# An-Najah National University

## Faculty of Engineering and Information Technology

### Computer Engineering Department


## Hardware Graduation Project

# Tennis Ball Collector


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# Acknowledgments

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# Abstract

Tennis, a widely popular game, is a racket sport that takes place on a rectangular and flat surface court. During tennis training sessions, manually collecting the balls can be a laborious task , and the process of retrieving the balls manually can be time-consuming and physically demanding.

This project aims to address the laborious task of manually collecting tennis balls during training sessions by developing an autonomous robotic tennis ball collector. The objective is to design a robot capable of navigating the tennis court, detecting tennis balls using image processing techniques, and autonomously collecting them, thereby allowing players to rest instead of manually retrieving the balls. The robot features four independently-actuated wheels. A gate mechanism is employed to push the tennis balls into a basket mounted on the robot. A camera mounted on the robot captures images, which are processed using OpenCV libraries on a Raspberry Pi to detect tennis balls through an edge detection algorithm.

This project presents an effective solution for automating the collection of tennis balls during training sessions, providing convenience and relief to players from the manual collection task.

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# Chapter 1

# 1 Introduction

This chapter will shed light on the difficulties that our project solved. It will also explain our main objectives, and the importance of this platform.

## 1.1 Problem

Gathering the tennis balls that have been used and played in various areas of the court can be a wearisome and exhausting task for tennis players during training sessions. And it wastes their energy .

## 1.2 Objectives

The objective of this research is to introduce robotics into the sports field and implement automation to replace humans in performing labor-intensive tasks such as ball collecting. The ultimate goal is to develop a robot prototype capable of addressing the problem statements previously identified.

The project is divided into four main parts: the Navigation System, the Avoiding Obstacle System, the Ball Collector System, and the Ball Recognition System. Each component plays a crucial role in achieving the overall objective.

## 1.3 Significance of The Work

The value of our project serves several important purposes in the context of tennis. First, collect balls efficiently, it eliminates the need for players or ball boys/girls to manually retrieve the balls, saving time and effort during practice sessions or matches. This allows players to focus on their game without interruptions. Secondly, consistent performance, The robot ensures consistent performance in ball collection. Unlike humans, who may experience fatigue or inconsistency in retrieving balls, the robot maintains a constant pace and accuracy throughout its operation. Finally, spectator Experience, in professional tennis events, ball collector robots can enhance the overall spectator experience. Their presence adds a futuristic and technologically advanced element to the game, making it more engaging and visually appealing for the audience.

Overall, a tennis ball collector robot offers efficiency, safety, and increased training opportunities for players. It helps streamline the practice or match process and contributes to an improved experience for both players and spectators.

# Chapter 2

# 2 Constraints and Earlier course work

## 2.1 Constraints

We faced several limitations, with the most significant being the tennis ball detection methodology. Achieving an accurate method requires additional time and expertise in collecting sufficient samples of tennis balls for image processing, so we found that relying solely on color and shape detection is the right alternative. Despite this, our accuracy is generally good.
Additionally, constructing the robot's exterior design proved challenging compared to our initial vision.

## 2.2 Earlier course work

1. **Microcontrollers and PIC Lab** :
   These classes provided a comprehensive understanding of Arduino fundamentals, covering topics such as basic serial communication and the control of stepper and servo motors.
2. **Critical Thinking and Research Skills**:
   This course has equipped me with valuable skills in conducting research and writing reports. It stands out among the non-technical courses as one that offers lifelong benefits.

# Chapter 3

# 3 Literature Review

Tennis is a widely popular racket game that is enjoyed by individuals of all ages. It serves as both a professional sport and a cardio activity. During training sessions, numerous balls are utilized to practice different shooting techniques. However, once the training session concludes, the tedious task of collecting all the scattered balls arises, which can be both time-consuming and exhausting for the player. To address this issue, researchers have undertaken studies and proposed various ideas and solutions to streamline the ball collection process, aiming to make it more efficient and less burdensome for players.

From what was mentioned in the paper by S. Jacob,[4] He obtained a patent for his invention aimed at resolving the issue of collecting tennis balls.This design allowed for the balls to be squeezed and compressed into a container. By utilizing the steel rods, the device facilitated the collection of the tennis balls by effectively directing them into the container, providing a practical solution for ball retrieval.

In 2012, the researcher delved further into the details of his electric ball collector device designed specifically for tennis. The device aimed to improve the speed of ball collection by incorporating a vacuum suction into a tradi-

tional receptacle.[1]

A similar approach was presented in Nanthawam Am-Eam's research, which combined solar cell energy with hydraulic power.A DC motor is used to convey the balls to the container . [3]

In 2016, there were Researcher who introduced an intelligent tennis ball collector [2], building upon N. Am-Eam's previous research. This robot was capable of autonomous navigation along a predetermined path while also having some obstacle-avoidance capabilities. Additionally, users could manually control the robot using an Android application.

This paper proposes a vision of an autonomous robot that addresses the mentioned drawbacks by incorporating obstacle avoidance capabilities while searching for tennis balls on the court and collecting them. Additionally, it emphasizes the importance of a friendly design and the utilization of modern technology.

# Chapter 4

# 4 Methodology

This chapter will talk about the design of the system. the components that are used and their properties, and discuss the development process.

## 4.1 Description of selected design

We divided the general goal of autonomously collecting tennis balls into four main functions. All the functions need to work together to produce a fully functional design. One of our biggest concerns is how the machine will pick up balls and hold onto them, and after going through several design concepts. We have decided on a gate that spins to push the balls onto the basket. The basket is the balls storage area located above the wheels

## 4.2 Mechanical Part

The mechanical components of the candidate are gate, wheels,motors, and storage area. In this section, we will discuss the material and for each component.

### 4.2.1 Wheels

The wheel is a mechanical part that provides movement for the robot. it is connected to a dc motor. Our robot has four driving wheels.

Figure 1: Driving Wheels

### 4.2.2 Gate

This part is made from wood. it is designed with the capability to connect with a servo motor to rotate it to push the balls to the storage area.

### 4.2.3 Storing area

This part is designed to store the collected balls inside it. It is placed at the front of the robot so that the balls can enter it immediately without the hassle of going somewhere first.

## 4.3 Controller Part

### 4.3.1 Arduino uno

Arduino Uno is used to control the operation of the motors and receive serial commands from the raspberry pi to

determine the direction of movement and rotate the gate when approaching the ball.

### 4.3.2 Raspberry Pi 3 Model B

Raspberry Pi running custom software that utilizes the open-source computer vision library, OpenCV. OpenCV offers a convenient built-in function capable of detecting imperfect circles within an image. This function performs a mathematical operation to identify circles and provides the coordinates and radii of the detected circles.

Moreover, the Raspberry Pi will be responsible for sending serial commands to an Arduino when tennis balls are detected.

## 4.4 Power source

### 4.4.1 Power bank 5v

The Power bank supplies the power to the servo motor and Arduino as shown in Figure 4.

### 4.4.2 Raspberry Power Cable

The power cable supplies the necessary electrical power to the Raspberry Pi, allowing it to function and perform tasks as shown in Figure 5.

Figure 2: Power bank

Figure 3: Raspberry power cable

### 4.4.3 Lithium battery

These kinds of batteries have great use in robotics and portable . So we use it to obtain the required power to the DC motors so the robot can move easily. as shown in Figure 5.


Figure 4: Lithium Battery

## 4.5 Electronics

### 4.5.1 Wires

They are used to distribute electricity from a source to an outlet.

### 4.5.2 Servo motor

A servo motor is used for precise control of something's movements. They enable the robot to achieve accurate and repeatable motions, making it suitable for pick operations.

### 4.5.3 Ultrasonic Sensor

The ultrasonic sensor provides the robot the accurate distance measurements to optimize its collection process, and it can help to avoid obstacles.

Figure 5: servo motor


Figure 6: ultrasonic sensor

### 4.5.4 Raspberry Pi Camera

The camera can capture images or video footage of the robot's surroundings, allowing it to identify and locate ten-

nis balls. With appropriate image processing techniques and algorithms, the robot can detect the distinctive color, shape, or pattern of tennis balls and accurately recognize them amidst the background.

### 4.5.5 H bridge Motor driver L298N

H-bridge provides flexibility in changing the motor's direction, regulating its speed, and offering motor protection features.

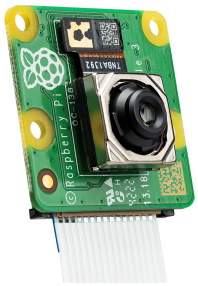

Figure 7: Raspberry pi camera

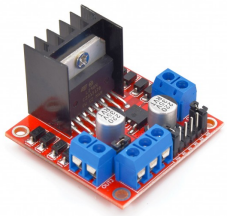

Figure 8: motor driver L298N

## 4.6 Image Processing

The open-source OpenCV library used an algorithm to detect the shape and color of the tennis ball

To perform ball detection, the Raspberry Pi will run custom software that utilizes the open-source computer vision library OpenCV. This library provides a built-in function that performs a mathematical operation called the Hough Circle Transform to detect circles in an image and return coordinates and radii of detected circles. In order to improve efficiency and accuracy, the program first preprocesses the image before performing the Hough

Circle Transform. This preprocessing includes downscaling the image from HD resolution to a less performance-intensive resolution, then transforming the image to HSV colorspace and applying a threshold mask to filter out all colors outside of a range aimed to capture just the tennis balls.

### 4.6.1 Image Acquisition

Acquiring images is a crucial initial stage in image processing since the image's quality directly impacts the final results. In this research, we utilized the standard library of the Raspberry Pi camera to set a relatively low resolution (640 x 480) for the input video. The intention behind this decision was to minimize the processing time required to extract a snapshot from the video frames.

### 4.6.2 Filtering

The input image was filtered by the GaussianBlur function to produce a blurred image. The smoothing effect helps to reduce noise and remove small details.

Figure 9: Blured Image

### 4.6.3 HSV Mask Operations

Tennis balls have a yellow-green color that is unique from their environment. The HSV mask is used to filter out the tennis balls from the image based on their color. First, we convert the captured frame from the RGB color space to the HSV (Hue, Saturation, Value) color space using the cv2.cvtColor() function. This conversion allows us to separate the color information from the intensity information, making it easier to work with specific colors. After converting the frame to HSV, we produce a binary mask where the white pixels represent the tennis balls (falling within the specified color range) and the black pixels represent the rest of the image.

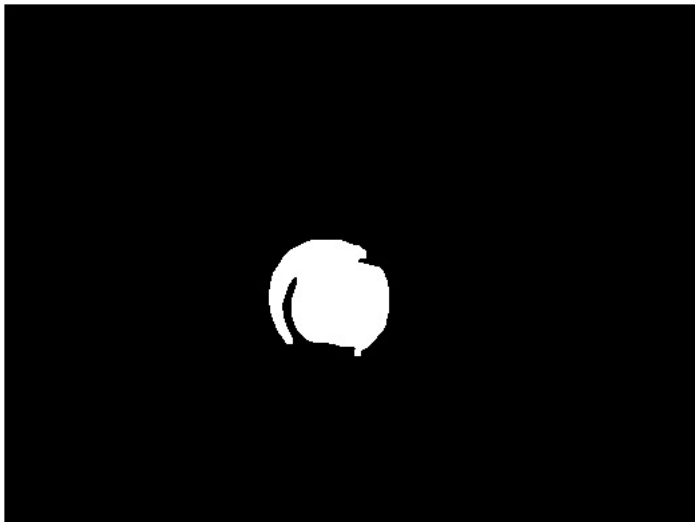

Figure 10: Threshold - masking for the tennis ball

### 4.6.4 Edge Detection

using find the contours ( the outlines or boundaries) of objects in an image. We used findContours() function which returns a list of contours detected in the image. Once we have obtained the contours , we can perform further processing on them, such as filtering based on area, shape, or other criteria, to identify the tennis balls in the image.

### 4.6.5 Circle Detection

Finding the minimum enclosing circle for each detected contour using minEnclosingCircle() function. This function calculates the center and radius of the circle that en-

closes the given contour.

Figure 11: Image processing techniques flowchart

## 4.7 Circle Detection for tennis ball.

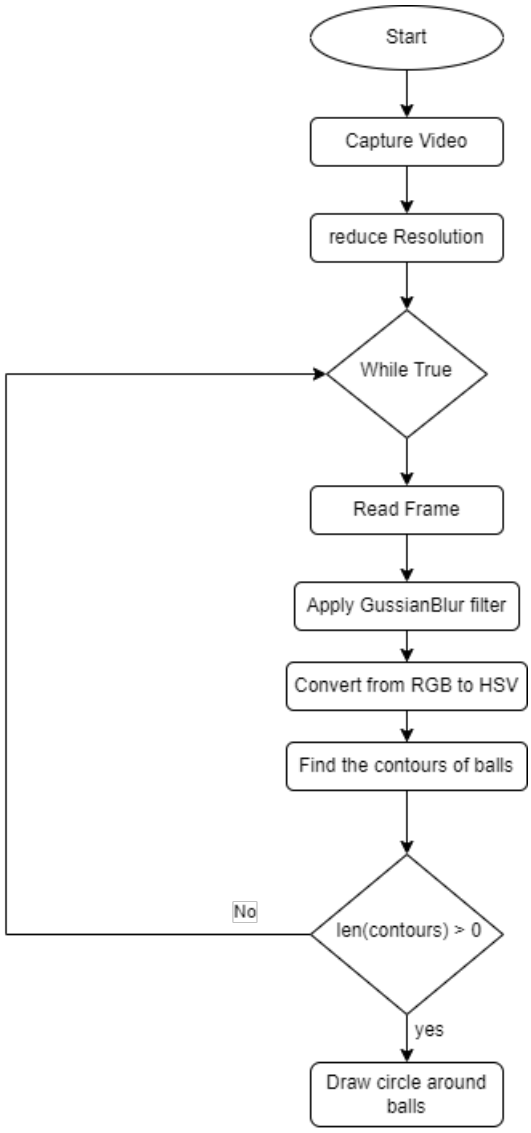


Figure 12: Image processing techniques flowchart

## 4.8 Implementation

### 4.8.1 Raspberry pi

Raspberry Pi was used to control the movement of the car and to detect balls.

As we explained previously about the Image processing to detect the tennis ball, We will explain the way it controls the robot movement through serial commands that is sent to the Arduino Uno . The raspberry Pi will rotate to the right searching for balls until two full rotations are complete. If the rotations are complete and no balls were found the Arduino will move forward a little so it can detect objects in different areas. If the camera detects a tennis ball, it will send commands like, move left and move right, to the Arduino to center the ball according to the presence of the ball on the x-axis. So the robot will continue moving left and right until the ball is in the middle. After the ball is centered the raspberry send a command to move forward to the ball to the Arduino and the Arduino will move the robot according to the Ultrasonic sensor. When the ball is close enough it will rotate the gate on.

### 4.8.2 Arduino Uno

Tennis collector movement is controlled by waiting for serial commands from raspberry pi using Arduino, when it receives a command it decides what action to take according to the code, the command will be executed by Arduino. The commands are ”SearchBalls”, the Arduino begins to rotate right in short steps and in the same time avoid any

obstacle in the front of the robot until the raspberry sends ”Forward” which indicates that it has found a ball, or it will not send anything, causing the Arduino to continue rotating right until the full cycle of rotation has been completed, when it’s completed then the Arduino goes forward to scan and search for balls again. A ”Forward” command indicates that the raspberry pi detected a ball, and if the ball center does not appear in the center of the camera frame, the Arduino will receive the command ”Left” or ”Right” to place the ball center in the center of the camera frame, then the Arduino will move the robot in short steps until it reaches the tennis ball using an ultrasonic sensor distance to detect if the ball is close enough to rotate the gate to let the ball enter.

The shown figure down below is the final result of Our robot .

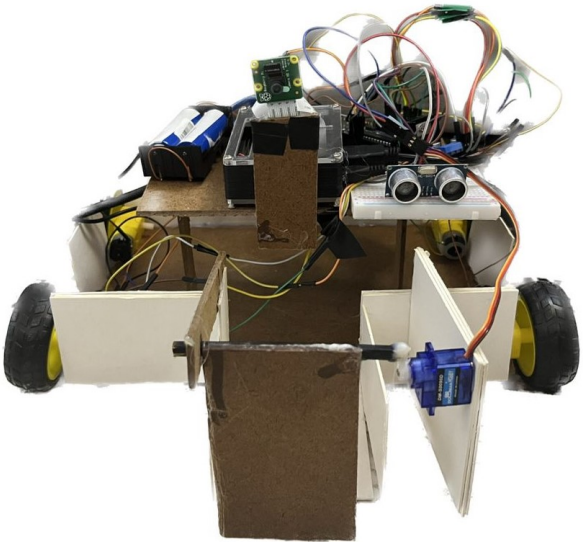

Figure 13: Final Robot Design

# Chapter 5

# 5 Discussion

## 5.1 Limitation

We encountered several challenges that had an impact on the overall progress. One of them is the lack of hardware parts in the local market , such as : Raspberry pi which proved to be time-consuming and caused delays, approximately a month, which had a negative effect on the project timeline and execution.

The scarcity of hardware parts not only slowed down the project but also posed difficulties in obtaining the required resources for development and testing. It hindered the ability to proceed with certain aspects of the project that heavily relied on the Raspberry Pi. In general , all of this created a time limitation.

However, despite these obstacles, We persevered and worked diligently to overcome them.

## 5.2 Final Result

The final result of this project is the development of a reliable and effective device that successfully performs in the majority of the tested scenarios. The device has met all the objectives set forth in the project.

# Chapter 6

# 6 Conclusion/ Recommendations and Future Works

## 6.1 Conclusions

In this research, we have developed an autonomous robot from scratch to fulfill our specific requirements and customization for the market. Our robot serves multiple important purposes. Firstly, it efficiently collects tennis balls, saving time and effort during practice sessions or matches and allowing players to concentrate on their game without interruptions.

Additionally, the presence of ball collector robots in professional tennis events has the potential to greatly enhance the spectator experience. The inclusion of such advanced technology adds a futuristic and engaging element to the game, improving overall enjoyment for the audience.

We firmly believe that our project aligns with the goal of advancing technology solutions in various aspects of our lives, making human life easier and more efficient. To achieve this, we have taken into consideration both the outer design of the robot and the implementation of new technologies to incorporate impressive features.

In summary, our autonomous tennis ball collector robot serves as an efficient solution that supports technological advancements, making the lives of individuals more convenient and effective. We have prioritized design and incor-

porated cutting-edge technology to create a superior robot with exceptional capabilities.

## 6.2 Future Work

Much can be done as future work regarding our version which aims to leverage robotics technology, the goal as we mentioned is to streamline and automate processes in sports, enhancing efficiency and reducing the need for manual labor.

We will install an additional camera at the top of the tennis court to enable the localization and detection of all the tennis balls present. This camera will capture the necessary visual data, and object localization will be performed based on grid coordinates. These grid coordinates will then be used as inputs for our path planning algorithms.

Once the optimal path is generated by the path planning algorithm, The information collected from the tennis ball detection system will be sent to the control system of the robot. The control system will interpret the path data and guide the robot to navigate the court efficiently, ensuring that all tennis balls are collected along the determined path.

By incorporating this camera-based object localization and path planning system, we will aim to enable the autonomous future robot to effectively detect and collect tennis balls while following an optimized path.

# References


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