Play Room Organizer

Presented in partial fulfillment of the requirements for Bachelor degree in Computer Engineering

Faculty of Engineering and Information Technology | Computer Engineering Department

Academic Year: Summer Semester 2021/2022

Hardware Project

Student Names: Masa Koni
Mai Fahed
Ahmad Atout

Supervisors: Dr. Samer Arandi
Dr. Emad Natsheh

Date: 05/09/2022

Acknowledgment

We would love to extend our sincere appreciations to all individuals who helped us in this project. Without their support and help, it would not have been possible. We are highly grateful to Dr.Samer Arandi and Dr.Emad Natsheh for their guidance and relentless supervision in providing the essential material about the project along with their support in completing the project. A huge thanks goes to our families for supporting us during this difficult and stressful experience, and our colleague who helped us in developing the project and individuals who helped us out willingly.

Disclaimer

This report has been written by Masa Koni Ahmad Atout and Mai Fahed at the Computer Engineering department, Faculty of Engineering, An-Najah National University. It has not been altered or corrected, other than editorial corrections, as a result of assessment and it may contain language as well as content errors. The views expressed in it together with any outcomes and recommendations are solely those of Masa Koni, Mai Fahed and Ahmad Atout. An-Najah National University accepts no responsibility or liability for the consequences of this report being used for a purpose other than the purpose for which it was commissioned.

Contents

List of Figures

Nomenclature

Abbreviations

Abbreviation	Definition
CHT	Circular Hough Transform
HMI	Human Machine Interaction
2DOF	Two Degrees of Freedom
DC	Direct Current
LED	Light Emmiting Diode
VNC	Virtual Network Computing
OS	Operating System
SD	Secure Digital

Abstract

Most parents work full time jobs and have limited time to spend with their kids. The Play Room Organizer was suggested to organize toys in different piles. It will save the cleaning time; help teach kids about colors and give the parents more time to do other activities with their children. The main feature for distinguishing the objects is color detection using image processing. The car will have three modes, first mode is the automated mode where the car sorts the objects according to color and put them in the suitable place, second mode is manual mode using hand gestures, where the person decides which object he want, pick it up and put it in the place he wants and the last mode is voice control where the car picks the object according to the command from the person and put it in the suitable place. The python code for finding the objects was developed alongside the Arduino code that determines how the car will reach the object, and then the hand gesture and voice module codes were developed. Similar projects are in the market but does not have the hand gesture and voice control features.

1 Introduction

1.1. Problem

Playroom areas are always in use of the children and tiding the room takes a lot of time and effort from parents also, kids don't like cleaning their rooms. A solution was introduced which is to build a robot that turns cleaning to a game, kids will have fun, learn the colors, and tidy the room in the process. The robot will have three modes, the first organises balls in different boxes automatically which can be used for cleaning the room only, and two interactive modes for the kids, one that is controlled by voice, and the other is controlled by the kid's hand gesture.

1.2. Objectives

The main purpose of building a robot like this is to lighten the burden on people from having to do all the work manually , especially if the work is in huge amounts, and create an automated robot that does all the organization. And particularly in discarding parents from the duty of cleaning the constant mess the kids make, and help kids develop a better knowledge of colors and color names.

1.3. Scope of The Work

The project will deal with a combination of software and hardware components, for the hardware part Arduino mega will be used to control the hardware parts including, dc motors, servo motors, Bluetooth module, buttons, LED and voice module. For the software part raspberry-pi will be used associated with image processing, to detect shapes and colors and send commands to the Arduino.

1.4. Significance of The Work

Most parents work full time jobs and have rather a limited period of time in which they spend with their kids, and would like to spend this period bonding with their kids or teaching them new skills. The importance of this robot is offering parents longer time with their kids and help kids with distinguishing between the colors, their name and learning about directions. Another plus side for the robot is, organizing the room will not be something to worry about as the robot cleans the room while keeping the kid entertained.

1.5. Organization of The Report

The body of the report will start with the **The First Chapter, Introduction,** providing a background for the research. **The Second Chapter, Constraints and Earlier Coursework,** that shows project constraints, and who they were overcame and solved. Previously taken courses that were helpful in building this application in any step of its development.

Followed by **The Third Chapter, Literature Review,** which establishes familiarity and understanding of the current research and includes any similar project.

Then **The Fourth Chapter, Methodology,** that includes a systematic plan to resolve the problem, the process of building this robot, software tools, hardware equipment.

After comes **The Fifth Chapter, Results and Discussion,** to summarize the data collected, their statistical treatment and compare the results.

And finally **The Sixth Chapter, Conclusion and Recommendation,** will show the final project summary,with everything learnt in the journey of building it. Also, it'll introduce some of the features/subsystems that can be added in order to improve and enrich it.

2

Constraints and Earlier course work

2.1. Constraints

- The car could not hold heavy weight so the movement is sometimes slower than anticipated, so batteries have to be recharged continuously to avoid the slow movement.
- The delay from the raspberry-pi and from the camera is immense so the robot must move slowly in order to detect the objects.
- The Circular Hough Transform (CHT) is not very accurate and sometimes fail to detect circles, which results in not finding the balls from the first time. So we used CHT with a tolerable percentage of error.
- Time Limit: it has been implemented in a period of time being 2 months, which is considered a challenging amount of time to build this whole project in both parts software and hardware. Choosing the idea, deciding features, searching the topic, taking courses to deal with Arduino and raspberry pi, collecting sensors and control modules, writing the full code and assembling everything into the model.

2.2. Earlier Course Work

- **Image processing:** Helped with the image processing part used on the raspberry-pi.
- **Micro-Controllers:** Gave a background on how to deal with microprocessors and how to control the hardware parts through them.
- **CPU Lap:** Helped with debugging the hardware, and finding when and where it is faulty.
- **Critical Thinking and Scientific Research:** Introduced how to perform a good research and write it into paper. And presented latex markup and solid scientific paper writing was made possible through this course.
- **Micro controllers Lab:** Brought theoretical knowledge into practice in dealing with I/O, serial communication, motors, and had a last part in which Arduino programming was introduced for the first time.
- **Digital Circuits Lab:** Introduced dealing with mini-circuits which are the main building blocks of this project in the first place, wiring them breadboards and testing them.

3

Literature Review

This paper discusses image processing techniques to detect objects and organize them in different boxes by deriving the results to hardware parts to move the robot to the right box. Many papers were published with different methods to detect objects.

After studying these papers; it was decided to use CHT to detect the circles. Some robots were used for Human-Machine Interaction (HMI), so the robot had to be accurate, fast and robust. 3D sensing (stereo) was used to fulfill the accuracy and robustness with state-of-the-art estimation algorithms (Birbach and Frese,2009) [1]. Handling multiple flying balls and reducing the initiation time in a new environment. But such accuracy was not needed for this robot because the balls are going to be still.

Another paper was published about an entertainment robot for playing ball and it did not require a specific ball color or background structure, it's main purpose is engaging the human in a robot-human game by intercepting and not making any action after (Laue et al., 2013) [5].

While reading papers about moving balls it was clear that a complex algorithm is not needed in this project. So, it was decided to look for the best algorithms for still balls. The CHT is probably the most widely used technique for detecting circular shapes within an image.(Flores-Mendez and Suarez-Cervantes, 2009) [3].

As in "The Hough transform versus the UpWrite", the CHT was introduced and compared it with the UpWrite for detecting circles, lines and ellipses. It was concluded that the accuracy of object detection, for ideal images and images with speckle noise, depends on the complexity of the object being detected (McLaughlin and Alder, 1998) [7]. Concluding that CHT would be great in this case as images are with speckle noise.

For further Studying about what method to use, "Comparative study of Hough Transform methods for circle finding" introduced five methods for circle detection that are based on variations of the Hough Transform. The five methods are: the standard CHT, the Fast Hough Transform of Li et al.1, a two stage Hough method, and two space saving approaches based on the method devised by Gerig and Klein2. The methods have been applied on real images and synthetic imagery, and compered based on reliability, accuracy, computational efficiency, and storage requirements. (Yuen et al., 1990) [10].

For building the physical hardware components deep research was established to know the basics for building robots using Arduino. It was found that using a car structure is to be included to make the movement easier (Malachowska and Severinsson, 2019) [6].. As in a golf ball collector robot the robot uses a Pixy camera to detect golf balls and charging station. The software was programmed via an Arduino Mega and The prototype was created mainly using lathe, mill, 3D printer, laser cutter and a vacuum forming machine. (Olsson and Kringberg, 2016) [8].

Another 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 (Chen and Dai, 2016) [2]. Helped in introducing both interactive and automated mode for Playroom Organizer Robot.

All researches related to ball detection focused on image processing. Another study was performed to detect a blob using OpenCV library, and implemented it by designing and constructing a simple mobile robot. The main focused was using HCT to detect the position of balls. By using Bluetooth module as a serial communication, the computer will send signal to the mobile robot to move and grab the ball. This study shows a satisfactory result in which averaging a 60% successful rate in the executions of the program (Owen, 2011) [9].

4

Methodology

In this chapter, we are going to talk about the design of the system, the components that were used to accomplish it, and discuss the development process and the outcome at the end of that process afterward.

4.1. Overview of The System

In this research, a smart robotic car was developed, operating in several modes and understanding the environment around it. To achieve such results Raspberry Pi and Arduino were used as controllers.They were utilized together to add a challenge in learning new things. Establishing serial communications between them (Krauss, 2016)[4].

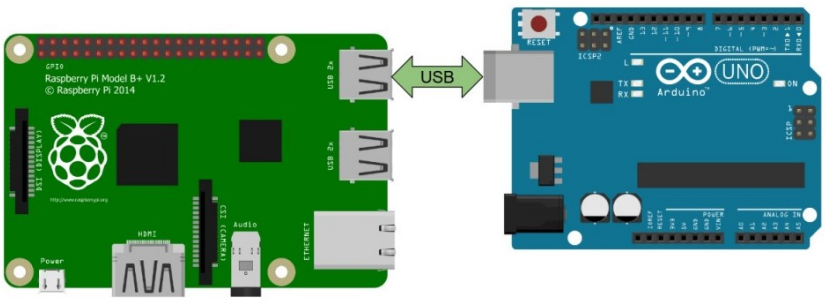

Figure 4.1: Serial communication between Raspberry pi and Arduino

In the automated mode and the voice control modes the Raspberry Pi served as the robot's brain while Arduino served as its muscles, except when the user decided which color he wants. The Raspberry pi process the captured frames from the raspberry pi camera and then sends commands to the Arduino to control the robot's movement; using four Direct Current Motors (DC) connected with wheels, a servo motor that controllers a gripper and ultrasonic sensor in the front of the robot to avoid collision and measure the distance to the ball.

While in the hand gesture mode it was all Arduino work, the robot moves according to signals sent from the Arduino UNO with an accelerometer that has a predefined responses for the different angles the user perform.

4.2. Hardware Components

In this section, the design and tools used are described so as to show the full process of Play-Room Organizer's development and its basis.

4.2.1. Car Structure

1. Arduino Mega 2560:
   The Arduino mega was used as the main micro-controller for the robot. It was providing signals to control the movement of the robotic car, and communicating with all the hardware in the project.

Figure 4.2: Arduino Mega 2560 micro-controller

2. Raspberry Pi 3 model B:
   A Raspberry pi 3 model B was used for its wide abilities with image processing using the raspberry pi camera module.

Figure 4.3: Raspberry Pi 3 model B

3. Raspberry Pi Camera Module Version 2.0:
   A raspberry pi camera module v2 was used to capture live images of the area so the raspberry pi could process them and make the robot aware of the shapes surrounding it.

Figure 4.4: Raspberry Pi Camera Module

4. Power Bank:
   A power bank was used to supply the Raspberry Pi and Arduino mega with 5 Volts and 2 Ambers.

Figure 4.5: Power Bank

5. DC Motors:
   DC motors are the most common type of motor to move wheels of cars. DC motors normally have just two leads, one positive and one negative. If the two leads were connected directly to a battery, the motor will rotate. If the leads are switched, the motor will rotate in the opposite direction.

Figure 4.6: DC Motors

Figure 4.7: Wheels

6. H bridge:
   Was used to control the direction of the spin of DC motor, without changing the way the leads are connected. An H bridge is an electronic circuit that can drive the motor in both directions. H-bridges are used in many different applications, one of the most common being to control motors in robots. It is called an H-bridge because it uses four transistors connected in such a way that the schematic diagram looks like an ”H”.

Figure 4.8: H-bridge Motor Driver

7. Servo Motor:
   A servo Motor MG995 to control the 3D printed robotic arm.

Figure 4.9: Servo Motor

8. 3D Printed Robotic Arm:
   A 3D printed robotic Arm that is connected to a servo motor to catch balls.

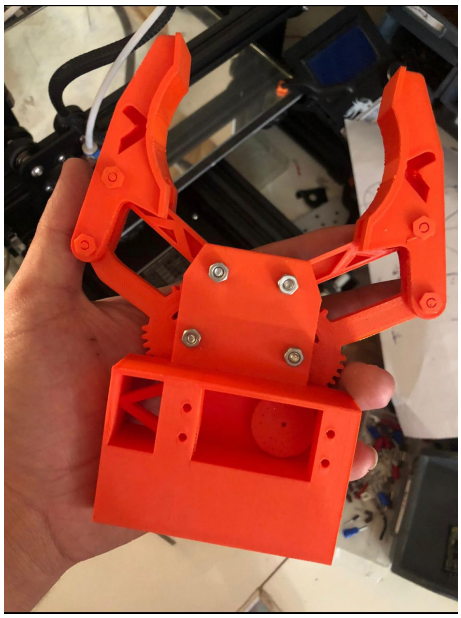

Figure 4.10: 3D Printed Robotic Arm

9. Lithium Batteries:
   Lithium batteries were used because of the high current they provide, and motors are known for their need of high current and voltage to be able to move such heavy robots. 12 Volts were used as a power source for DC motors, and 4 Volts were used as an external power source for the Servo motor.

   NOTE: Please take care while using lithium batteries. When the batteries fail to operate safely or are damaged or a short circuit happens, they may present a fire or explosion hazard.

Figure 4.11: Lithium Batteries

Figure 4.12: Lithium Batteries holder

10. Diode:
    A diode is a semiconductor device that essentially acts as a one-way switch for current. It allows current to flow easily in one direction, but severely restricts current from flowing in the opposite direction (Zhang et al., 2015) [2]. So a diode was used to cancel the return current that was coming from the lithium batteries through the H-bridge.

Figure 4.13: Bluetooth Modules HC-05

11. HC-SR04 Ultra Sonic Sensor:
    The HC-SR04 Ultrasonic distance sensor is built around two ultrasonic transducers. The first functions as a transmitter, converting electrical signals into ultrasonic sound pulses at 40 kHz. The receiver detects sent pulses. If it receives them, it generates an output pulse whose width can be used to calculate the pulse's distance traveled. So Ultrasonic sensors were used to calculate distance between the robotic car and the object it wants to catch and for obstacle avoidance.

Figure 4.14: HC-SR04 Ultra Sonic Sensor

12. Voice Recognition Module:
    A voice recognition module was used for the voice mode in the robotic car.

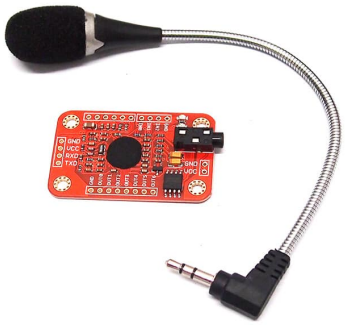

Figure 4.15: Voice Recognition Module

13. Breadboard:
    To connect All the pieces together and form a unified system.

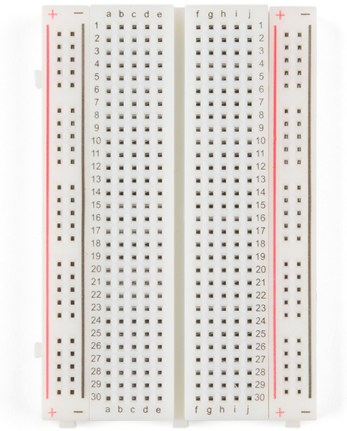

Figure 4.16: Breadboard

14. HC-05 Bluetooth Module:
    HC-05 Bluetooth Module was used for communication between the glove that was used for hand gesture movement mode and the Arduino on the robotic car.

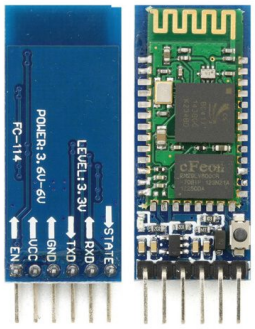

Figure 4.17: Bluetooth Modules HC-05

15. Light Emitting Diode:
    LEDs were used as a visual representation to show what state the robot is running in.

Figure 4.18: LED

16. Push Button:
    Push button was used to change between the three modes the robot operates in, and change between the two modes in the hand gesture part.

Figure 4.19: Push button

4.2.2. Hand Gesture

1. Arduino UNO:
   It was used in the hand gesture feature to read values given from the accelerometer sensor and push it to the Bluetooth module that communicates with the Arduino on the robotic car.

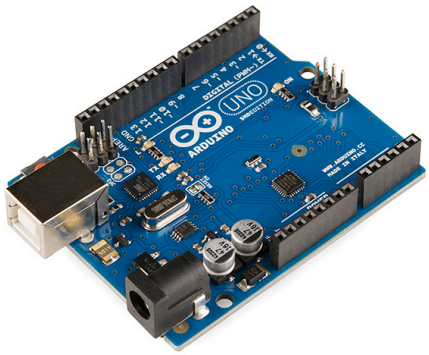

Figure 4.20: Arduino UNO

2. Accelerometer:
   A gt-61 accelerometer was used to calculate the hand gesture movement according to the x-y-z axis.

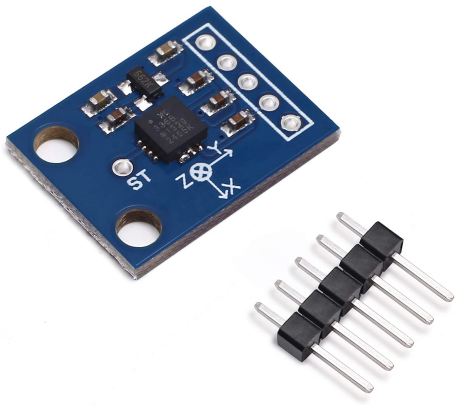

Figure 4.21: GY-61 Accelerometer

4.3. Robot Assembly

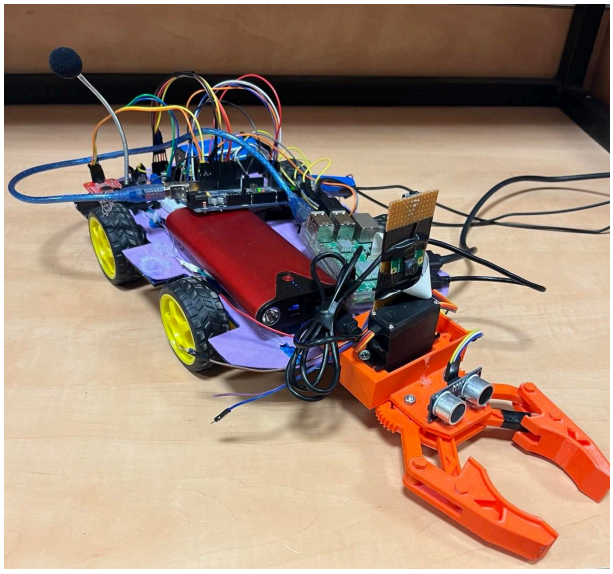

Figure 4.22: Front View for Playroom Organizer

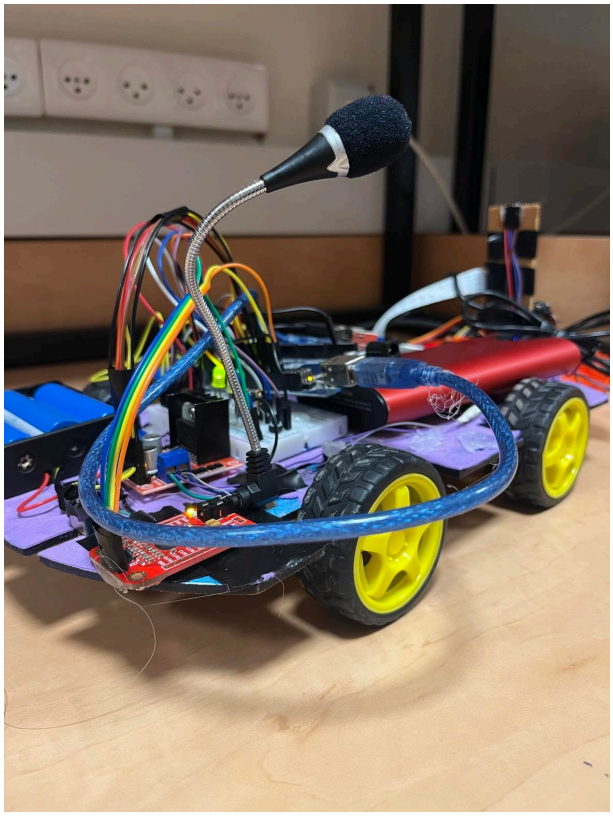

Figure 4.23: Back View for Playroom Organizer

4.4. Implementation

4.4.1. Raspberry Pi

Raspberry Pi was used to control the movement of the car and to detect objects:

- **Circle Detection:**
  Balls are detected by applying a series of filters. The GaussianBLur filter is first applied to soften the edges and reduce the noise. Then the frame is converted to Hue Saturation Value because, HSV is used to separate image luminance from color information making it easier when we are working on or need luminance of the frame.

  Then a threshold is applied on the frames with the upper and lower bound of each color (red, green, blue) to detect all objects within a specified bound. That is followed by a series of erosion and dilation filter to also increase the accuracy for detecting balls.

  Finally the contours are found from the frame after the processing, then HCT function is applied with parameters that were determined by trial and error. To ensure that the counters that are found are circles two test cases must be met which are. If the center of the circle is almost equal of the center of the contour. If the area the circle is almost equal to the area of the contour.

- **Car Movement:**
  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 raspberry requests the Arduino to move forward a little so it can detect objects in different areas.

  If the camera detects a 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 car 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 car according to the Ultrasonic sensor. When the ball is caught the raspberry pi sends a command called 'Hand' o the user decides where he wants to put the ball.

4.4.2. Arduino

- **Car Movement:**
  Car 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 until the raspberry sends "ForwardtoBall" 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 the Raspberry will send "Forward05m" command, then the Arduino goes forward 0.5 meter to scan and search for balls again.

A ”ForwardToBall” 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 ”RotateLtoBall” or ”RotateRtoBall” 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 ball using an ultrasonic sensor distance. Dropping the ball in the suitable box will be completed by the hand gesture mode once the gripper have picked up the ball.

- **Voice Recognition:**
  Car movement is controlled by waiting for serial commands from voice recognition module that is connected with the Arduino to raspberry pi, when it receives a command it decides what action to take according to the code.

  The commands are ”Green”, ”Red” and ”Blue”, when it receives to Raspberry Pi, the raspberry pi will start detecting the target ball and sends ”SearchBalls” to the Arduino, causing the Arduino to rotate right in short steps until the Raspberry sends ”Forwardto-Ball” indicating the target ball has been found.

- **Hand Gesture:**
  The robotic car movement is controlled by the human hand gesture Using several components interacting with each other. The main component that was used to detect the angles of the hand movement is the GY-61 Accelerometer, An accelerometer is a device that measures the force of acceleration due to gravity along the X, Y and Z axis. It applies in all the applications requiring tilt sensing.

  The accelerometer measures the acceleration and produces a voltage proportional to the acceleration. Any micro-controller with analog Pins can read this voltage. This accelerometer gets connected to the Arduino that is placed on the wearable glove along with the accelerometer and the HC-05 module and gives the Arduino the exact measurements of the x-y-z axis voltages as an analog input so the Arduino could process these values and decide the right action to do. after receiving those values the Arduino code processes them and decide to which direction the robot should go and sends those values to the robotic car Arduino using the HC-05 Bluetooth module which communicates with the Arduino serially and with the other HC-05 module placed on the robotic car wireless using Bluetooth Signal. HC-05 modules gets configured to recognize each other and connect to send and receive data in between the slave (the module on the robotic car) and the master(the module on the glove).

  The Arduino on the glove processes the values taken by the accelerometer and based on it decides what command it should send to the other Arduino on the robot, the command could be ”move forward”, ”move backward”, ”turn left” and ”turn right”, so when the Arduino on the robot receives those commands, it behaves based on what was received.

  A push button was placed on the wearable glove to switch between two modes, The first mode sends movement commands (the one that was talked about before) and the other mode sends commands to control the gripper on the robotic car which are ”grab” and ”release”.

5

Results and Analysis

The final product is a robotic car with three modes, the first mode is a fully automated mode that organizes balls in different boxes, the second mode controls the car by hand gesture, and the last mode controls the car by voice. Many challenges were encountered during the development process.

Starting with OpenCV, from detecting objects and trying to reduce the percent of error in ball detection. As the process of finding balls depends majorly on good lighting and slow movement from the car.

Due to the absence of hardware parts in the local market and the high price, it was difficult to find parts, such as Raspberry Pi and lithium batteries. Raspberry Pi, H-bridges, servo motors got burned while testing the project, which caused a delay in completion.

The Raspberry Pi was burned due to its high sensitivity. It was difficult to deal with the servo motor, that pulled a high current, which lead us to use lithium batteries instead of Duracell batteries. The H-bridge returned current into the circuit, which caused defects in our work.

6

Discussion

6.1. Testing

- Automated mode, the Arduino mega is connected directly to the Raspberry Pi via serial port and the Raspberry Pi is powered by a power bank, the car was able to detect balls placed around the car by Raspberry Pi camera. This was done several time to ensure that the code and method were both valid.
- A power bank was connected to the Arduino for the hand gesture mode, while the other Arduino was connected to a pair of Duracell batteries and they communicated via Bluetooth with each other. The robotic car emulated the exact motion of the input action after the glove is worn, and the person made a specific gesture while wearing the glove.
- Voice mode involves connecting an Arduino mega to a Raspberry Pi via serial port and powering up the Raspberry Pi with a power bank. This test requires a person to speak a specific color to the voice recognition module, Then the Raspberry Pi camera used by the robotic car to detect the balls based on the input color voice.

6.2. Learning Curve

It is undeniable that some things needed additional research and some extra trial, but with a great set of documents, plenty of online tutorials, and a community of supportive people, the learning mission was not as challenging or steep as it initially seemed. Our system required learning about new hardware parts that we were not familiar with before and had to learn from scratch while developing it. We learned about Raspberry Pi, having knowledge about this hardware part was important to us because it helped us develop a simple and effective method of controlling a robot with a Raspberry Pi camera.

7

Conclusions and Recommendation

7.1. Things we learned

- How to access Raspberry Pi through Virtual Network Computing (VNC), how to use it with Arduino together and send commands, and how to download its Operating System (OS) on Secure Digital (SD) card.
- Understanding how to use motors such as a servos and DC motors to meet the needs of the application.
- How to set up an accelerometer on the Arduino.
- How to use a voice recognition module with the Arduino board and how to train this module with voice instructions.
- How to develop problem solving skills.

7.2. Future Work

Future work will include making the robot detect different patterns to pick up more objects. Attaching servo motor to the camera, so the robot will be able to cover a larger area without moving. A future feature will also include saving the robot's path after dropping the ball, allowing it to return to its original location before catching the ball by reversing its steps.

The robot is proposed as a prototype for a big robot to transport goods in warehouses and harbors. The Robot will pick goods from the trucks and place them at their appropriate places. Text recognition and bigger scale will be used, which provides a more efficient and time-saving manner to organize the goods.

References

[1] Oliver Birbach and Udo Frese. “A multiple hypothesis approach for a ball tracking system”. In: *International Conference on Computer Vision Systems*. Springer. 2009, pp. 435–444.

[2] Hung-Kuang Chen and Jyun-Min Dai. “An Intelligent Tennis Ball Collecting Vehicle Using Smart Phone Touch-Based Interface”. In: *2016 International Symposium on Computer, Consumer and Control (IS3C)*. 2016, pp. 362–365. DOI: 10.1109/IS3C.2016.100.

[3] Alejandro Flores-Mendez and Angeles Suarez-Cervantes. “Circular degree Hough transform”. In: *Iberoamerican Congress on Pattern Recognition*. Springer. 2009, pp. 287–294.

[4] Ryan Krauss. “Combining Raspberry Pi and Arduino to form a low-cost, real-time autonomous vehicle platform”. In: *2016 American Control Conference (ACC)*. IEEE. 2016, pp. 6628–6633.

[5] Tim Laue et al. “An entertainment robot for playing interactive ball games”. In: *Robot Soccer World Cup*. Springer. 2013, pp. 171–182.

[6] Julia Malachowska and Ellen Severinsson. *Robotic ball retrieving: A method to detect, collect and retrieve a ball*. 2019.

[7] Robert A McLaughlin and Michael D Alder. “The Hough transform versus the UpWrite”. In: *IEEE Transactions on pattern analysis and machine Intelligence* 20.4 (1998), pp. 396–400.

[8] Marcus Olsson and Fredrika Kringberg. *POKI: Robotic ball collector on golf ranges*. 2016.

[9] Keane Owen. “IMPLEMENTING IMAGE PROCESSING IN DESIGNING AND CONSTRUCTING A BALL COLLECTING ROBOT”. PhD thesis. Swiss German University, 2011.

[10] HK Yuen et al. “Comparative study of Hough transform methods for circle finding”. In: *Image and vision computing* 8.1 (1990), pp. 71–77.

[11] Yuhao Zhang et al. “Origin and Control of OFF-State Leakage Current in GaN-on-Si Vertical Diodes”. In: *IEEE Transactions on Electron Devices* 62.7 (2015), pp. 2155–2161. DOI: 10.1109/TED.2015.2426711.