[1] Xie Shouyong. Fuzzy control for navigation and obstacle avoidance of greenhouse robot [J]. Journal of agricultural machinery, 2002, 33 (2)

[2] Zhao Ying, Chen Bingqi. Straight line detection of farming robot walking target based on machine vision [J]. Journal of agricultural machinery, 2006.

[3] Li Shenghui, Zhou Jun, Ji Changying, et al. Obstacle detection of intelligent agricultural vehicles based on panoramic vision [J]. Journal of agricultural machinery, 2013, 44 (12): 239.

[4] Ma Hongxia, Ma Mingjian, Ma Naetal. Baseline recognition based on Hough transform in the vision navigation of agricultural vehicles[J]. Journal of Agricultural Mechanization Research, 2013, 35(4): 37–43.

[5] PANDA R K, CHOUDHURY B B. An effective path planning of mobile robot using genetic algorithm[J]. IEEE International Conference on Computational Intelligence & Communication Technology, 2015, 145(15) : 287-291.