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THE DESIGN OF TABLE TENNIS ROBOT COMBINED WITH DEEP LEARNING

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ABSTRACT

This paper analyses the equipment based on a table tennis opponent made by combining machine vision and embedded control of deep learning .It is mainly divided into two parts: hardware and software. The hardware part includes the sensor part, the power transmission part and the shape structure part; the software part includes the machine vision part and the embedded control algorithm part. Machine will be through the combination of sensor and machine vision monitoring to the position of the table tennis, and the machine will by monitoring the opponent posture can be used to predict the flight path of the ball, and then to forecast the movement trend, and the parameter data transmit to MCU, MCU will receive the data and compare the sensor received data integration, and then control mechanical arm swing to hit the ball.

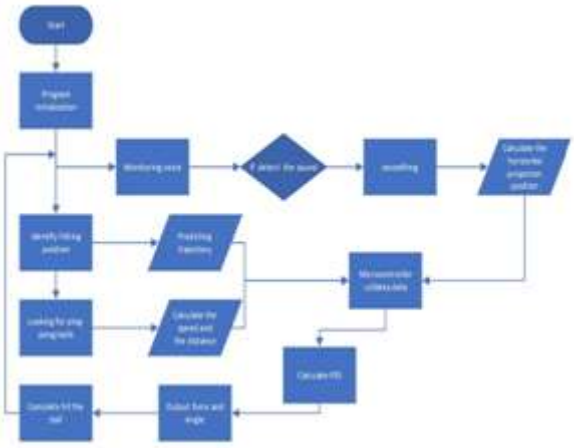
KEYWORDS: Deep learning; Single chip microcomputer; Serial port communication; Motion control.

1. INTRODUCTION

With the rapid development of modern technology and the extensive application of artificial intelligence, the exploration of more high-tech is getting deeper and deeper.Robot technology, with its high intelligence and broad application field, has become an important symbol of a country's high-tech level and industrial automation degree.[2] Innovation is the driving force of development, and innovation is the application of known knowledge and the exploration and challenge of unknown fields. Nowadays, machine vision is slowly coming into our lives. Every innovation in technology, from vehicle counting at the intersection to face identification at the bank, is a great challenge, so we decided to launch the challenge: try to combine machine vision and embedded to make a table tennis robot.

2. THEMONITORING AND TRAJECTORY PREDICTION OF BALL MOVEMENT

2.1 When playing table tennis, robots need to make accurate predictions about the trajectory of fast-moving ping-pong balls[3].Sensor selection and monitoring principle Table tennis will make a clear sound when colliding with the table. The speed of the sound is approximately equal to 340m/s. The length and width of the table close respectively to 3m and 1.5m .The diagonal length is about 3.4m and half of the width is 0.75m.So time is:



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It can be concluded that the time range of each sound transmission to the microphone is 2.2-9.9ms, and the I/O port of stm32f103 MCU can reach 18MHz. Therefore, the microphone can be placed at the midpoint of the four sides of the table to sense the landing point of the ball on the horizontal plane.Infrared proximity switch has high sensitivity, the characteristics of the induction range far, use two angled approach switch with the net parallel and level up to 45 degrees on both ends of the desktop can perceive ahead of a ball in the left or the right area roughly range do pretreatment, using machine vision can monitor to the ball in the approximate location of a vertical plane, and according to the size of the spheres can distinguish the ball near and far, predict roughly the distance.

2.2 Prediction of motion trajectory

Table tennis is mainly affected by three forces after a player makes a shot: gravity G. During the flight of the ping-pong ball, it is always affected by the gravity, and the direction of the gravity is vertically downward. The magnitude is:

G = mg

Air resistance F1, the diameter of the ping-pong ball is d, the rotational angular velocity is ω, the air viscosity coefficient is 17.8*10^-6, the air density is ρ, the forward translational velocity of the ping-pong ball is v, so the Reynolds number is:

R=ρvd/η

The resistance F1 is proportional to the square of the translational velocity, so the resistance is:

F1 = 0.5 * CA ^ 2 v

The magnus force F2 caused by the rotation of the ping-pong ball is a viscous effect, which is produced when the rotating object moves in the viscous fluid. The process of the motion of the ping-pong ball in the air can be approximately regarded as the motion process of a uniformly distributed rigid sphere in the fluid. Moreover, when the ping-pong ball rotates, the boundary layer around it will generate circulation. Under the combined action of the backflow and circulation in the front, the flow velocity will be accelerated when the incoming flow and circulation are in the same direction, and the flow velocity will be slowed down on the contrary. According to kowski's circulation theory, magnus force can be obtained as follows:

F2 = 8/3 * (πρωd^3v)

Priority acquisition when table tennis on the desktop to the voice of microphone will pass even by the I/O port trigger external interrupt of the single chip microcomputer, the inside of the external interrupt program will be a time lag of four microphones collection to determine the approximate location of a table tennis in the placement for the table, at the same time computer circulating the ball target monitoring and feedback, coupled with the force analysis of the ball, will constitute a proportion relation:(x,y,z)=k1(x1,y1,z1)+k2(x2,y2,z2)+k3(x3,y3,z3), where k1 is the coefficient corresponding to the parameters generated by the microphone, x1,y1,z1 is the spatial

position parameter generated by the microphone, and k2, k3 is the parameters obtained by the machine vision calculation and force analysis.

3. DESIGN OF SHAPE AND STRUCTURE

3.1 Selection and design of the manipulator

The core part of this work is the robot arm. The installation form and position of the robot arm not only affect the strength, stiffness and bearing capacity of the robot, but also directly affect the appearance of the robot.The robot arm is the part that supports the racket. In the design, not only the weight of the racket should be considered, but also the dynamic load and rotational inertia during the movement. In addition, in order to prevent excessive deformation during the movement, the robot arm adopts a relatively hard aluminum mechanical arm. Considering that the manipulator will rotate relatively along the axis of motion in the linear motion, a guiding device is set and a certain form of buffer measures are also adopted. The final decision is to adopt the aid coordinate structure: the arm is composed of a rotating pair and two moving pairs.Relatively speaking, the space is small and the working range is large.

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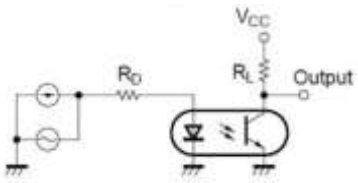
3.2 Layout and design of sensors

Sensors in the system ACTS as the eyes of the machine, so the choice of sensor and its important to grab the distinct characteristic of suit the remedy to the case of the object, and so we caught the characteristics of table tennis will fall on the surface of the table sound, use a microphone to collect small ball position very well, so we put four microphone to the halfway point of the four edges and external interrupt will be connected to the microcontroller I/O side, when the ball hit the table trigger collection procedures;As the table tennis ball will pass through the net, two proximity switches are used to parallel the net and the horizontal surface is 45 degrees to the left half or the right half of the ball can be placed on both ends of the table in advance to perceive the ball in the left half or the right half of the general range to do a good job.

4. DESIGN OF HARDWARE CIRCUIT

4.1 Optocoupler circuit for isolating high and low voltage

The normal work of the infrared proximity switch voltage is 12 v, and stm32f103 microcontroller IO port so the working voltage of 3.3 v for the convenience of single chip microcomputer to collect ir proximity switch output signal, we choose to use the light coupling circuit will be 12 v signal in the form of light into a 3.3 v level signal input microcontroller again, because of our optical coupling chip photosensitive resistance tolerance is not very understanding, so the series in photosensitive resistance we use potentiometer resistor replacement value fixed carbon film resistor, which is convenient to adjust the series resistance, increase the rate of debugging.



4.2 Filter circuit for microphone filter

Because the fidelity of the sound collected by the microphone is poor, and we only need to know whether the sound is collected by the microphone or not, we do not need to know the physical force such as the sound type and frequency collected by the microphone, so we can filter the signal of the microphone according to the filtering mode of the power supply circuit.In this work we use the capacitor filter, a nonpolar ceramic capacitors in parallel on both ends of the microphone, such a simple circuit can filter out noise distortion of the output signal jitter disappear, ensuring that there is sound when MCU receives the signal for high level, there is no sound for low level MCU receives.

4.3 Design of SCM port and interface

Firstly, the MCU collects the data of the distance between the sound and the ball, so the signal output end of the sensor used for sensing the position is connected to the external interrupt pin of the MCU to ensure that the chip can sense the position of the ball in the first time, so that it can make the corresponding response in the first time. Since the level signals output by different sensors are completely different, we have done corresponding current limiting and voltage reducing processing at the ports used for input. The signals of steering gear and stepper motor are PWM wave, so the four PWM wave signal ports of SCM are defined as the pins of control motor.

Secondly, single-chip computer at work and will get the location of the image processing data and positions of the sensor data are integrated, so the single chip microcomputer and computer connection is necessary, considering the single chip microcomputer and computer using bluetooth or wifi wireless communication mode between has certain delay, communication mode choice for cable communications. Although there are all kinds of single chip microcomputer port, but the computer is almost only usb port is the most common ports used to transfer data, so choose in online communication on the communication mode of uart serial port and your communication way, just single chip microcomputer system board on the pin of uart3 already packaged miniUSB interface, so only need a usb – nimi USB cable can complete the connection of computer and single

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chip microcomputer. In addition, in order to ensure the stability of the connection, we prepared a spare interface: the ch340 chip is used to convert the usb into TTL signal, and then the TTL signal is transmitted to the MCU.

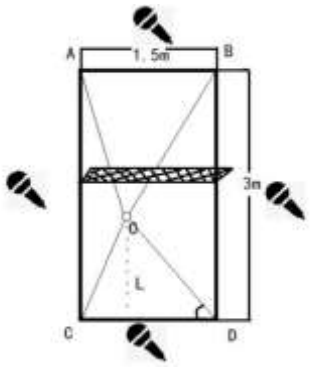
5. DESIGN OF PROGRAM AND ALGORITHM

5.1 Design of Microphone software filtering program

If you want to predict the position of the ball more accurate filtering this link and its important, even in the hardware circuit has been using capacitance signal filtering, also can't directly give software filter for this step, the interference signal of the microphone for intermittent irregular pulse signal, the software of the machine filter algorithm is using a "median average filtering method", "the average median filtering method" is also known as "the pulse interference average filtering method", the filtering method can eliminate the pulse interference of the occasional deviation caused by the sampling value, the periodic interference has a good inhibitory effect.

5.2 The algorithm of using microphone to locate the ball

Microphone array sound source positioning has a wide range of USES. It can be used for front-end preprocessing of high-quality speech recognition software, for sound acquisition under strong noise environment (such as aircraft cabin), and also for teleconferencing, video conferencing [4-6] and other systems. Because the ping pong ball must collide with the table when it makes a sound, it must be on the horizontal plane at that moment instead of in three dimensions, so the distance between the ball and the four microphones is a straight line and there is no vertical component. With the development of speech application and artificial intelligence, the speech enhancement technology based on microphone array has been paid much attention. Compared with the traditional single-channel speech enhancement algorithm, the microphone array can utilize the spatial information of the signal and has better noise suppression effect[1].Make the left front corner microphone A, the right front microphone B, the right rear microphone C, the left rear microphone D, and the instantaneous position of the ball O point. If the distance between point O and CD is L, then L/tan Angle DCO+L/ Angle CDO is equal to the width of the table of 1.5m. In the same way, a series of relations can be obtained. The position of the ball can be calculated according to the difference between the four points reaching ABCD.



5.3The algorithm of using machine vision to identify the posture of people when they serve

Through study and analysis, the posture and movement direction of table tennis are absolutely related to the opponent's service posture and movement. By grasping this characteristic, the machine will monitor the

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opponent's hitting posture and predict the movement trend of the ball in advance, providing reference for the motion of the "lead racket" of the robot arm.

Considering the complex work environment, rivals, such as clothing and body size factors will cause interference to the link, here the deep learning machine vision algorithm, this method greatly simplifies the design of visual algorithm, only need to collect data, production data set is relatively simple steps, such as to complete the rest of the work to the machines of the algorithm. The machine learning framework we choose here is the tensor flow supported by Google company, and the yolo model with constant computation cycle is selected for the target model. Yolo is "you only look once" short, just as its name implies in yolo network runtime only need to scan it again, therefore, yolo picture each computation time is almost constant, guarantee to rivals in a computing cycle completed position detection, this network model greatly convenient for the overall algorithm on the time distribution of each part, to better handle the entire operation of the machine cycle.

5.4 Program design of real-time monitoring of the ball using machine vision

The monitoring of the ball does not need to be too complicated. Firstly, the ball is a moving object with a constant color and shape. The monitoring of the ball can be completed by combining the color recognition function, circle detection function and optical flow positioning function in the open source computer vision library "opencv".

The first is to find all the moving objects using the optical flow positioning function. Then, all the prototypes in the sensitive area were detected by edge detection. Then, the inner color of these circles is identified. If the RGB value in the circle is within the set threshold value range, the current circle is considered as a ball.Finally, the distance between the ball and the robot arm is roughly estimated. Here, the radius of the circle formed by the projection surface of the ball is used. The distance between the ball and the robot arm can be preliminarily calculated by the radius.

5.5The algorithm of computer data and sensor data integration

The computer can predict the position of the ball relative to the table in advance through machine vision, but the predicted position error is relatively large. The sensor is relatively accurate, but the real-time position information has a high delay in time. Both of them have certain defects. You give them some weight and then you add them up, and that sum is the final input to the control algorithm.

5.6 PID algorithm of controlling motor motion

Mechanical arm and motor rotor inertia, so it cannot simply be open loop control, the need to install the accelerometer in the mechanical arm and angular velocity sensor, the choice of sensor for mpu6050 here, the acceleration and angular velocity sensor is integrated in the sensor, communication mode for the iic, with speed, occupy less port advantages. The use of PID algorithm can make the manipulator achieve the desired position

and attitude more quickly and accurately, and the closed-loop motor control can avoid the impact of individual PWM pulse loss.

Incremental PID algorithm mathematical model: if outk-1 is used to represent the last output control signal value, then the current output value should be OUTK, and the relationship between the two is:

$$OUTK = OUTK - 1 + \Delta OUT$$

Δ OUT is the incremental value should be output;
The deformation of the above equation can be:

$$\Delta OUT = OUTK\ OUTK - 1$$

The output of the position algorithm:

$$Kp * OUTk = (Ek) + (Ki \sum_{n} Ek) + (KD\ (Ek - Ek - 1)) + OUT0\text{-}1 \text{ type}$$

Last location algorithm output:

$$OUTk - 1 = (Kp * Ek - 1) + (Ki \sum Ek) + (KD\ (Ek - 1 - Ek - 2)) + OUT0\text{-}2 \text{ type}$$

The above equation 1 minus 2 is the increment of adjacent two times:

$$Ki = Kp * (T/Ti);$$

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KD = (Kp * (TD/T)
Δ OUT = OUTK OUTK - 1 = KP (EK - EK - 1) + (KP * (T)/Ti) EK + (KP * (TD)/(T) * (EK - 2 + EK EK - 1-2))
EK: the deviation of this time;Ek-1: deviation from last time;Ek-2: deviation from last time;Kp: algorithm gain adjustment;Ti: integration time;TD: differential time constant.

This PID algorithm can only calculate the most recent three deviations, do not need to store all the historical deviation data, save the memory of the single-chip microcomputer, the amount of calculation compared with the conventional algorithm greatly saves the amount of mpu calculation.

6. CONCLUSION

This paper proposes a positioning method that combines machine vision with traditional positioning, which is a brave attempt to combine the existing technology with the cutting-edge technology. The machine vision is used to predict the movement of the ball in advance and then the sensor is used to accurately locate the ball. In terms of positioning accuracy, this method exceeds the effect of the two working alone

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