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Innovative Inhalation-activated Badminton Ball Picker

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Abstract: *As an international sport, badminton has garnered a large following due to its high entertainment value and spectator appeal. To facilitate the cleaning of badminton courts and reduce the labor involved in manually picking up shuttlecocks, this project introduces a smart device capable of automatically collecting scattered shuttlecocks and neatly stacking them. Moreover, given that low humidity can damage the feathers of a shuttlecock, particularly during winter and thereby shortening its lifespan, the project also includes a humidifying storage box to address this issue. The project integrates embedded system design with mechanical engineering to achieve its goals.*

Keywords: *embedded system design, automatic collection, mechanical structure*

1. Introduction

1.1. A ball-absorbing device is needed

In badminton games or practice sessions, players often hit shuttlecocks to various corners of the court. Manually collecting these scattered shuttlecocks is a laborious task, particularly in large venues or training facilities. Therefore, developing a device capable of automatically retrieving the shuttlecocks can significantly enhance the cleaning efficiency and overall hygiene of the venue, while also reducing the workload on staff. Moreover, an automatic retrieval device can boost players' training and gameplay efficiency, as they will no longer need to spend time searching for and collecting scattered shuttlecocks on the court. Consequently, creating an automatic ball retrieval system can improve work efficiency, site cleanliness, and overall user experience [1].

1.2. A device that can prompt the operator that the badminton is fully loaded

In the daily management of a badminton court, timely cleanup of the shuttlecocks on the court is essential. However, operators often lack awareness of when to empty the collection bin before it becomes full of shuttlecocks. Therefore, designing a device that alerts the operator when the bin is full has become crucial. Such a device can assist operators in managing the badminton court more efficiently, ensuring timely emptying of the collection bin, and preventing a decrease in cleaning efficiency and potential equipment damage due to overfilling.

1.3. Design ideas

In the suction-based badminton pickup device I designed, the dust collection box is divided into three compartments: the first is equipped with a brushless motor and fan blade, responsible for the initial absorption of the badminton; the second chamber serves as the storage area for the collected badminton; and the third chamber humidifies the badminton, as they are prone to damage in dry environments, which can reduce their lifespan. The device features a culvert connection switch that operates automatically. An infrared distance sensor detects when the badminton has filled the collection chamber. Once full, a buzzer inside emits an alert to the operator by modulating the sound frequency and activates the culvert closure mechanism to prevent accidents.

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2. System design

2.1. Electronic circuit design

2.1.1. The buzzer module

A buzzer, as shown in Figure 1, is an electronic component designed to produce sound, operating on the principle of electromagnetic induction. Typically, a buzzer contains a piezoelectric ceramic plate or a vibrating diaphragm. When voltage is applied to the buzzer, the piezoelectric ceramic plate undergoes vibration. This vibration, in turn, causes the diaphragm within the buzzer to produce sound[2].

There are two main types of buzzers, and Figure 1 is a diagram of the Buzzer module.

1) Piezoelectric Buzzer: This type of buzzer uses the piezoelectric effect to generate sound. Upon application of voltage, the piezoelectric ceramic element vibrates, producing sound.

2) Electromagnetic Buzzer: This type of buzzer generates sound through the movement of a vibrating diaphragm within an electromagnetic field. Upon application of voltage, the electric current in the electromagnetic coil produces a magnetic field, which in turn causes the diaphragm to vibrate and emit sound.

Coding Principle: Define the output pin where a high-level output signifies that voltage is applied.

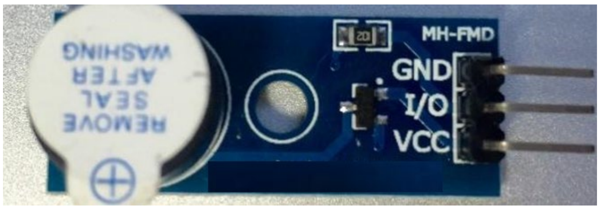

Figure 1: Buzzer module

2.1.2. How to make the buzzer produce the corresponding tone

Pass the initial value from the frequency table to the timer. Once the timer overflows, it triggers an interrupt request to the CPU, prompting the CPU to execute the interrupt service routine. At this point, the level of the buzzer pin connected to the MCU can change, allowing the initial value to be reloaded into the timer for timing. This process enables the generation of a tone at the corresponding frequency. To extend the tone, utilize the delay function. Play music by matching the frequencies and pitches to their corresponding lengths. The code is shown in Figure 2.

```
if (distance < 8 && distance >= 0) {

  delay(5000);
  if (distance < 8) {
    myServo.writeMicroseconds(1000);//
    for (int x = 0; x < length; x++) {
      tone(tonepin, tune[x]);
      delay(durt[x]);
      noTone(tonepin);
```

Figure 2: Control Code Diagram

2.1.3. The Adunino UNO module

The Arduino UNO, as shown in Figure 3, is a 32-bit microcontroller featuring 14 digital input/output pins, 6 analog input pins, a USB interface, a DC power jack, an ICSP header, and it can interface with other microcontrollers through its hardware serial port connectors. This project utilizes its serial communication and digital control capabilities, as shown in the following figure.

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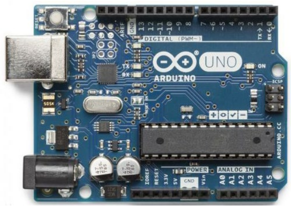

1Figure 3: Arduino UNO

2.1.4. Infrared ranging module

The infrared ranging module is depicted in Figure 4 and the infrared ranging module is depicted in Figure 5. Through serial port communication, connect A4, A5 of ardunio. The code is depicted in Figure 6.

Figure 4: Infrared ranging module

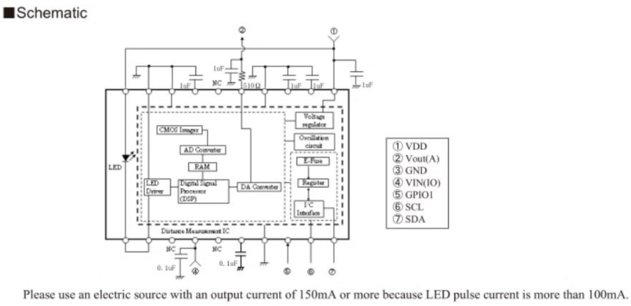

Figure 5: Conneciring diagram of infrared ranging module

```
void fish()
{
  Wire.beginTransmission(ADDRESS);
  Wire.write(DISTANCE_REG);
  Wire.endTransmission();

  Wire.requestFrom(ADDRESS, 2);

  while (Wire.available() < 2);

  high = Wire.read();
  low = Wire.read();

  distance = (high * 16 + low) / 16 / (int)pow(2, shift); // 计算距离（单位：CM）
  Serial.print("距离为 ");
  Serial.print(distance);
  Serial.println(" 厘米");
}
```

Figure 6: Code diagram

2.1.5. Convert channel and electrical modulation control

Convert control principle:

Suction is generated by the high speed of numerous motors, and absorption into the culvert is achieved by altering the wiring. For controlling the brushless motor, Pulse Width Modulation (PWM) is utilized, managed through the functions of the service library. Start and stop buttons are added for the brushless motor; pressing these buttons provides the motor with start and stop PWM signals. The convert schematics is depicted in Figure 7, operation principle is depicted in Figure 8, and Control code of the brushless motor is depicted in Figure 9.

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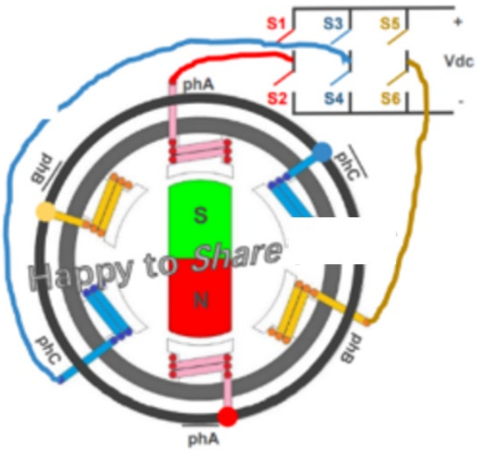

Figure 7: Convert schematic diagram

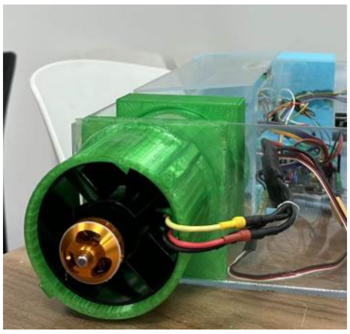

Figure 8: Operation principle

```
void loop() {



  if (digitalRead(button7Pin) == HIGH) {
    //
    myServo.writeMicroseconds(1400);
  }

  if (digitalRead(button8Pin) == HIGH) {
    //
    myServo.writeMicroseconds(1000);
  }
  digitalWrite(3,HIGH);

  }
```

Figure 9: Control code of the brushless motor

Electrical modulation control principle:

The working principle of a brushless motor involves controlling the intelligent circuitry within the motor to precisely regulate the current and voltage, thereby controlling the motor's speed and torque, as depicted in Figure 10. The electronic controller communicates with the sensors inside the brushless motor, monitoring the rotor's position and speed in real time, and adjusts the current and voltage according to preset parameters, as depicted in Figure 11. This ensures stable and efficient operation of the brushless motor. Additionally, electronic modulation can also control the start, braking, reversal, and other functions of the brushless motor, thus meeting the requirements of various operating scenarios[3-4].

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Figure 10: Electrical adjustment

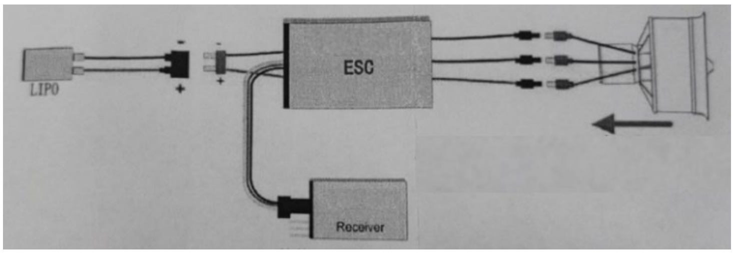

Figure 11: Wiring diagram

2.2. Machine design

2.2.1. Culvert

As the primary power component of the entire device, the culvert is sized at 70mm, chosen based on the characteristics of shuttlecocks, as depicted in Figure 12. This culvert is capable of generating a suction force of 1800g. Since the device is not entirely sealed during installation, approximately 95% of the suction may be lost at the pipe inlet. However, even though only 90g of suction remains, it is sufficient to pick up a 6-7g shuttlecock and ensures minimal damage to the feathers to the greatest extent possible.

Figure 12: Culvert

The culvert is connected to the bottom of the left side of the cabin, and an air duct is present on the lower left side of the cabin. Both ends of the air duct are fitted with perforated covers to facilitate air circulation and are securely attached to the bulkhead, ensuring an effective seal throughout the entire channel.

2.2.2. The receiving device for the badminton

The badminton receiving device is situated in the middle of the air tube and has an overall round shape, with a center resembling a funnel, as depicted in Figure 13. Its diameter matches the bottom of the badminton, allowing it to effectively cradle and secure the shuttlecock, ensuring its proper placement within the tube. This design helps the receiving tube to maximize its capacity for holding more badminton. The circumference of the fixed seat is configured in such a way that it does not impede the airflow through the pipeline.

This device can prevent the shuttlecock from being directly sucked into the culvert by the powerful airflow, which could cause it to collide with the fan blades, potentially leading to improper rotation and the risk of damaging the internal motor.

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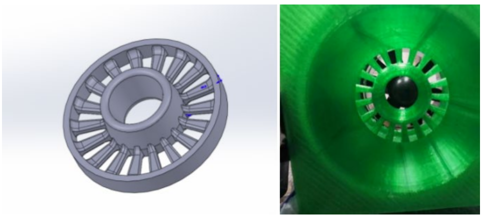

Figure 13: Receiving device of badminton

2.2.3. Replacement storage tube

The storage tube is positioned above the air duct. When the badminton in the storage tube are full, the operator can replace it, placing the full storage tube into the storage bin located on the right side of the suction tank, and then insert an empty storage tube to continue the collection process, ensuring uninterrupted operation.

During the ball absorption process, the high suction power of the culvert may also draw in dust from around the badminton into the pipe, which could potentially settle in the storage tube. The use of a replaceable storage tube can simplify the cleaning process for the operator and help maintain the cleanliness and tidiness of the device's interior.

The storage tube has two open ends, with the lower end featuring an 89mm by 84.6mm square cover, as depicted in Figure 14. At the center of the storage tube, there is a hollow, circular platform attached to its inner wall. Badminton at the bottom can be suspended from the bottom of the storage tube, allowing the tails of the badminton to protrude, which increases the storage capacity of the tube. The opening size is designed to snugly hold the badminton; it can be manually pulled out when necessary. Moreover, the suction of the culvert is calibrated to prevent overabsorption of the badminton, striking a balance that is just right.

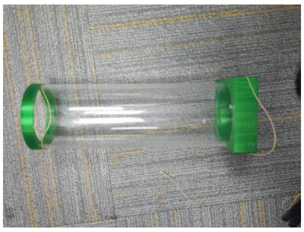

Figure 14: Replacement storage tube

2.2.4. Badminton humidifier

The badminton humidifier is situated atop the third compartment and is utilized to humidify the shuttlecocks prior to competition, thereby enhancing their elasticity and flight stability, as depicted in Figure 15. In a dry environment, shuttlecocks may become dry and brittle, losing some of their elasticity, which can impact the ball's flight trajectory and speed. Consequently, proper humidification through the humidifier can restore flexibility and stability to the shuttlecocks, improving the quality of play and the players' experience. This humidification process is typically conducted before the competition to ensure optimal shuttlecock performance during the event.

To facilitate the extraction of the humidifier for water replenishment, a drawing board measuring 73.8mm by 83mm was designed. A circle with a diameter of 63.4mm was cut at the back of the board to accommodate the round humidifier at its base. The slide rail design ensures that the position of the humidifier will remain unchanged during removal, preventing any shift due to improper handling.

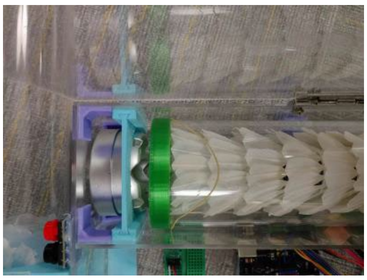

Figure 15: Badminton humidifier and chute

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2.2.5. Badminton suction ball tube

A 3mm-thick acrylic pipe with an inner diameter of 75mm is used, which significantly exceeds the top diameter of 66mm, facilitating the better absorption of badminton. To aid in storage, the lower end of the suction pipe depicting in Figure 16 is equipped with a connecting port depicting in Figure 17, and the air outlet of this connection has a diameter of 65mm. The suction provided by the culvert allows the badminton to enter the storage tube orderly.

Figure 16: Badminton suction tube

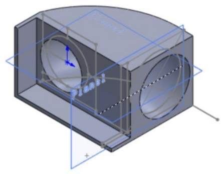

Figure 17: Connection port

2.3. Software design

2.3.1. Program flow diagram

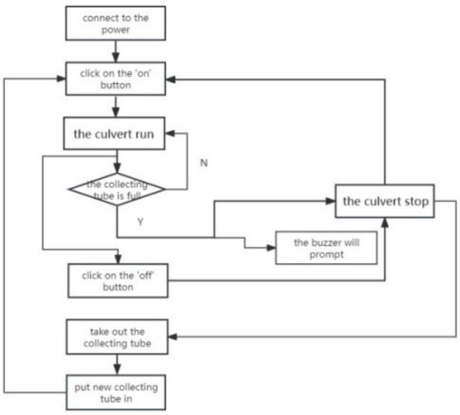

Figure 18: Flow chart

I utilize the culvert to absorb the badminton. Consequently, the suction-based badminton picker employs an Arduino to govern the brushless motor's rotation. The entire operational process of the suction badminton picker is as shown in Figure 18.

3. Experiment and discussion

In a field strewn with shuttlecocks, I hold a badminton ball pickup device, press the red button to activate the culvert, aim the badminton suction pipe at the tail of a shuttlecock, and the powerful airflow from the culvert sucks the shuttlecock into the pipe. It then passes through the junction and falls neatly into the storage tube. When the shuttlecocks are filled to capacity, the infrared ranging module detects that the storage is full. After 5 seconds, the culvert ceases rotation, and a buzzer alerts us that the storage tube has reached maximum capacity, indicating the need to replace the storage tube to continue operation. If the number of shuttlecocks is less than a bucket's worth, I can interrupt the collection process by pressing the black button[5].

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Experimental objective:

I will investigate the adsorption effectiveness of the suction-type badminton ball picker on shuttlecocks and explore its application value within the badminton field.

Experimental procedure:

1) Prepare a suction badminton pickup device and some badminton.

2) Open the suction device and point it at the badminton. Press the suction button to suck the ball.

3) Measure the efficiency and speed of the suction device to absorb badminton.

4) Performed many experiments and discussed the experimental conclusions.

Physical diagram of the experimental operation is depicted in Figure 19.

Figure 19: Physical diagram of the experimental operation

Experiment conclusion:

1) The badminton absorption speed is about 0.8s one.

2) The badminton collection capacity of a single badminton trip is 10. The badminton collection is depicted in Figure 20.

Figure 20: Collection tubes after the collection is completed

3) Badminton humidification time single 8s.

4) The single use time of the whole machine is about 25 ~ 30 min after full charging.

Experimental discussion:

1) Adsorption effect of the pickup device: it can be learned from the experiment that the suction badminton pickup device has a high adsorption effect, which can quickly absorb the badminton and fix it inside the pickup device.

2) Application value: Inhaled badminton suction device has important application value in badminton competition, which can help athletes to inhale badminton suction device quickly and accurately, and improve the efficiency and accuracy of the competition.

Experimental improvement:

(1) The adsorption force and stability of the ball pickup device, as well as its applicability under different environmental conditions, can be further studied to improve its practical application value.

(2) Optimize the suction mechanism to ensure that it can effectively inhale the badminton without

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causing damage to the ball. This includes adjusting the suction strength and picking up more suitable pipes and more sensitive sensors.

(3) Considering the convenience and comfort of the operator, a light, easy to portable structure can be designed in the future, and an adjustable handle can be added.

Experimental summary:

Through experimentation and discussion, it can be concluded that the suction-based badminton ball picker possesses high adsorption effectiveness and significant application value, playing an essential role on the badminton court. In the future, further research and refinement aim to enhance the performance and stability of the ball pickup device, ensuring it meets the demands of various competition scenarios.

4. Conclusion

In this paper, I have designed and implemented a badminton pickup device based on the inhalation principle. The device uses a culvert as the power source and is equipped with two switches for power control. When the storage tube is filled with badminton, the buzzer sounds, signaling the culvert to cease operation. Experimental validation has demonstrated the feasibility and utility of this pickup device. In practice, it can significantly enhance the cleaning efficiency of a badminton court, reducing both labor and time costs. Additionally, the buzzer design alerts users to clean the storage tube in a timely manner, ensuring continuous operation of the pickup. Overall, this inhalation-based badminton pickup has significant potential value for practical application, offering convenience and benefits for the management and maintenance of badminton courts. Future work will focus on further optimizing the structure and performance of the pickup, enhancing its stability and durability to better meet the needs of various occasions.

Innovation Points:

Inhalation Mechanism: Traditional badminton pickups typically rely on manual collection or simple mechanical devices. In contrast, our suction pickup employs an inhalation mechanism akin to a vacuum cleaner, capable of effortlessly sucking badminton off the ground.

Efficiency Improvement: This inhalation mechanism can significantly enhance the efficiency of ball collection, particularly when numerous badmintons are dispersed across the court following training sessions or competitions.

Reducing Physical Labor: By minimizing the need for coaches and players to bend over for ball collection, this device helps alleviate strain on the waist and back, thereby reducing physical exertion.

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