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The Design of Automatic Picking-up Tennis Car

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Abstract: Tennis is a popular sport. It takes time and effort to pick up the ball manually. In order to solve the problem of picking up the tennis balls on the tennis court and improve the efficiency of picking up the balls on the court, an automatic picking up tennis car is designed. The vision sensor is used as a tool of image acquisition and pre-processing. High performance single chip microcomputer is used as control system, infrared sensor and ultrasonic sensor are used for distance measurement, obstacle avoidance and motor drive. A small vacuum pump is used as a ball suction device, which can automatically identify, locate and pick up tennis balls. In addition, the car also has wireless charging function to ensure that the car can work for a long time.

Keywords: Tennis; Visual recognition; Tennis picking-up; Vacuum pump; Motor drive; Wireless charging

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1. Introduction

With the continuous development of science and technology, people's living standard is increasingly improving. People's pursuit of life is not only limited to food, clothing, housing and transportation, but also the demand for recreational activities is also growing. Tennis, as a simple and fashionable sport, gradually enters people's life, and has the trend of popularization [1].

After investigation, it is found that people often need to pick up tennis frequently and repeatedly in the court when playing tennis. This process takes a long time and is very boring. Therefore, if intelligent car is used to take the place of manual labor; it can greatly improve the efficiency of picking up the ball, save time and labor [2].

The project is devoted to the research of an automatic tennis pick-up car, which uses the Mu image sensor as a tool for image acquisition and pre-processinng, the STM32 high performance single chip microcomputer as control system, the infrared sensor and ultrasonic sensor to measure distance and avoid obstacles, drive by motor. With the small vacuum pump as the ball suction device, the tennis ball can be automatically identified, positioned and picked up.

In addition, the automatic tennis pick-up car is small in size, light in weight, intelligent, and can pick up more than one ball at a time, and can pick up the scattered tennis in a short time. In addition, the car also has wireless charging function, which can effectively solve the problem of endurance caused by the lack of battery power.

2. Overall structure design of automatic tennis pick-up car

2.1 Principle of picking up the ball

The tennis ball is generally made of rubber, and the outer layer is covered with a mixture of wool and nylon. As shown in Figure 1.

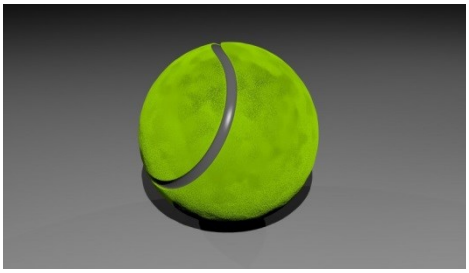

Figure 1.Tennis ball.

Due to the tennis ball has the characteristics of small volume and light weight, the vacuum pump is suitable to be used as the power device in the design of tennis car. Under the action of vacuum pump, the tennis ball is sucked into the ball storage box [3]. In order to finish picking up the tennis ball quickly, reduce the resistance of the device and improve the efficiency of picking up the tennis ball, the pipe for picking up the ball is arranged along the inclined plane. The force on the tennis ball in the inclined pipe is shown in Figure 2.The force on the tennis ball on the inclined pipe is shown in Figure 2.

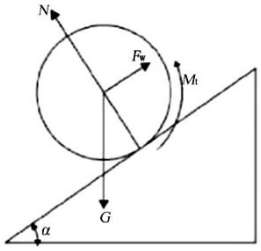

Figure 2. Force Analysis of tennis ball in the pipe.

The mechanical equilibrium equation is as follows:

$F_w - G\sin\alpha - G\cos\alpha f = 0$ (1)

F_w: Suction of vacuum pump. *f*: Rolling resistance coefficient.

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$$\begin{cases} F_W = \frac{1}{2}\rho v^2 C_D A \\ G = mg \\ G\sin\alpha + fG\cos\alpha \le F_W \le \frac{G}{\sin\alpha} \end{cases} \quad (2)$$

ρ: Air density; v: Wind speed; C: Air resistance coefficien(0.5 for sphere); A: Windward area;

According to the force analysis, the wind speed provided by the vacuum pump should meet the following two requirements: the tennis ball can roll up the slope smoothly and uniformly, and reach the ball outlet; the tennis ball can fall into the ball storage box smoothly from the ball outlet.

As shown in Equation :

$$\sqrt{\frac{2mg(\sin\alpha + f\cos\alpha)}{C_D \pi R^2 \rho}} \le v \le \sqrt{\frac{2mg}{C_D \pi R^2 \rho \sin\alpha}} \quad (3)$$

The maximum cross-sectional area of the suction pipe is Smax. The safety factor is K. The air flow (L / min) of the micro vacuum pump can be approximately expressed as:

$$\begin{cases} V = \mathrm{K}S_{\max} v \\ \mathrm{K}S_{\max}\sqrt{\frac{2mg(\sin\alpha + f\cos\alpha)}{C_D \pi R^2 \rho}} \le v \le \mathrm{K}S_{\max}\sqrt{\frac{2mg}{C_D \pi R^2 \rho \sin\alpha}} \end{cases} \quad (4)$$

2.2 Structural dimension design of suction ball pipe

The inclination angle between the suction pipe and the horizontal plane is α = 37 °. In order to be able to pick up multiple tennis balls at the same time in a limited time, the open design can be adopted: the maximum open area Smax = 150 mm × 80 mm, the cone angle of the opening is 50 °.

In order to pick up the tennis ball into the correct storage ball device, a square tennis outlet is formed by cutting the end of the pipe, and then a vertical track with a length of 20 mm is connected at the outlet, to make the tennis ball fall accurately. The pipe structure is shown in Figure 3.

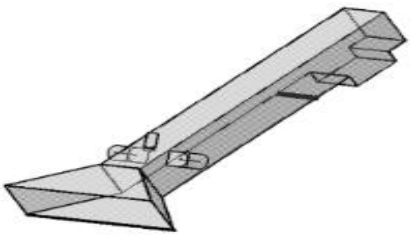

Figure 3. Pipeline structure.

2.3 Ball suction device - selection of vacuum pump

According to the flow range of the vacuum pump selected in this design, air leakage and tennis surface wear are considered.

Choose safety factor is K=1.4; Mass of tennis ball is m=58g; D=66mm; α =37 ° ; Smax=150 × 80mm2; g=9.8N/kg. It can be calculated that the suitable range of the vacuum pump flow is about twenty point one six ~ 29.53m3/min.

In this design, the specific parameters of the selection of the brush free vacuum pump are shown in Table 1.

Table1. Technical parameters of brush free vacuum pump

Voltage /V	Iload current /A	Power /kW	Air flow / (m3/min
24	<2	<33.6	28

2.4 The overall design of the ball picking up car

The automatic pick-up tennis car is composed of the following parts: car body device, ball suction device, image acquisition and processing device, control system, storage ball device, driving motor, etc. The tennis car uses the connection between the vacuum pump and the ball suction pipe to realize the automatic ball picking up of the tennis ball.

The isometric view of the automatic tennis car is shown in Figure 4.

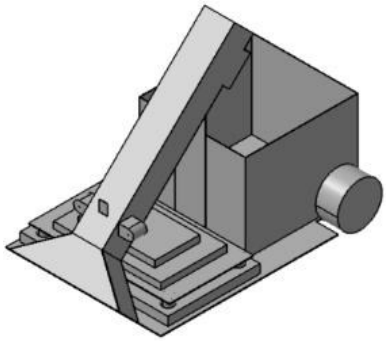

Figure 4. The isometric view of the automatic tennis car.

2.5 The characteristic function of the car -electromagnetic resonance wireless charging technology

The magnetic vibrator used in this design is composed of a large inductance coil with small capacitance in parallel or series, the transmitting coil is attached to the power supply, the receiving coil is attached to the automatic tennis pick-up car, and the same resonance frequency is the necessary condition of energy transfer. When the transmitting end emits electromagnetic field at a fixed frequency, the receiving end needs to vibrate at the same frequency, so that it can receive the transmitted energy and achieve the purpose of charging [4].

Compared with electromagnetic induction, based on the mode of magnetic resonance, wireless charging realizes a long transmission distance, efficient power supply, and is a one to many power supply mode.

3. The system configuration of tennis pick-up car

3.1 Motion control system

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The STM32 module is the core control circuit of the whole tennis car. Without the drive control module, it is impossible for the car to complete all kinds of actions and tasks. Therefore, the motion control system is the core system of the tennis pick-up car.

3.2 Overview of sensors in the control system of the tennis pick-up car

In order to work normally, it is necessary to detect the tennis in the field and avoid the obstacles in the field, and at the same time, it is necessary to operate stably in the field.

In view of tennis court may have other sundries, so a single sensor can not meet the requirements. Therefore, visual recognition module and a variety of sensors are used to work together to improve the efficiency of ball picking and obstacle avoidance.

3.3 Vision recognition system of tennis pick-up car

It is necessary to distinguish and identify tennis balls, and it requires small module size and high stability. Therefore, open-source Mu vision sensor is selected.

3.3.1 Visual recognition software technical parameters

(1)Write the initial code to the Mu vision sensor using the computer opening program.

(2)Enter setup mode.

(3)Set to sphere detection mode.

(4)Set the USB output result message to know the detection result when connecting the serial port.

(5)Run Mu vision sensor separately offline, no tennis ball detection output in the field of vision.

(6)Put the tennis ball into the vision field of Mu visual sensor, you can see that the output message is tennis ball detected at this time.

3.3.2 Pre-processing the collected image

(1) Collection of tennis court information

The tennis court covers an area of about 670 square meters (36.60 meters long x 18.30 meters wide). In this area, the standard size of doubles court is 23.77m (L) × 10.97m (W), and that of singles court is 23.77m (L) × 8.23m (W).

The tennis court's information is shown in Figure 5.

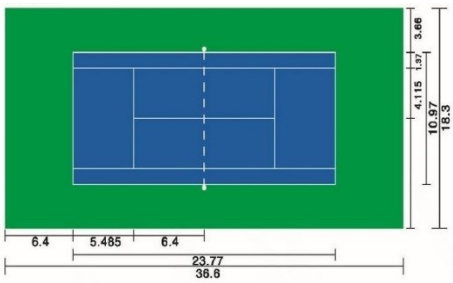

Figure 5. Tennis court's information.

3.3.3 Tennis information collection and processing

Because most of the images collected by the tennis car are in motion state, the motion state will be collected because of the vibration or route deviation during the process of the tennis car moving in. It may lead to inaccurate recognition of Mu vision sensor, and even cause program logic to fall into a dead cycle. So it is necessary to preprocess the collected image before image acquisition.

The image collected by Mu vision sensor is preprocessed every 10 frames, and the target threshold is compared with the collected threshold. A three-dimensional coordinate system is established. According to the difference between the image center coordinate and the spherical center coordinate, the position and distance between the tennis ball and the car are determined.

3.4. Distance measurement and obstacle avoidance system of tennis pick-up car

3.4.1. Use of infrared sensor and ultrasonic sensor

In this design, ultrasonic and infrared sensors are selected as the detection sensors of the distance and obstacles of the tennis pick-up car.

According to the principle of bionics, ultrasonic positioning is adopted. Specifically, the ultrasonic generator is used to transmit the ultrasonic wave, and the distance is measured based on the reflected acoustic signal received by the acoustic receiver. Then the electric signal processed by the microprocessor is used to control the car to make an emergency stop or avoid action.

The ultrasonic transmitter is led out by the front-end circuit in the STM32 main control. When the ultrasonic is working, the STM32 main control will output a high-level power supply to the ultrasonic voltage stabilizer, and then the ultrasonic transmitter will enter the transmitting state. When the ultrasonic sensor works, the STM32 master control starts timing at the same time, and calculates the distance through the round-trip time of the sound wave.

STM32 main control also provides the same level to the ultrasonic receiver, and the ultrasonic sensor starts to run at the same time of sending low level to the outside. When there is an obstacle in front of the tennis car, the obstacle will reflect the acoustic signal back. When the receiving end of the ultrasonic sensor receives the returned acoustic signal when the acoustic wave returns, after the processing of each circuit, the STM32 master control will stop timing and calculate the distance of the obstacle through the return time and speed of the acoustic wave. Finally, sometimes, the ultrasonic sensor can not detect the obstacles. When the distance between the obstacles is too close to the ultrasonic sensor and the timer controlled by STM32, there will be a logic error, resulting in the failure of normal detection distance. The infrared sensor and ultrasonic sensor are used together to test the detection distance. The infrared sensor can compensate for the defect of blind area in ultrasonic detection. As shown in Figure 6.

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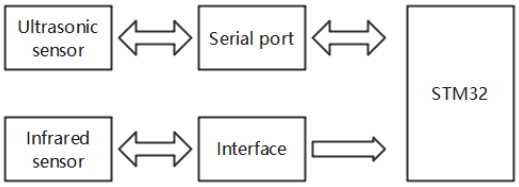

Figure 6. Work flow chart.

As shown in Figure7, 1, 2, 3 and 4 are ultrasonic sensors, and a, b and c are infrared sensors. This installation method can improve the efficiency of avoiding obstacles of the ball picking car.

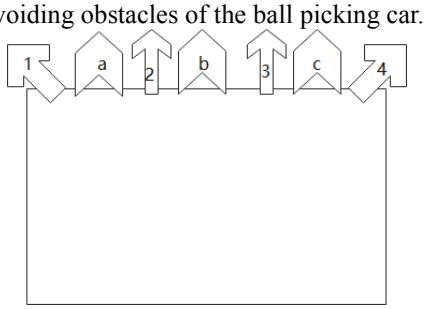

Figure 7. Installation position of infrared sensor and ultrasonic sensor.

Using ultrasonic sensor and near-infrared sensor, when encountering the barrier around the site, automatic turning can be realized by adjusting the driving direction. Tennis pick-up cart can be equipped with a number of ultrasonic sensors to be used in different situations. When installing the sensor, it should be noted that it is higher than the tennis ball diameter and lower than the height of the common field partition, and the sensor recognition distance is not easy to be too large. Each sensor has a different angle from the ground, or the tennis ball on the boundary will be missed. As shown in Figure 8.

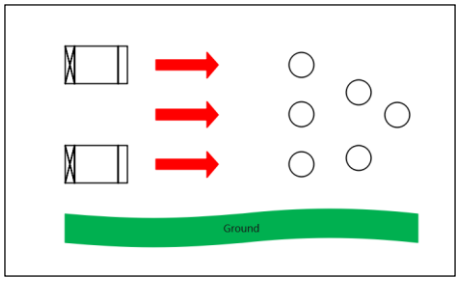

Figure 8. Schematic diagram of sensor installation angle.

Using ultrasonic and infrared sensors to avoid obstacles can avoid obstacles accurately in the normal distance range, even in the very near range of the tennis cart can also avoid obstacles accurately.

3.5 LCD display system of tennis pick-up car

In order to display the working and system state of the ball picking car, an LCD screen is designed to display the basic information of the ball picking car. Figure 34 is the basic system flow chart of LCD screen. STM32 main controller writes the communication instructions with CPLD, which can perform various display controls on LCD screen as the core component of the controller. CPLD mainly realizes the functions of three modules:

(1) Protocol analysis module;
(2) SRAM reading and writing control module;
LCD timing driving module.

The display driver is mainly implemented by CPLD, including LCD timing driver, communication protocol analysis and SRAM read-write control.

4. Conclusions

In this paper, we design the tennis pick-up car . It uses STM32 single-chip microcomputer as control system, uses Mu vision sensor to identify tennis ball, uses the combination of ultrasonic sensor and infrared sensor to realize tennis ball positioning, ranging and avoiding obstacles, is driven by motor, and uses suction generated by vacuum pump to realize tennis ball picking.

In the process of image processing, the calculation method is complex and the adaptability is poor, which is the main disadvantage of this study. Through the introduction of effective intelligent algorithm, we can quickly and accurately get clear and accurate tennis image, the interference caused by the motion state of the car. Based on the idea, we will expand the application of the procedure mentioned above by further study.

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References

[1] T.F. Lv, B.L. He. Electronics World, 12 (2013) 68-69.
[2] D.Y. An. Northeastern University, (2008) 23-27.
[3] L.B. Geng. Automation & Instrumentation 5 (2016) 118-119.
[4] W.W. You. Chinese Journal of Liquid Crystals and Displays, 3 (2015) 444-450.

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