A Design of Embedded Plate & Ball Control System Based on Machine Vision

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Abstract

The control system is an experimental device to track the position of the target object and control the trajectory of the sphere by the actuator-rudder-driven platform motion. The research content of this design includes image processing, machine vision, motion control and many other fields. In this paper, the mechanical structure of the plate&ball control system and the printed circuit board of the main controller are designed, and the PID-based control algorithm is designed on the basis of the ball control ability analysis and the real-time detection analysis of machine vision. On the hardware platform with good self-designed performance, the precise sphere coordinates are obtained by the Hough circle detection algorithm, and then the position and speed of the sphere are controlled by the PID controller.

Keywords: Embedded, Plate&Ball control, Hough circle detection, PID control

1. Introduction

Today, with the rapid development of science and technology, humans use tools to distinguish themselves from animals, and the use of machines exceeds the limits of the body. The automation technology that combines control theory, machine vision, and mechanics has become the mainstream of today's industrial development, freeing humans from tedious and repetitive tasks. Therefore, the cricket ball control system which contains the machine vision detection and control algorithm is an important experimental platform. In recent years, Zhou Shudao proposed the design and implementation of bivariate cascade PID cricket control system.[1] Han Guangxin proposed the design of auto disturbance rejection controller of cricket system based on backstepping method.[2]Xu Yunji proposed the cricket visual control system based on double loop PID algorithm and Otsu method.[3]

2. Design of the System

2.1. *The composition of the system*

The system composition is shown in Fig.1 and Fig.2. The plate center mounted on the top of the central universal joint which is mounted on the pedestal through central knighthead. The plate can be swung up and down on the center of the central universal joint. The motor is mounted on the pedestal and the upper and lower tilts of the flat x-axis and y-axis are carried out by the corotation and reverse of the steering engine. The camera is mounted directly above the plate to detect the position and speed of the ball and as feedback for the control system, changing the steering engine angle to control the ball's speed of motion. By regulating the angle of the steering engine, we make full use of the rotation of the plate, control the movement trajectory of the ball through the rotation angle of the plate, and achieve the goal of moving the ball according to the predetermined orbit.

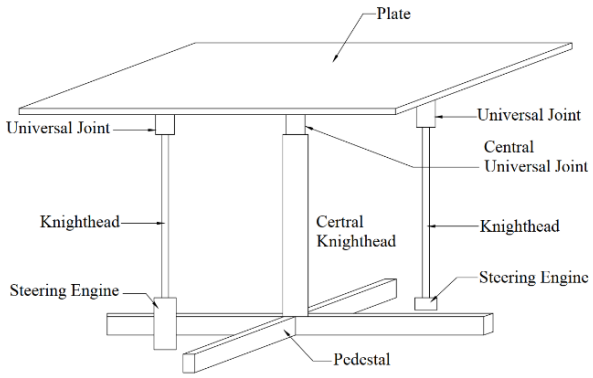

Fig. 1. A diagram of the mechanical structure

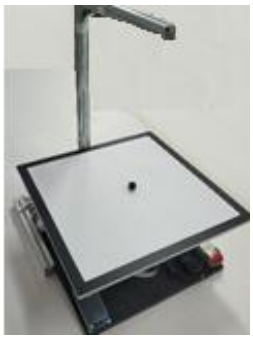

Fig. 2 Physical image

2.2. *Design ideas*

The image information of the current plate is obtained by the camera, and the center point of the plate is calculated after the boundary point is calculated[4]. The Descartes coordinate system is constructed from the center point of the plate as the reference coordinate system to identify the small ball coordinates, and the coordinates of the center of the circle are obtained by the Hough circle detection program[5]. The coordinates of the set target point are compared with the coordinates of the center of the circle to find out the error, and the error is inputted the controller as the variable. By the controller to find the variable, the steering engine drive the plate to move, so that the ball smoothly parked on the target point of the plate, or to perform some set stunts, such as rolling tracking or obstacle movement[6].

The main goal of this paper is to design an embedded plate&ball control system based on machine vision, to capture images by means of a camera, to obtain the position of the ball phase on the plate through image processing application, and to use the PID algorithm to control the ball at a fixed point.

The design covered the following areas:

- The design of machine vision-based embedded plate&ball device debugging platform. The microcontroller MK60DN512 is the main board, on-board OLED, Bluetooth, rotary encoder, steering engine and voltage module. Manipulating the angle of the rotary plate of the two-way steering engine makes it easy to manipulate the ball's movement posture.
- The image processing technology to process of the collected picture including grayscale processing, graphic sharpening, filtering, the Harris corner point detection to obtain the boundaries of the plate, the corner point after the connection of the graphics binary. To expand the form search and approach to obtain the boundary data of the plate, relying on the Hough circle measurement technology to obtain the location data of the ball.
- Design the HMI of the plate&ball control system, observe the position of the ball, as well as the effect of PID manipulation, show the difficult factors of the control system and the directly affected factors. At the same time, the parameter graphical interface of PID parameters is designed, as well as the setting of the position of the ball. In order to infer the direct effect of different PID coefficients on the stability of the system.

3. The Design of the System's Hardware

The MK60DN512 chip used on the embedded control board is a high-performance ARM produced by NXP with a 32-bit Cortex-M4 core that is highly resistant to interference and reliability. Internally integrated hardware multiplier, fast operation, fast DMA transmission, kernel can overclock to 200MHz, bus frequency up to 100MHz. Power consumption is no more than 50mA. As shown in the fig.3,the chip has 144 pins, and memory space is expandable, from 32 KB flash/8 KB RAM to 1 MB flash/128 KB RAM, with an optional 16 KB cache to optimize bus bandwidth and flash execution performance.

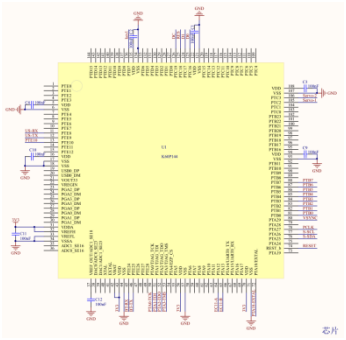

Fig. 3 MK60 diagram

It is mainly used in the high efficiency of requests and high precision control level. The MK60DN512's processing core function is strong, efficient and easy to develop, which not only ensures the stability, efficiency and availability of the microprocessor cricket control system design based on machine vision, but also streamlines the design difficulty of the control system, which greatly advances the research progress of this design.

The Joint Detection Behavior Organization JTAG port is customized on the MK60 kernel structure, and the application download and simulation mechanism can be done through the JTAG port. The K60's clock circuit consists of two parts, one of which is the main crystal of the chip, designed to emit the working clock necessary for the chip and peripherals. The rest is the clock circuit of the instant clock RTC, which supplies a set of counters that measure time during power-up and sleep configurations on the system, and the RTC real-time clock consumes very little energy. The main crystal of the plate&ball control system board uses an active crystal of 50MHz. Some microcontrollers contain clocks inside, in the case of system requirements are not high the core clock of the microcontroller can be used, and it is not necessary to design an external clock circuit.

The hardware system also includes on-board camera, Bluetooth, 0.96-inch OLED display, 3.5-inch touch screen, encoder, steering engine of external drive plate and many other external equipment. With OV-7725 camera module up to 150 frames per second, the noise removal capability is powerful and the signal-to-noise ratio is high. Built-in hardware two-value module, image processing effect is perfect. High sensitivity under weak ambient light and stable image. Compared with similar OV series cameras (300,000 resolution) such as OV-7670, OV-6620, it is the best image quality. In the commissioning of the cricket control system needs to issue a strategy or select different parameters, the user and the cricket control system need to exchange information with each other. The 3.5-inch touchscreen, made by supplier Tao Jingchi, was designed as a human-computer interface (HMI, Human-Machine-Interface). The screen resolution is 480 x 320 and the wide operating voltage can operate between 4.75-7V. The screen has a built-in master chip, and 16M FLASH and 3584Byte RAM storage. The interface to interact with the user can be designed in advance on the upper terminal, the screen can be connected via the serial port (USART-232 module) protocol, and the preset instructions can be sent to switch pages or modify data properties. The in-line Bluetooth module HC-05 can be connected to a Personal Computer with Bluetooth or various mobile smart devices, enabling the connection of the parameter debugging process to be converted to a wireless connection. In order to achieve the optimal control effect using a digital rudder, the selection of Le Magic Sol's 20KG large torque digital rudder, product weight 65g. It takes only 0.16 seconds to complete a 60-degree rotation at a 7.4V rated voltage, with an operating voltage of 6-7.4V. The empty load current is 100ma. The platform angle can be adjusted quickly and precisely in the cricket control system.

4. The Design of The System’s Software

4.1 *Real-time detection of the machine vision*

After collecting the overall environmental map of the cricket control platform system, a color graphic (RGB format) is collected. The RGB format is more practical in machine vision algorithms, and the image is made up of many pixels2. For example: the resolution is 800 x 600 images each pixel has three channels, red, green and blue each color depth of 8 bits, in the data structure is an 800 x 600 two-dimensional matrix, each point in the matrix contains (255,255,255) three channels of information, a huge amount of data. In order to reduce the amount of computation will first grayen the image processing, based on the visual effects of the human eye and proposed weighted average algorithm, because the human eye is different sensitivity to red, green, blue, so it is given different weights to make it more in line with the visual senses. In terms of human visual senses, the weights of selecting three colors are generally red 0.3, green 0.59, and blue 0.11. Grayscale parameters is :

$$Gray=0.30*R+0.59*G+0.11*B \quad (1)$$

To identify the size of the platform board of the control system, to obtain boundary information, it is necessary to filter the corresponding features, and the common features of machine visual image processing are round, edge and corner points. In this design, a rectangle with four sides and an equal length is used as a motion platform to drive the sphere movement on the board. Because of the use of rectangles as the driving plate shape of the control platform, the most obvious feature of the matrix is the four corners, only need to be detected corners. Corners are considered to be the intersection of two lines in everyday concepts, and rectangles are characterized by four corners. Broadly speaking, however, corners are image points with specific characteristics. Machine vision algorithm can obtain these characteristics in the image with pixels as the coordinate points, with digital image processing features. A pixel change in any one direction causes a grayscale value to produce a jump, which can be considered a corner point. Platform corner points are mainly 90 degrees of the intersection of two lines, so the detection accuracy is high using the Harris algorithm when detecting points of right angle classes.

Object tracking has always been one of the first technologies in the field of machine vision research in the process of scientific and technological development, and the most important thing in the development of tracking program is the accuracy and synchronization of object tracking. These two characteristics are important for filtering algorithms, the most frequently used of which is the Cam-Shift algorithm3, which has a relatively small amount of computation and is therefore fast to process. Targets can be tracked when the background environment is not very complex, such as when tracking a moving object indoors, with the help of graphic color changes.

The Cam-Shift algorithm optimizes the tracking of the target object in the case of uneven lighting to some extent, and uses the size distribution information of matrix values to track in the image matrix. In essence, the algorithm makes the optimal judgment of local processing of the results of the mean drift algorithm for each frame, and automatically adjusts the size of the retrieval core (kernel) to achieve the positioning of the tracking object.

Random Hough circle detection algorithm is a method to find straight lines, circles and other simple shapes in the image. The basic idea is to turn the problem of curve or straight line detection in the original image into the problem of peaking in parameter space. Because the circle contains 3 free parameters, it is necessary to vote for peaks in 3D space, which is large in computation and large in memory consumption, and the algorithm has a long operation time. Therefore, XU et al. proposed (Randomized Hough Transform, RHT) random Hough transformation, using three new operating mechanisms, namely, random sampling in image space, dynamic link list in parameter space, and convergence mapping connecting image space and parameter space, thus speeding up the operation speed and improving memory utilization. However, random sampling introduces a large number of invalid accumulation and invalid sampling, which has a great influence on algorithm recognition performance when dealing with complex backgrounds and larger images. Therefore, some scholars have proposed an improved RHT algorithm5, but it is undeniable that when dealing with the background is simple, especially the recognition of small images, the random Hough transformation operation is very fast and the recognition accuracy is high.

Algorithms that rely only on color to track models have some defects, and it is difficult to obtain accurate location information when the target object is subjected to uneven lighting. In order to solve this problem, a random Hough circle transformation is introduced, and Hough circle detection has high precision and fast speed for circular target recognition. The real-time positioning and tracking of moving spheres on the control plate is realized by combining Cam-Shift and Hough circle transformation.

4.2 *Ball control strategy*

In complex plate&ball control systems, PIDs can be used as feedback controllers when system characteristics cannot be fully analyzed. The response speed of the plate&ball control system is in line with the control requirements by adjusting the scale band, integral coefficient and differential terms.[7] This strategy is an effective control strategy, through different PID values, the sphere position can be closed-loop control. The closed-loop control involved in the PID controller is to give feedback on the input amount, which is a quantity of controlled variables that can directly affect the system, and feedback generally refers to the variable that can visually represent the state of the accused object.

PID control is actually the comprehensive effect of the three controls, which is proportional control, integral control and differential control[8]. Corresponding to the current error, past cumulative error and future error.

Proportional control is one of the simplest control methods, the output of this controller is directly proportional to the error of input.

Integral control automatically changes the output when steady-state error occurs, so as to eliminate steady-state error. When there is an error in the system, the integration control, according to the size of the integration time, the output of the regulator will change at a certain speed, and constantly carry out the output.

The role of differential control: The function of differential control is to predict the future trend of error signal through the change rate of error. By providing forward control, differential control can stabilize the charge process. It is often used to offset unstable trends resulting from integral control.

In the designed control platform, the coordinates and sphere motion rate of the sphere in the Descartes coordinate system are controlled by PID-based string stage. The output of the small ball position PID controller is used as the setting value of the small ball speed PID controller, and the output of the small ball speed PID controller controls the actuator steering engine, thus having a better control effect on the position of the ball. The control block diagram is shown in Fig.4.

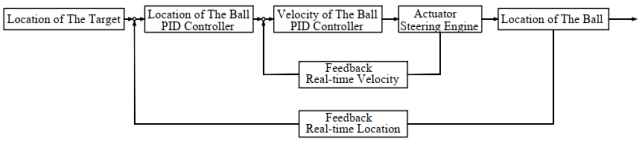

Fig. 4. Ball control string-level PID control chart

5. Conclusion

Plate&ball control system is a two-dimensional extension of the control of the inverted pendulum, the ball movement on the plate is not limited, only by the control plate movement to complete a specific track tracking. It is a comprehensive research topic for researchers who want to study automation and motion control in depth. Control feedback is tracked by Hough circle detection in the machine vision algorithm, and then the steering engine motion output is calculated. The controller continuously calculates errors to adjust the output in real time to complete the control of the position and speed of the sphere. The control platform of this design is a good combination of various disciplines. In the future engineering practice, the development of machine vision will greatly promote the popularization of intelligent systems, machine vision will be widely used in industry, agriculture and military.

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