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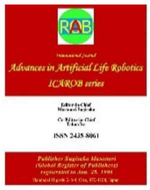

Research Article

Design of An Embedded Humanoid Soccer Robot based on Image Processing

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ABSTRACT

As a humanoid robot, the humanoid soccer robot integrates artificial intelligence with competitive sports skillfully. It is an intelligent control system which integrates mechanical structure, computer, circuit design, automatic control, decision-making, communication, and other technologies. In recent years, it is a very good research platform in the field of artificial intelligence and robots. This paper designs a humanoid soccer robot based on STM32 processor, and completes the theoretical analysis and experimental verification, the specific work is as follows:Through theoretical analysis and experimental verification, the stability, working parameters and the division and cooperation of STM32 and 51 series single-chip computers of humanoid soccer robot system are analyzed, and determine the final control scheme. STM32 drives the camera to collect information, process images and make decisions. STC12C5A60S2 controls the robot steering gear to complete the corresponding action. Serial communication is used between the two controllers. The peripheral circuit mainly includes OV7725 camera module and TFT-LCD LCD display module. In order to recognize and approach soccer by humanoid soccer robot and kick soccer into the goal, we should design the action programs such as straight walking, left turning, right turning, head scanning course, left translating, right translating and kicking. Reasonable images processing and decision algorithms are also designed. Finally, the control program is developed on Keil software platform for debugging. The experimental results show that the humanoid soccer robot designed in this paper can accurately identify the soccer ball and the goal, and accurately complete the kicking actions, which meets the relevant requirements of the expected design and scheme.

1. Introduction

As a research product of artificial intelligence in the field of robotics, humanoid robots are the frontier and hotspot in the field of robotics. As a member of the humanoid robot family, soccer robot is a dynamic experimental platform with high degree of confrontation. Humanoid robots can imitate human thinking mode to perceive the characteristics of the external environment and make judgments and make corresponding actions to complete a task [1]. The performance requirements of the humanoid soccer robot are very high. The humanoid soccer robot not only has the ability to walk, but also has the ability to play difficult actions such as football. This not only requires the humanoid soccer robot's body to have good coordination and stability, but also requires the humanoid soccer robot to have visual function [2]. The robot uses image processing to quickly find the football, track it and shoot. The soccer robot designed in this paper is designed according to the human body shape. It has a head, two arms and two legs, and can stand on both feet and walk on both feet. Robots can perceive the external environment through sensors equivalent to human perception, and sensors must be installed in a position similar to human perception. At the same time, the robot can recognize the orange, white and green color target, and can track the object with regular shape and single color. According to the design requirements, the soccer robot must be able to complete the basic movements such as straight line, left turn, right turn, kicking the ball, and can correctly recognize the soccer, goalkeeper and goal through machine vision, and the distance between the robot and the ball is 0.5 meters.

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2. System scheme design

This design uses a dual-controller control scheme. The hardware mainly includes the humanoid soccer robot trunk, steering engine, controller, camera and display screen. STM32 is used as the main controller to collect and process images. STC12C5A60S2 is used as the slave processor to control the robot to complete the corresponding actions. STM32 and ST12C5A60S2 SCM use serial port to communicate. The flow chart of STM32 and STC12C5A60S2 is shown in Figure 1.

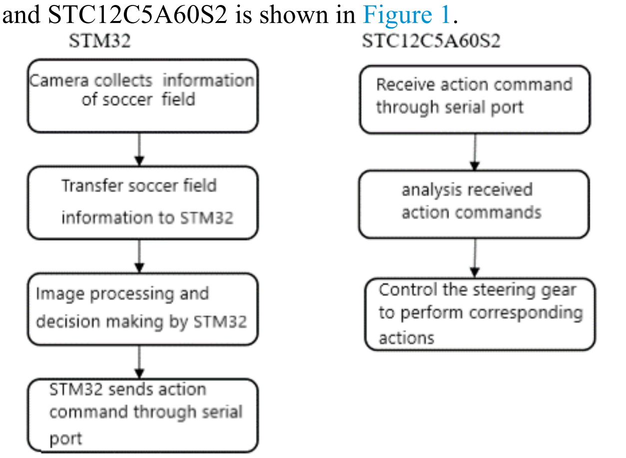

Fig.1. The flow chart of STM32 and STC12C5A60S2

3. Design of robot hardware system

3.1. *Robot structure design*

This design uses the SHR-8S humanoid robot of Beijing Senhan Technology Co., Ltd. According to the relevant requirements of hardware, the height of the robot is designed to be 360 mm, its shoulder width is 165 mm, its chest thickness is 115 mm, and its mass is 1.5 kg. It is composed of head, arm, hip, thigh, etc. It is a small humanoid robot. In this design, another steering gear is installed on the head, which combines the two degrees of freedom of the head itself, so that the information of the soccer field can be collected quickly. The position of 17 + 1 steering gear is 2 at the head, 2 at the left and right arms, 1 at the left and right shoulders, 1 at the left and right hip joints and 4 at the left and right legs respectively [3]. The design of the structure is shown in Figure 2.

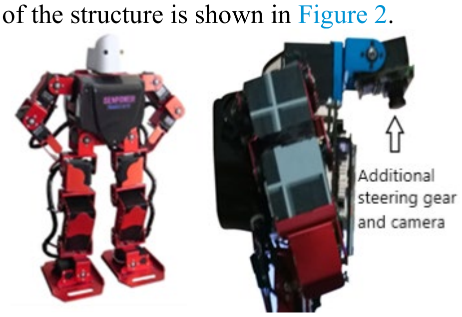

Fig.2. Robot picture

3.2. *Introduction of controllers and peripheral modules*

The main controller used in this design is STM32F103, 32-bit microcontroller, based on ARM Cortex-M3 core, LQFP-144 package. Compared with similar controllers, CPU can process data quickly and support multi-path execution of data instructions. The CPU operating voltage range is 2.0-3.6V. With external button battery, it can realize power-off data storage. This chip has very high performance, excellent real-time performance, reasonable and rich peripherals, low power consumption, low price, rich software support package [4], rich and comprehensive technical information, easy to develop, which is very suitable for this design.

The slave controller selected in this design is the control board with STC12C5A60S2 single chip microcomputer as the core. Most of the components adopt the full surface mounting technology. The design of the control board is reasonable and powerful [5]. All the external interfaces of STC12C5A60S2 series single chip microcomputer are expanded for convenient use. It is shown in Figure 3.

Fig.3. STC12C5A60S2

The camera selected in this design is OV7725 camera, 300000 pixels, high frame rate, up to 120 frames per second [6], high-speed dynamic, can quickly capture position information, suitable for robot to capture the position of football. The data format of the output image supports YUV (422 / 420), yCbCr422 and RGB565. The output data format identified in this design is RGB format, which is convenient for feature extraction in the future [7]. The data collected by the camera is cached in the FIFO cache on the back of the camera, and then the external devices obtain the captured image data through the signal pin below by Figure 4.

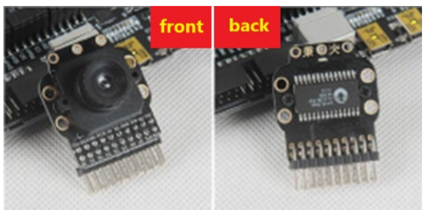

Fig.4. OV7725 camera

The display screen is used to display the image information captured by the camera in real time. It can determine the effective collection range of the camera for easy programming and debugging. The display screen is used as a calibration reference medium to determine the action that the robot will perform based on the football position displayed on the display screen, thus completing the task of tracking football and shooting. The display screen selected in this design is the 3.2-inch TFT LCD screen that is shown in Figure 5. This screen has the advantages of light weight, high reliability, low driving voltage and much less power consumption than CRT screen, which saves a lot of energy [8].

Fig.5. LCD screen

4. Analysis of football recognition and control program

4.1. *Soccer recognition*

RGB, YUV and HSV are commonly used color spaces for robots [9]. RGB is the physical primary color, Y is the brightness signal, U and V are the chroma signal, H is the hue, S is the saturation and V is the brightness, the conversion formula is as follows:

$$\begin{cases} Y = 0.299R + 0.587G + 0.114B \\ U = -0.147R - 0.289G + 0.436B \\ V = 0.615R - 0.515G - 0.1B \end{cases} \tag{1}$$

$$\mathrm{V} = \max(\mathrm{R}, \mathrm{G}, \mathrm{B}) \tag{2}$$

$$\mathrm{S} = \begin{cases} \dfrac{V - \min(R, G, B)}{V} \; if\ V \neq 0 \\ 0\ if\ V = 0 \end{cases} \tag{3}$$

$$\mathrm{H} = \begin{cases} \frac{60(G-B)}{S} \quad if\ V = R \\ 120 + \frac{60(B-R)}{S}\ if\ V = G \\ 240 + \frac{60(R-G)}{S}\ if\ V = B \end{cases} \tag{4}$$

RGB model is seldom used in artificial intelligence because it is easy to be affected by the light. However, the conversion from RGB space model to YUV and HSV model involves a lot of calculation, which will be a great burden on the controller of soccer robot and seriously affect the real-time performance of robot. For the robot recognition, there are only three colors: green, orange and white. The color is less and the shape of the recognition object is regular. In RGB color space, the recognition effect is not greatly interfered by experiments under different light intensity. Considering the relatively simple calculation of RGB model, the RGB color space is selected in the design.

The image collected by the camera is an RGB color image, which can be recognized from the image by STM32 image binarization method, and then the subsequent decision-making tasks can be completed. Through repeated experiments under different light conditions, the threshold value of image segmentation is determined, and then the image is segmented into background and target, achieving good experimental results. The comparison before and after processing is shown in Figure 6.

Fig.6. Original graph and binary partition graph

4.2. *The design of robot decision*

In this design, LCD screen is used to display the image after binary image processing, and LCD screen is used as calibration reference, that is to say, it can display 24 lines and 240 columns of pixels in the middle part collected by the camera. According to the position of the target displayed on the LCD screen to determine the next action to be performed by the soccer robot, Figure 7 is a schematic diagram of the LCD screen area with 24 lines and 240 columns of pixels, and the number at the bottom of the figure is the number of columns of pixel points.

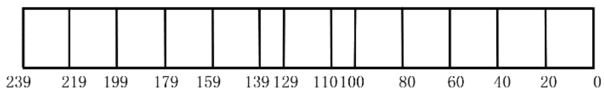

Fig.7. Schematic diagram of the LCD screen

In the process of approaching a soccer, in a line of pixels: if the pixels on each column marked with a number are white, that is, the robot does not see the soccer, the robot heads up; if the pixels on each column marked with a number are black, the robot sees the soccer, and the soccer is in front of the robot, the robot lowers its head and goes straight for one step; if the pixels in the 129 and 110 columns are all Black, no matter whether the other columns are black or white, it is considered that the soccer is in front of the robot, and the robot lowers its head and goes straight for one step; if only the pixels in column 0 are black or the pixels in column 0 and column 20 are black, and the soccer is on the left side of the robot, the robot turns left; if only the pixels in column 239 are black or the pixels in column 239 and column 219 are black, and the soccer is on the right side of the robot, the robot turns right.

From approaching football decision-making program to shooting decision-making program: the robot camera rotates upward along the x-axis from the initial position until the football is detected, and the rotation angle is set as α. As shown in Figure 8, when α ≥ 2.22 °, the approaching football decision-making program is executed; when α < 2.22 °, the foot ball has reached the foot of the robot, and the shooting decision-making program is executed as shown in Figure 8.

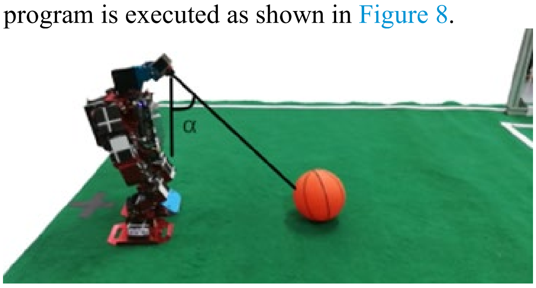

Fig.8. Definition of α

In the process of shooting, as the goalkeeper robot usually stands in the middle of the goal, the design of this robot shoots left or right instead of in the middle to avoid the goalkeeper robot. The robot heads up and turns left to detect the left edge of the goal line, as shown in Figure 9. When more than nine columns of pixels marked with numbers on the LCD screen are black, it is considered that there is no goalkeeper in front of the left edge of the goal line. The robot shoots at the left edge, otherwise it shoots at the right edge of the goal line.

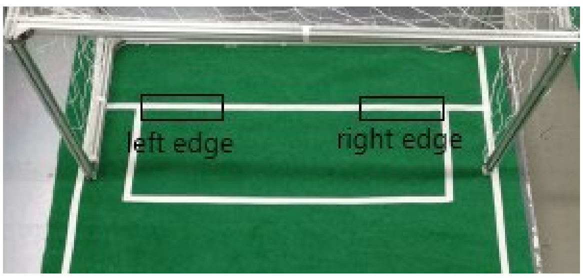

Fig.9. Goal edge

5. Conclusion and future work

Based on STM32F103 single chip microcomputer, this paper studies the humanoid soccer robot system, designs a threshold binary image processing algorithm and soccer tracking and shooting program, and applies the algorithm and program to build the hardware system of humanoid soccer robot, which can recognize and track the objects with single color and regular shape. And completed the football tracking and shooting tasks well. The whole system hardware is simple and clear, and the software efficiency is high and the logic is strong.

Although the design meets the design requirements, due to the limited level of the author and the limitation of research time and test conditions, the following improvements are needed for the design and research of humanoid soccer robot:

The height of the soccer robot must be increased, and the shooting speed must be accelerated to meet the requirements of the next stage of the game, that is, to complete the air ball shooting, so the driving source of each joint must have greater torque, and the robot system must make some improvements in the control of the steering gear with large torque. At present, soccer robots do not perform well in shooting angle control. The solution is to add gyroscope to the robot body, which makes the robot control system add gyroscope interface. This design only completes the design requirements in the simple competition environment, but also needs to study the soccer recognition, tracking, shooting and other issues in the more complex environment.

References

1. Nagatani K, Kiribayashi S, Okada Y, et al., Emergency response to the nuclear accident at the Fukushima Daiichi Nuclear Power Plants using mobile rescue[J]. *Journal of Field Robotics*, 2013, 30(1), pp 44-63.
2. Haipeng Li, *Research on vision of humanoid soccor robot based on arm*[D]. Hebei: Yanshan University, 2013.
3. Ke Liu, *Research and implementation of target recognition algorithm and action planning in humanoid robot* [D]. Hebei: Yanshan University, 2011, pp. 7-8.
4. Tian Deyong, PWM experiment teaching based on STM32 timer *[J]. Electronic technology and software engineering*, 2019 (20), pp. 102-103.
5. Yuan Yongchao, Deng jiongfeng. Research on automobile anti-theft device based on STC12C5A60S2 *[J]. Computer products and circulation,* 2019 (07),178.
6. Zhimin Ren, Design of an image real-time display system based on OV7725 *[J]. Fujian computer*, 2013, 29 (01), pp. 128-130.
7. Caixia Zhao, *Research on target dynamic tracking based on STM32 mobile robot* [D]. Inner Mongolia: Inner Mongolia University, 2017.

8. Xiaoliang Chu, Analysis of TFT-LCD technology development trend *[J]. Electronic world*, 2018 (20), pp. 73-74.
9. Wenping Xi, Jian Zhang, Design of vision recognition system for humanoid soccer robot based ARM *[J]. Microcomputer and application*, 2015, 34 (09), pp. 51-53.

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