An Intelligent Tennis Ball Collecting Vehicle Using Smart Phone Touch-Based Interface

Hung-Kuang Chen
Dept. of Electronic Engineering
National Chin-Yi University of Technology
Taichung, Taiwan 40109
Email:hankchentw@gmail.com

Jyun-Min Dai
Dept. of Electronic Engineering
National Chin-Yi University of Technology
Taichung, Taiwan 40109
Email: a0987235547@gmail.com

***Abstract*—Tennis is an interesting racket sport played by millions of recreational and professional players and is also a very popular worldwide spectator sport. Players ranging from the beginners to the professionals usually require a lot of practices. At the end of such practices, the tennis balls are usually scattered randomly over the surface of the tennis court; hence, it is time consuming and annoying to retrieve the balls one-by-one manually. Traditional tennis collectors mostly focus on providing the player with a more efficient tool to shorten the pick-up time; however, it still requires a lot of efforts for the player to collect the tennis balls. In this paper, we proposed a novel tennis ball collecting vehicle. Unlike traditional labour taking tennis ball collectors, our new collector, combining an intelligent vehicle with a wheeler-based tennis ball collector, can either be interactively controlled by an Android smart phone through the Bluetooth communication or automatically collect tennis balls along a predetermined route with collision detection and avoidance. Furthermore, through the Android touch-based user interface, our system provides a more interesting and user-friendly remote control solution for tennis ball collection.**

***Keywords*-intelligent vehicle; microcontroller; sports equipment; Bluetooth; remote sensing;**

I. Introduction

Tennis has been one of the most popular racket sports ever since its innovation. However, it takes a lot of practices for a novice player to master the skill of various kinds of stroke. A common practice is to familiar the stroke by repetitive training. Consequently, it is not uncommon to see hundreds of tennis balls distributed randomly over the entire surface of the court after the training. After such intensive practices, both the trainer and the trainees were weary and tired, ball collection by then became a pain- taking and time consuming heavy load. To serve this need, tennis ball collectors were developed to help alleviating such burden.

II. Related Works

Traditional tennis ball collectors are mostly human operated that requires user intervention during the collecting process. Earlier tennis collectors are mostly stroller-and-basket-based [1]–[6], most of them consisted of a handle and a steel-framed basket with specialized spacing allowing tennis ball to be squeezed into during the collecting process as the player pushing the stroller over the balls. Since the size of the tennis balls varied from 2.57 to 2.70 inches, it is not easy to find a proper spacing to tolerate all sorts of tennis balls.

Inspired by the wheeler-based golf ball collectors [7], [8], later designs of tennis ball collectors were mostly wheeler-based [9]–[17], or a combination of both [18].

Not until recently, most designs were labour taking, which require the player's labour work to push the carter or stroller over the entire court. For the balls spread over the corner or the hill of walls, players still have to pick-up the ball manually. A recent trend of the newer design is to enhance the tennis ball collector by electronic devices. A number of newer designs enhanced by electronic devices such as the vacuum-based collector [19] and the vehicle-based collectors [20]–[23] were proposed.

Following this trend, we proposed a novel design combining a novel wheeler-based collector with an intelligent vehicle. Unlike traditional tennis ball collector that requires a considerable amount of user intervention, our design supports both autonomous programmed route navigation and interactive wireless remote control. With our collecting vehicle, the user may rest on a comfortable place in the court using his smart phone to start the collection of tennis balls either autonomously or interactively.

III. The Intelligent Tennis Ball Collecting Vehicle

Our intelligent tennis ball collecting vehicle is essentially an autonomous vehicle equipped with a novel tennis ball collector. A conceptual design of such device is given by the illustration presented in Fig. 1.

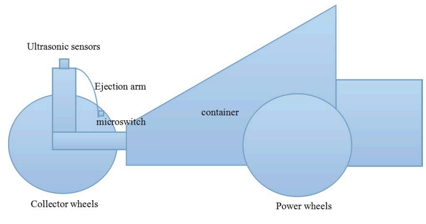

Fig. 1. An illustration of the design of our autonomous tennis ball collector

We have built a crude implementation of our idea using

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acrylic, angle steel, and the circuitry we have proposed earlier in this paper. A photograph of our prototype is presented in Fig. 2.

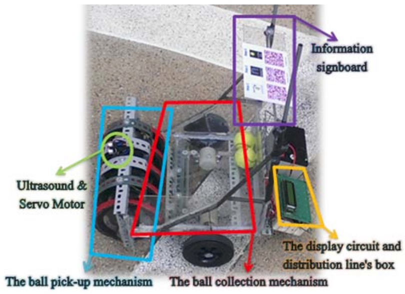

Fig. 2. A snapshot of the user interface of client-side application on Android smart phone.

To show how this vehicle works, we have presented a series of snapshots in Fig. 3.

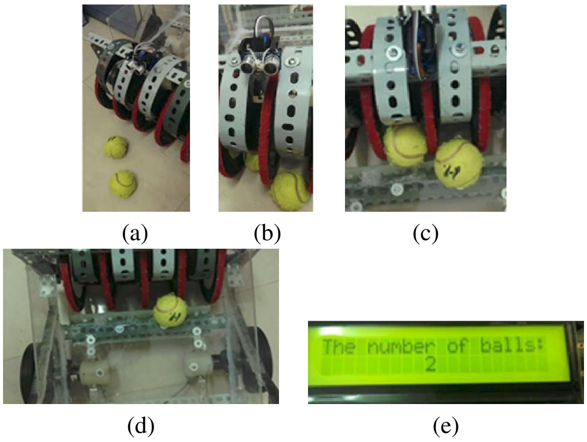

Fig. 3. The process of tennis ball pick-up: a) the vehicle moves toward the balls; b) the collector picked up the balls; c) the ejection arm ejects the collected balls and triggered the counting; d) the ejected balls falls into the container; e) the count of balls displayed on the LCD screen.

We will begin the discussion of our implementation with the tennis ball collector then proceed to the intelligent vehicle and associated software.

A. The Tennis Ball Collector

To collect the tennis balls, we have designed a novel multiple channel tennis ball collector. To show how this works, we begin our discussion with a basic collector as follows.

1) The basic tennis ball collector: Our basic tennis ball collector, as shown in Fig. 4, comprises a pair of parallel acrylic discs joined by four springs, each was drilled a hole at their center from which they can be attached to an axle. To accommodate the tennis balls in between, the two discs are made of resilient material and four springs are attached. As the discs rolling through the tennis balls, the ball is then squeezed in between the two discs. Since the diameter of a typical tennis ball is about 2.57 to 2.70 inches, the space between the acrylic discs is about 2.5 inches.

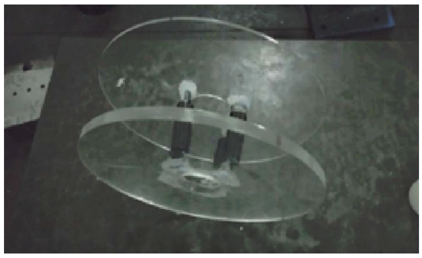

Fig. 4. The basic tennis ball collector

The four springs provide the spring force necessary for the pair of acrylic discs to grasp the tennis balls. To increase the frictional force and prevent the tennis ball from sliding out of the basic collector, a strip of rubber band is attached to the outer rim of two discs.

2) The multiple channel tennis ball collector: By cascading a number of basic ball collectors side-by-side with an axle passing the holes at the center of the acrylic discs, we may easily extend our design of the basic tennis ball collector to multiple channel tennis ball collector as shown in Fig. 5.

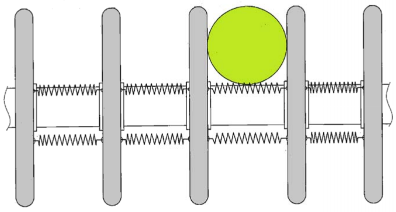

Fig. 5. A schematic view of the multiple channel tennis ball collector.

The multiple channel tennis ball collector is then attached to the front of the intelligent vehicle as the front wheels. When the vehicle moved and ran over the tennis balls, the collector grips the tennis balls with the acrylic discs.

3) The ejection arm and the micro-switch: Refer to Fig. 6, on top of each channel, a thin metal plate attached with a micro-switch is used to eject the gripped tennis balls. As the collector wheels rolling upward, the gripped tennis ball may eventually touches the ejection arm and triggers the micro-switch. By then, it is ejected to the container and the counter is incremented.

B. The Intelligent Vehicle

The circuitry of our intelligent vehicle comprises the microprocessor control unit (MCU), the Arduino Uno control board, and four peripheral modules: namely, the sensing unit (SU), the Bluetooth wireless communication unit (BWCU), the display unit (DU), and the motor drive unit (MDU). A block diagram of the system is depicted in Fig. 7.

The MCU of our intelligent vehicle is a standard Arduino Uno powered by an ATmega328 processor and standard USB

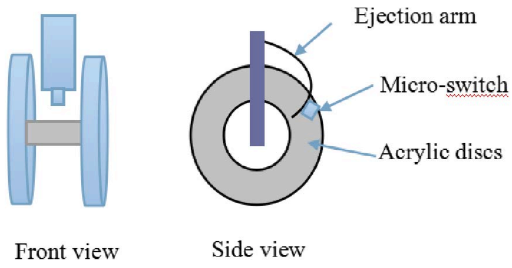

Fig. 6. An illustration of the ejection arms and the micro-switches installed on the top of the tennis ball collectors.

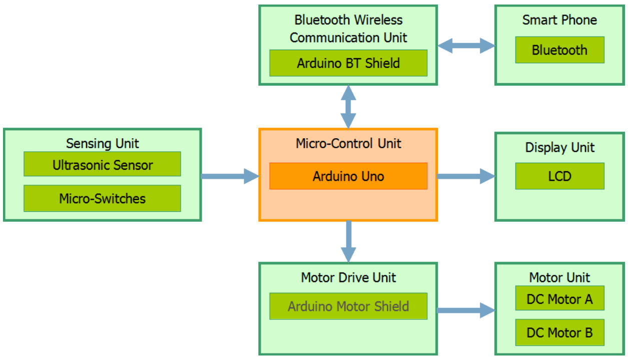

Fig. 7. A block Diagram of our autonomous vehicle system.

interface, which directly connected with the sensing unit (SU), the Bluetooth wireless communication unit (BWCU), the display unit (DU), and the motor drive unit (MDU). Whereas, two other devices, i.e. the smart phone unit (SPU) and the motor unit (MU), are indirectly paired or connected with the Bluetooth wireless communication unit and the motor control unit, respectively.

The BWCU module is responsible for the Bluetooth communications with the SPU, an Android-based smart phone. Our application running on the smart phone with user friendly touch screen interface is developed using Amarino SDK [24].

Our system adopted two types of sensing devices, i.e., an ultrasonic sensor and a set of micro-switches used for collision detection and triggering tennis ball counting, respectively. The sonic range finder we have adopted is the ultrasonic sensor module, HC-SRF04, comprising an ultrasonic transmitter, a receiver and a control circuit. To determine the distance between our vehicle and the obstacles,we may approximate the distance D between our vehicle and the nearest obstacle by the duration of high-level output from the ECHO port, T_{high}, according to the formula given as follows:

$$D = \frac{T_{high} \times V_{sound}}{2}, \tag{1}$$

where the speed of sound denoted as V_{sound} is approximated by 340(m/s) .

The counting of collected balls is sensed via the triggering of micro switches. As the collected ball in each channel rolled backward, it will eventually touched the micro-switch installed on the top of each ejection arm and triggered the increment or the counter. Since our vehicle supports multi-channels, racing condition should be avoided. Hence, the counting signals must be individually processing rather than cascaded sequentially. The number of collected balls is then displayed concurrently on the LCD screens of the vehicle and the Bluetooth connected smart phone.

The motor drive unit, denoted as MDU, contains a dedicated motor driver (L298), a voltage regulator (78M05), and two H-bridges driving the two DC motors [27]. We may control the motors by means of the master enable control input (Master Enable) and four logic inputs(PIN 1 4). To move the vehicle, two DC motors driven by L298N are controlled by sending corresponding logic signals.

C. The Software

Two platforms are used in our implementation: i.e., Arduino and Android. To distinguish the codes running on one platform from the other, we will call the codes developed with Arduino IDE, running on the Arduino Uno, the *server* and the smart-phone application developed with Android SDK, running on the Android smart phone, the*client*. Basic operations such as the navigation guidance and collision avoidance are coded into the *server*; whereas, the navigation commands from the user are issued by clicking on corresponding icons on the touch screen interface of the *client* running on the smart phone. The codes for Bluetooth communications between client and server are developed with Amarino to bridge the platforms between Android and Arduino [24].

D. The server-side application on Arduino platform

The *server* accepts Bluetooth connections from Android-based smart phones and directly controls the vehicle accordingly. The communication between the MDU and MCU start with baud rate setting command **Serial.begin** to to initiate the communication followed by the baud rate initialization. To configure and assign logic values to MDU ports, IN1-4, according to the navigation command receiving from BWCU, the **pinMode** and **digitalWrite** commands are issued accordingly. Furthermore, to adjust the rotation speed of motors M1 and M2, one may variate the pulse width of PWM signals connected to EN1 and EN2 in accordance with the speed.

1) Automatic roaming: Since the processing power of Arduino is not suffice for image processing and optimal route calculation, we do not put much efforts in developing intelligence for tennis ball recognition and optimal route scheduling. Instead, we only provide an exhaustive search approach to automatic tennis ball collection. For example, a route of exhaustive search of the tennis balls over a half-court starts from the left to the net, ends up with the returning of the vehicle to its original position by roaming the half court in a Zigzag pattern.

In the meantime, server keep performing collision detection to avoid colliding against the net, walls, or any other obstacles.

The amount of time taken to complete automatic roaming can be approximated by

$$T_{roaming} = L \times V_{vehicle} + T_{turn} \times K, \qquad (2)$$

where $T_{roaming}$ stands for the total roaming time, L for the length of route, $V_{vehicle}$ for the speed of vehicle, T_{turn} for the turning latency, and K for the number of turns.

In our case, we have determined from experiment that our vehicle speed is about 0.5 m/sec and the vehicle turn latency is around 1.7 seconds. For a standard court, it takes about 3 minutes and 18 seconds.

E. The client-side application on Android plateform

The *client* establishes Bluetooth connection with the *server* and provides interactive navigation controls over the intelligent vehicle. To install the *client* application on the smart-phone, the user may use their smart phone scanning corresponding QR Codes of the applications. If Bluetooth connection is established, the user may control the collector vehicle through the touch screen interface of our client application by touching corresponding icons. Once the connection is established, the user may switch the automatic navigation control either to automatic mode or to manual control by pressing on the on/off button on the top of the screen.

IV. Experimental Results

In order to simulate the distribution of the tennis balls after a common stroke or serve practice, the tennis balls are randomly distributed over a half court at the start of test. In each test, the user has to guide the vehicle, using their smart phone, to collect the the tennis balls as soon as possible.

According to our test results, the navigation time for interactive control may varies from 4 to 15 minutes depending on the user's skill. As for the automatic full-range roaming mode, our test results shows that the time taken to complete the collection over the entire tennis court is around 4 to 5 minutes.

Note that shorter collection time can be achieved by reducing the number of turns and collisions. Moreover, the collection time can also be improved by replacing with faster motor. If the motors of higher speed are used, the amount of time can be reduced to less than 4 minutes.

However, with respect to the rate of successful collection, the experimental results reveals that the number of balls left on the bottom or the corners of walls or net may adversely affect the percentage of successful collection owing to the collisions.

V. Conclusion

In this paper, we proposed a novel tennis ball collecting vehicle by combining an intelligent vehicle with a wheeler-based tennis ball collector. Unlike traditional labour taking tennis ball collectors, our new collector can either be interactively controlled by an Android smart phone through the Bluetooth communication or automatically collect tennis balls along a predetermined route with collision detection and avoidance. In addition, our approach provides a more interesting and user-friendly remote control solution for tennis ball collection through touch-based user interface. After the practice time, the user may sit on a bench beside the court and have a rest while he was collecting the tennis balls. In comparison with traditional collectors, our approach significantly improves the user experience of tennis ball collecting from a painful task to an interesting one.

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