T.C.

BAHÇEŞEHİR UNIVERSITY

FACULTY OF ENGINEERING AND NATURAL SCIENCES

CAPSTONE FINAL REPORT

DODGEBALL PROJECT-I

Samed Ergün Işık Computer Engineering

Onur Karıncaoğlu Computer Engineering

Baris Deniz Kaya Electrical and Electronics Engineering

Mustafa Efe Satıroğlu Computer Engineering

Helin Turğut Electrical and Electronics Engineering

Advisors: Assist. Prof. Evrim Tetik Electrical and Electronics Engineering,

Assist. Prof. Selin Nacaklı Computer Engineering.

ISTANBUL

ABSTRACT

DODGEBALL PROJECT-II

Samed Ergün Işık Computer Engineering

Onur Karıncaoğlu Computer Engineering

Baris Deniz Kaya Electrical and Electronics Engineering

Mustafa Efe Satıroğlu Computer Engineering

Helin Turğut Electrical and Electronics Engineering

Faculty of Engineering and Natural Sciences

Advisors: Assist. Prof. Evrim Tetik Electrical and Electronics Engineering,

Assist. Prof. Selin Nacaklı Computer Engineering.

The Dodgeball Robot project is an autonomous robot designed using sensor and camera systems. The robot is built with an Arduino and operates with the help of ultrasonic sensors. Additionally, it incorporates a camera system to enhance its ability to dodge balls thrown at it. The robot, equipped with four wheels, moves left or right to avoid the balls. It is designed to successfully evade 9 out of 10 thrown balls. Each wheel is powered by a motor, and a motor driver is used to control the speed and torque of these motors. To expand the robot's field of vision, multiple ultrasonic sensors with limited viewing angles are employed. Powerful batteries and an additional power source directly connected to the Arduino ensure adequate power supply to the sensors and motor driver. This setup has been proven effective, with the Dodgeball Robot successfully dodging the majority of the balls thrown at it, demonstrating the project's successful implementation and functionality.

Key Words: Arduino, distance sensor, autonomous, motor driver, dodging.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

DC	Direct Current
RPM	Revolutions per Minute
V	Volt
STEM	Science, Technology, Engineering, Mathematics
3D	Three Dimensional
USB	Universal Serial Bus

1. OVERVIEW

The primary objective of this project is to create a robot capable of evading incoming balls. When the robot detected a nearby incoming ball, it took evasive action to prevent being hit. This required the robot to move swiftly enough to evade the ball effectively. Balls were thrown at varying speeds to assess the robot's performance, with the criteria for success involving the robot successfully dodging the targeted ball in at least 9 out of 10 trials at lower speeds. To achieve this, the robot utilized distance sensors and a camera-based system, amalgamating the data collected from these individual components to enhance its dodging capability.

For the electronic part of the project, Electrical – Electronics Engineering students have constructed the main body of the robot. An Arduino board has served as the microchip of the robot, controlled by an L298n motor driver, powered by a total of 12V batteries with 9V battery which is connected directly to Arduino UNO, and equipped with four HC-SR04 sensors, each with a 15-degree field of view, for detecting incoming balls. 6V DC motors have been connected to each wheel for movement capability. A code has been written to instruct the robot to move right when a ball approached from the left and left when a ball approached from the right. This code has been developed using the C++ programming language. The sensors have been precisely positioned to improve ball detection. After the completion of the robot, experiments will be conducted using tennis, handball, and volleyball balls.

The Computer Engineering students contributed by developing the software and camera system to track and predict the trajectory of the incoming balls. Using computer vision, the camera system detects the ball in real time and calculates their speed and direction. This data is then processed by the software to determine the optimal evasion path for the robot. The integration of these systems allows the robot to make quick and accurate decisions, enhancing its ability to dodge incoming balls effectively.

1.1. Identification of the Need

Our dodgeball robot can be utilized in various applications within industrial automation. It can optimize conveyor belt operations and prevent collisions between machines, thereby enhancing workplace safety. This allows for increased operational efficiency and elevates the effectiveness and safety of industrial automation to a new level. Additionally, it can also find application in the realm of sports. It can be used in athletes' training and education to improve their reflexes, speed, and tactics. Moreover, in schools' STEM programs, it can be employed to provide education in robotics and engineering.

In essence, our dodgeball robot embodies innovation and adaptability, seamlessly integrating into diverse environments to drive efficiency, safety, and learning. Whether in industrial facilities, sports training centers, or classrooms, its multifaceted capabilities empower users to elevate their operations, performance, and knowledge to new heights.Begin the second paragraph here.

1.2. Definition of the Problem

The dodgeball project necessitates the integration of sensors capable of swiftly detecting incoming balls and determining their trajectory. The robot's response should be rapid, enabling it to evade the ball successfully in at least 9 out of 10 instances. Additionally, it must accurately gauge the distance to the ball and ensure consistent ball speed, facilitating predictable evasion maneuvers.

The Computer Department students will spearhead the development of a sophisticated camera system. This system will continuously track the ball, generate a visual representation of its trajectory, and store the latest positional data for the robot's reference. Moreover, it will be equipped to transmit real-time signals to the robot, prompting it to relocate to the optimal position for evasion.

1.2.1. Functional Requirements

The dodgeball robot's primary function is to detect the ball coming towards it and determine the easiest escape route. Once the robot detects the ball, it stops fleeing when it realizes it won't collide with the ball. To successfully complete this task, the robot needs to escape successfully from 9 out of 10 throws. The distances and angles at which the ball will be thrown will be determined during the testing phase to ensure the robot can accomplish this task successfully.

The camera system plays a crucial role in addressing the problem. It continuously monitors the robot's surroundings, identifies incoming balls, and calculates their trajectories. This data is then used to update the robot's movement strategy in real time, ensuring it can respond quickly and accurately to avoid collisions. The software is designed to handle varying speeds and directions of the balls, providing a solution to the dodging challenge.

1.2.2. Performance Requirements

The product should Dodge the ball 9 out of 10. Also, the sensor will cover a specific area in the direction where the ball will be thrown. Each of the 4 HC-SR04 ultrasonic sensors used in our robot has a scanning angle of 15 degrees. Therefore, the robot can scan a maximum angle of 60 degrees. However, this scenario can only be achieved if the scanning areas of the 4 sensors do not overlap. Since this situation seems unlikely in our robot, we estimate the scanning angle of the robot to be 50 degrees, determined by taking the midpoint of the 4 sensors. All ultrasonic sensors in the robot are oriented in the same direction. As a result, the robot can only detect balls coming from the side where the sensors are located. Additionally, the robot's movement capability is limited to a single axis. To accurately measure the robot's performance, ball throws will be conducted using a ramp. This ensures consistent ball speed and angle, resulting in more precise data collection without variations.

The camera system must operate efficiently under various lighting conditions and should be able to process the video feed in real time. The software developed by the computer engineering students should ensure that the robot can make quick and accurate decisions based on the visual data. This requires the system to have a high frame rate and low latency, ensuring the robot's responses are timely and precise.

1.2.3. Constraints

Developing dodgeball robots there are various constraints. These include cost considerations, as the project can be financially demanding, impacting design choices and materials. Safety regulations must be strictly adhered to in industrial environments to ensure worker and equipment safety, while accuracy and precision are crucial for optimizing processes and simulating game scenarios effectively. Technological reliability and scalability are also essential, alongside energy efficiency and user-friendly interfaces for easy control and maintenance. Moreover, ethical and social implications of robot usage should be carefully considered throughout the project's development. By addressing these constraints comprehensively, the successful deployment and integration of dodgeball robots in diverse settings can be achieved.

In addition to the physical constraints of the robot's design, the camera system and software must operate within the computational limits of the onboard hardware. The algorithms used for image processing and trajectory prediction need to be optimized for performance, ensuring they can run efficiently on the robot's microcontroller. Additionally, the system must be robust enough to handle variations in lighting and environmental conditions.

1.3. Conceptual Solutions

The main problem is face in this project is the budget. Due to budget reasons, Due to these reasons, the HC-SR04 ultrasonic sensor has been selected as the most suitable sensor for us. This sensor is both inexpensive and easy to use. By utilizing multiple of HC-SR04 sensors, we achieve a higher scanning capacity and maintain the quality of more precise sensors. During the testing phase, it was determined that there was insufficient space on the robot to accommodate the HC-SR04 sensors. To address this issue, a T-shaped component was designed and printed using a 3D printer. After attaching this T-shaped component to the front of the robot, all the HC-SR04 sensors were mounted on this part. This configuration provided a larger scanning area and facilitated the collection of test data. To facilitate easier programming and usage of these sensors, the microchip Arduino Uno has been chosen. This not only aids us in programming but also helps us stay within budget. Additionally, electrical and electronic engineering students involved in the project have prior experience with Arduino from other projects, providing them with an advantage in this project. Furthermore, due to budget constraints, high-powered motors were not used. Instead, 4 piece 6V DC motors were employed, with each providing power to a separate wheel. This resolves issues related to traction and speed. Additionally, the dimensions of the robot were minimized to facilitate easier evasion of balls. With the dimensions deemed suitable, all necessary components of the robot were assembled within a 25cm-long space.

The Computer Engineering students proposed using a camera system integrated with the robot to enhance its dodging capabilities. This system, combined with the ultrasonic sensors, provides a comprehensive solution for detecting and avoiding balls. By leveraging image processing techniques, the camera system can accurately track the balls' trajectories, allowing the robot to make informed decisions about its movements. This approach balances cost, complexity, and performance, ensuring the robot can operate effectively within the project's budget constraints.

1.3.1. Literature Review

There are not many similar products on the market that will be produced in this project. However, when looking at similar product, the biggest difference of the product to be created in this project is that it is cheaper and portable compared to other products. It can provide the same functionality with such advantages.

The literature review I conducted within the scope of the project focused on examining the important findings of a previous similar project. The study other project successfully implemented a robot's strategies to evade incoming dangerous objects in a similar context. The basis of the project is the effective integration of high-resolution cameras and image processing algorithms. This project was successful in enabling the robot to effectively monitor its environment and plan its movements, thus avoiding dangerous objects. However, despite this work in existing literature, we aim to take a unique approach in this project. In particular, in our project "DodgeBall" we aim to make a robot that avoids incoming balls adopt a more dynamic and adaptive strategy. This strategy is designed to include new features such as the ability to predict the movement of balls, sensitivity to environmental variations and faster response. In this way, it will be possible to understand how our project will contribute compared to previous studies in the literature and how it will enrich the knowledge in the field.

1.3.2. Concepts

In this project one of the important thing is Budget. Because with this budget, we have limited options. The other thing is features. All features will be available, but concealer areas will vary. The last thing is complexity. If a too complex structure is used, there is a possibility that the project will fail. For this project, three different concepts were considered. The first concept is high in cost but also high in features. Additionally, its installation and usage are moderately complex. This concept involves using a single lidar sensor. Furthermore, high-speed and high-torque motors are used in this concept. The second concept has a moderate cost, average features, and complexity. In this concept, 2 precise ultrasonic sensors are considered. The third concept is low in cost but average in features and complexity. Although its complexity is average, it is more complex than the second concept. In this concept, it is proposed to use inexpensive 4 ultrasonic sensors (HC-SR04). There is no difference between the second and third concept in terms of motors and microchip used. The only difference lies in the sensors employed.

The third concept was selected for implementation due to its balanced approach to cost and performance. This concept employs three HC-SR04 ultrasonic sensors for object detection and a camera system for real-time tracking and trajectory prediction. The integration of these components provides a solution for the robot's dodging capabilities. The camera system enhances the robot's ability to detect and avoid incoming balls, complementing the ultrasonic sensors and ensuring a higher level of accuracy and efficiency.

Table 1. Comparison of the three conceptual solutions.

	Concept 1	Concept 2	Concept 3
Cost	high	low	medium
Complexity	medium	low	medium
Performance	High	medium	low
Features	high	medium	high

1.4. Physical Architecture

In this project there are 3 main part for physical arhitecture. Sensor, base, microcontroller. First one is sensor. The sensor is one of the most important part of the robot. Sensor is going to detect the incoming ball and measure their proximity. Then provide essential data to the microchip. For the sensor one of the best option is ultrasonic sensors. HC-04 sensor will be used as a ultrasonic sensor. The reason for selecting the HC-SR04 sensor is due to budget constraints and ease of use. For us, programming these sensors is easier compared to other options. To cover a larger scanning area and determine the direction of the ball's approach more precisely 4 piece HC-SR04 sensors have been utilized. The HC-SR04 sensors are positioned side by side.

The Second part is base. The REX Chassis Series 4WD Multi-Purpose Mobile Robot Platform has been selected as the robot platform. The purpose of choosing this platform is to create a robust structure while also obtaining more space without significantly increasing the size of the robot, thanks to its double-layered design. Additionally, the transparency of the platform makes it easier to detect and resolve any issues that may arise. Top of the base there should be breadboard for circuit elements. At the bottom there are 4 wheels and 4 piece 6V DC electric motors is located. The sensors are longitudinally arranged on one side of the robot, allowing for more space to be allocated for their positioning. This enables the robot to scan a larger area, facilitating more comprehensive area coverage.

Third part is microcontroller. For the microcontroller Arduino UNO is the best option. Arduino Uno has been deemed suitable for this structure due to its compact size and low power consumption. Additionally, the selected sensors and motors work very well with Arduino Uno, providing a high level of compatibility. In addition to this, as an electrical and electronics engineering students we used Arduino before. So, it is easy for us to understand and deal with it.

Additionally, to enable individual control of the motors and to protect them from high currents, the L298N Voltage Regulated Dual Motor Driver Board has been chosen. This board facilitates and secures the connection between Arduino Uno and the DC motors.

The camera system, continuously captures video feed of the environment. This feed is processed in real time to detect incoming balls and predict their trajectories. The data from the camera is integrated with the data from the ultrasonic sensors, providing a comprehensive view of the robot's surroundings. The microcontroller processes this information and adjusts the robot's movements accordingly, ensuring it can dodge incoming balls effectively.

This figure shows the general design of the System. An easy way to determine the directions of energy and data from this diagram can be identified. This way, it becomes clearer how the system communicates and operates.

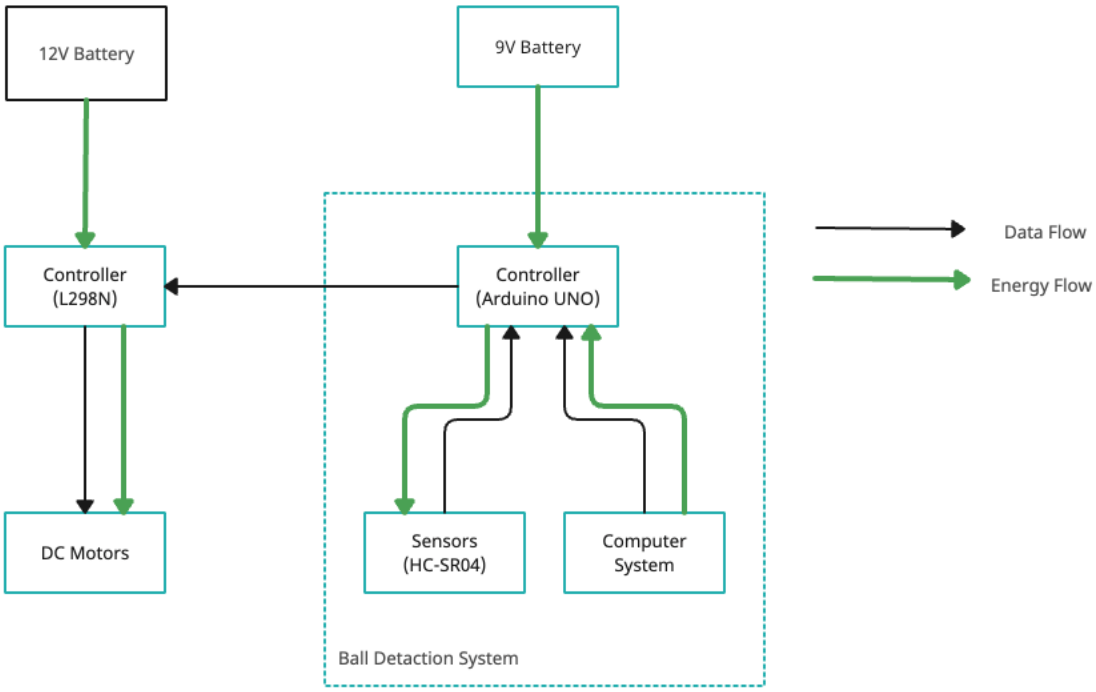

Figure 1. Interface diagram for the

The diagram clearly shows where the decision-making process takes place. Additionally, it provides insight into how the physical process operates.

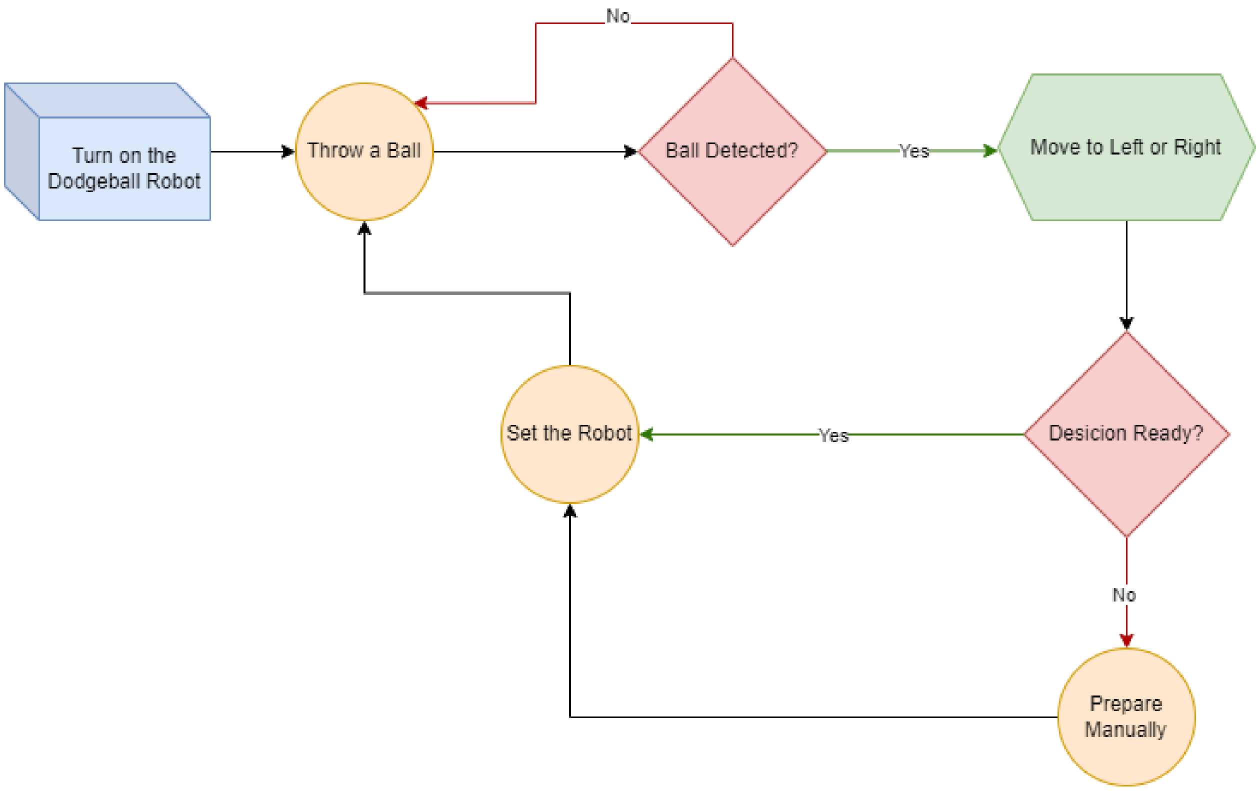

Figure 2. Process chart for the system

2. WORK PLAN

The Dodgeball Robot project has been developed through the collaboration of two sub-systems. The first sub-system, managed by Electrical-Electronics Engineering students, focused on the mechanical and electronic components, including sensors. The second sub-system, overseen by Computer Engineering students, developed the camera system and its associated software. The robot's primary function is to evade 9 out of 10 incoming balls using the integrated sensor and camera systems. The Electrical-Electronics Engineering students were responsible for the sensor-based mechanical and electronic aspects, while the Computer Engineering students developed the camera system.

The Computer Engineering students developed the camera system and the associated software to track the incoming balls and predict their trajectories. This involved programming the camera to capture real-time video feed, processing the images to identify the balls, and calculating their speed and direction. The software was integrated with the robot's control system, allowing it to make informed decisions about its movements based on the visual data. The development of the camera system required careful coordination with the electrical engineering team to ensure seamless integration with the robot's hardware.

2.1. Work Breakdown Structure (WBS)

The processes of the two sub-systems in the project initially progressed separately. These sub-systems were developed independently, each fulfilling its own requirements before being integrated with each other. After integration, the sub-systems were also tested independently to ensure their functionality. To facilitate individual observation of each sub-system post-integration, switches were connected to the ultrasonic sensors used in the robot, allowing their connections to be severed as needed.

The Computer Engineering students focused on developing the camera system and the image processing software. This involved setting up the camera, writing algorithms for real-time ball detection and trajectory prediction, and integrating these components with the robot's control system. The work was divided into several stages, including initial setup, algorithm development, testing, and integration. Regular meetings were held to ensure that the progress of the camera system aligned with the overall project timeline.

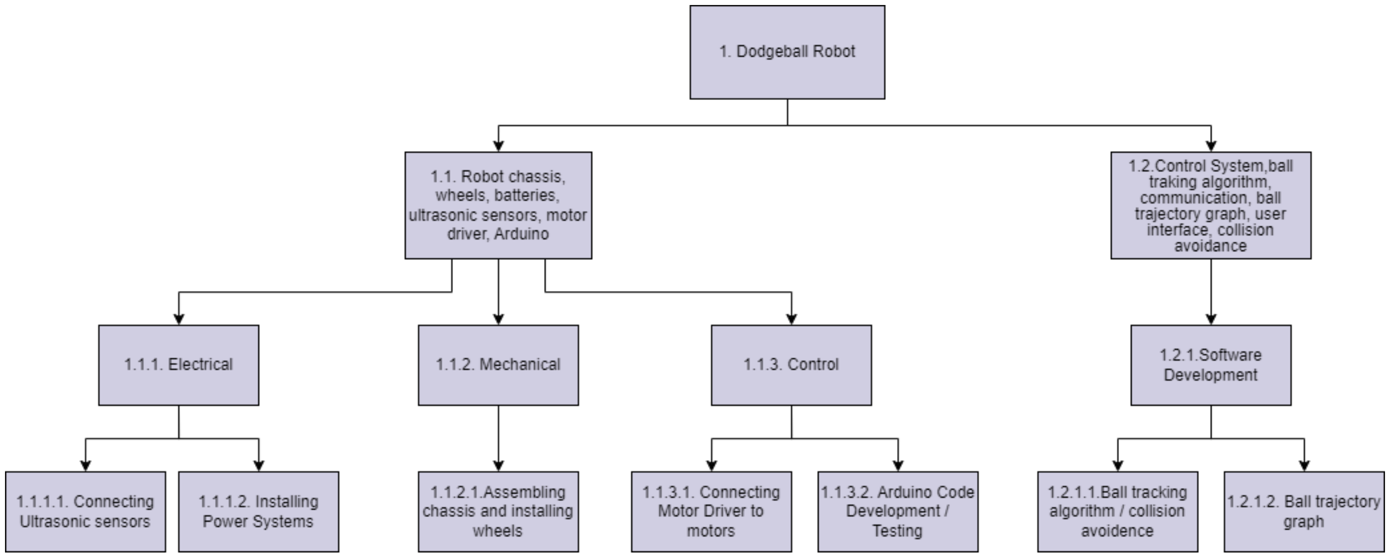

Figure 3. Work breakdown structure for the project.

2.2. Responsibility Matrix (RM)

In developing the project, tasks such as the mechanical assembly of the robot, electronics integration, coding for the Arduino, constructing the main body, and extracting data from the camera system developed by Computer Engineering students via Arduino were all handled by Electrical-Electronics Engineering students. Each stage of the development process, which was the responsibility of the Electrical-Electronics Engineering team, was executed with equal task distribution and collaborative effort. The steps undertaken included assembling the main body of the robot, attaching the wheels and their respective motors, connecting the Arduino UNO, L298n motor driver, and battery holder using a breadboard, positioning four HC-SR04 ultrasonic sensors on the lower sides of the robot, and connecting these sensors to the Arduino. Additionally, coding the Arduino to move right when the left sensors detect an object and move left when the right sensors detect an object, and providing an extra power source to the Arduino with a 9V battery were also tasks carried out by the Electrical-Electronics Engineering students.

The Computer Engineering students were primarily responsible for the development of the camera system and the image processing software. This included setting up the hardware, writing the necessary code, and integrating the system with the robot's control mechanism. They also worked on optimizing the algorithms to ensure real-time performance and accuracy. The collaboration with the electrical engineering students was crucial for the seamless integration of the hardware and software components.

The integration of the Arduino and sensor system with the system created using the laptop camera, along with the planning and reporting processes, were collaboratively carried out by all the students involved in the project.

Table 2. Responsibility Matrix for the team

Tasks	Barış Deniz Kaya	Helin Turğut	Samed Ergün Işık	Onur Karıncaoğlu	Mustafa Efe Satıroğlu
Electrical	R	R			
Mechanical	R	R			
Electrical Design	R				
Mechanical Design	R	R			
Arduino Software Development	R	R			
Control System	R	R	S	R	S
Camera System			R	R	R
Camera System Software Development			S	R	S
Integration	R	R	S	R	S
Planning	R	R	S	R	S
Testing	R	R	R	R	R
Reporting	R	R	R	R	R

R = Responsible; S = Support

2.3. Project Network (PN)

The main body of the robot was constructed, with wheels and a motor for each wheel attached. The development of the robot began with the mechanical aspects. Once this step was completed, the upper part of the robot was fitted with an Arduino UNO, an L298n motor driver, and a battery holder using a breadboard. Next, four HC-SR04 ultrasonic sensors were placed on the lower sides of the robot using a 3D-printed attachment. Each of these sensors was connected to the Arduino. Code was written in C++ for the Arduino, such that when the sensors on the right detected an obstacle, the robot would move left, and when the sensors on the left detected an obstacle, the robot would move right.

The Computer Engineering team developed the camera system in parallel with the electrical and mechanical components. After setting up the camera and writing the initial code, we tested the system to ensure it could accurately detect and track the balls. The next step involved integrating the camera system with the robot's control system, allowing the robot to use the visual data to make informed decisions about its movements. This integration required careful coordination with the electrical engineering team to ensure compatibility and synchronization.

After successfully completing both systems, the integration process was carried out using a USB A to USB B Arduino cable. One end of the cable was connected to the laptop, and the other end was connected to the Arduino, establishing the Dodgeball Robot system.

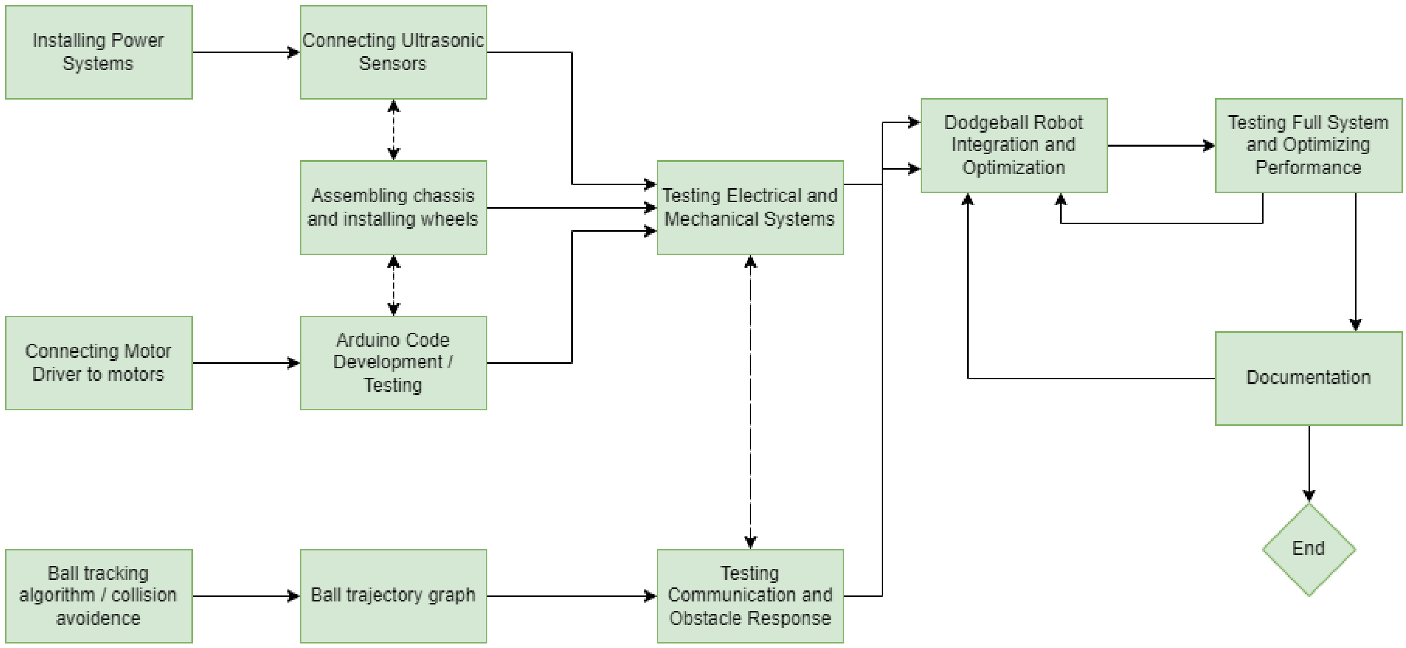

Figure 4. The project network.

2.4. Gantt Chart

In the first two weeks, a list of electronic and mechanical components needed for the project was created, taking the budget into consideration. Following this, the procurement process for these parts began, and all components required for the robot were ordered. Once the parts were procured, the assembly process for both the mechanical and electronic sections commenced. Alongside the development of the robot, tests were also conducted. This process continued until the end of the sixth week. Afterward, the focus shifted to the software development for the Arduino UNO integrated into the circuit. The development and testing of the Arduino code continued until the end of the ninth week. After completing the integration of the electronic and mechanical parts, tests of the electronic section were conducted using a handball, and by the end of the eleventh week, the sub-system developed by the Electrical and Electronics Engineering students was completed.

The Computer Engineering students spent the initial weeks setting up the camera system and writing the image processing algorithms. This was followed by a period of testing and integrating trajectory graph to ensure the system could operate in real time and under various conditions. The integration of the camera system with the robot's control system took place in the later stages of the project.

After the development phases of both sub-systems were completed, the integration of the two systems began in the eleventh week. During the integration process, updates were made to both the Arduino code and the code written for the camera system. Following these updates, various tests were conducted, and by the fourteenth week, the Dodgeball Robot was completed. While these tests and integration processes were being carried out, the progress of the robot up to that point was also documented. Once the tests were finished, the documentation process was completed simultaneously. After the documentation process was finished, preparation for the final presentation was completed in the last week.

Table 3. Gantt chart for the materialisation phase of the project.

TASKS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Electrical and Mechanical																
Selecting Mechanical and Electronic Materials																
Order Mechanical Parts																
Assemmle and Testing of Mechanical Parts																
Order Electronic Parts																Deniz
Assemble and Testing of Electrical Parts																Helin
Develop Arduino Code																
Test and Debug Arduino Code																
Integration Electrical and Mechanical Systems																
Testing																
Camera System																
Ball Treacking																Samed
Trajectory Graph																Onur
Future Position Prediction																Efe
Escape Maneuver																
System Integration and Testing																
Integration of All Sub-Systems																
System Optimization																ALL
Testing Full System																
Documentation and Presentation																
Document the Build																
Document the Verification Process																
Draft the Report																ALL
Complete the Report																
Prepare and Give the Final Presentation																
Exhibition																

2.5. Costs

The project expenses constitute the total expenditure and are listed according to the current prices of the products procured during the development process. Since the camera system utilizes the laptop's camera, there were no additional expenses incurred beyond the electronic and mechanical costs.

Table 4. Costs

Electro-mechanical	
Arduino Uno	378.30 ₺
4x HC-SR04 Ultrasonic Sensor	150.80₺
L298n Motor Driver	64.30 ₺
Standard Breadboard	44.50
4x Mini Breadboard	37.30 ₺
4x Wheel and 6V Wheel Motor Set	166.40 ₺
Robot Chassis	120.55 ₺
Battery Holder	36,80 ₺
USB A to USB B Printer Cable	150.55 ₺
DC Barrel Adapter	10.10 ₺
Batteries	440.20 ₺
Other Materials	315.40 ₺
System Total	**1912.20 ₺**

2.6. Risk Assessment

During the development process of the robot, potential and feasible risks were identified and ranked according to their risk levels. The first of these is motor driver failure. Multiple motor drivers were tested, with the type used in the project being the red L298n voltage-regulated dual motor driver. Before determining that this motor driver was suitable for the designed circuit, tests were conducted with the green L298n dual motor driver board, and it was observed that the red L298n motor driver was more appropriate and worked without issues. To ensure the motor driver operates correctly, a power source between 6V and 15V is required. Therefore, the number of batteries used was increased, effectively mitigating the risk of inadequate battery power. Additionally, to avoid further risks related to the power supply, a 9V battery was directly connected to the Arduino to provide consistent power.

Given that each HC-SR04 ultrasonic sensor has a limited field of view of 15 degrees, four HC-SR04 ultrasonic sensors were used to prevent the risk of "Insufficient Number of Sensors." This ensures the robot can detect incoming objects earlier, before they reach the robot. One of the existing risks is the improper functioning of the Arduino code. If the Arduino code fails to work, it can be rewritten and corrected. Improvements were made to the Arduino code by considering the positions of the sensors and the direction of the incoming ball.

For the camera system, potential risks included issues with image processing accuracy and real-time performance. To mitigate these risks, extensive testing was conducted under various lighting conditions and environments. The algorithms were optimized for efficiency to ensure they could run on the robot's hardware without causing delays. Additionally, fallback mechanisms were implemented to handle situations where the camera system might fail to detect the ball accurately, allowing the robot to rely on its ultrasonic sensors as a backup..

Table 5. Risk matrix

RISK LEVEL		**Severity** of the event on the project success		
		Minor	Moderate	Major
Probability of the event occuring	Unlikely	VERY LOW	LOW	MEDIUM
	Possible	LOW	MEDIUM	HIGH
	Likely	MEDIUM	HIGH	VERY HIGH

VERY LOW	This event is very low risk and so does not require any plan for mitigation. In the unlikely event that it does occur there will be only a minor effect on the project.
LOW	This event is low-risk; a preliminary study on a plan of action to recover from the event can be performed and noted.
MEDIUM	This event presents a signficant risk; a plan of action to recover from it should be made and resources sourced in advance.
HIGH	This event presents a very signficant risk. Consider changing the product design/project plan to reduce the risk; else a plan of action for recovery should be made and resources sourced in advance.
VERY HIGH	**This is an unacceptable risk. The product design/project plan must be changed to reduce the risk to an acceptable level.**

Table 6. Risk assessment

Failure Event	Probability	Severity	Risk Level	Plan of Action
Motor Driver Failure	Possible The motor driver may not be compatible with the circuit.	Major An alternative motor driver can be used instead.	HIGH	Using an alternative version of the L298n motor driver instead.
Insufficient Number of Sensors	Possible The HC-SR04 ultrasonic sensor type has a narrow field of view of 15 degrees.	Major The number of sensors used can be increased.	HIGH	Increasing the number of HC-SR04 ultrasonic sensors to improve the field of view.
Inadequate Battery Power	Likely The motor driver operates within a power range of 6V to 15V.	Major The number of batteries can be increased.	VERY HIGH	Increasing the number of batteries and adding a 9V battery directly powering the Arduino.
Failure of Commands from the Arduino	Unlikely Adjustments can be made on Arduino.	Major Changes can be made to the Arduino code.	MEDIUM	Rewriting the Arduino code according to the sensor positions and the robot's operating principles.
Camera Detection Failure	Likely Detection accuracy depends on environment	Major A ball with a distinct color or better lighting conditions can be used.	HIGH	Refine image processing algorithms for better accuracy and implement software fail-safes.

3. SUB-SYSTEMS

Sub-system name:Electrical and Electronics Engineering

In this project, an autonomous robot designed to evade incoming balls has been developed.

3.1. The Name of the Sub-system 1

In this project, Electrical-Electronics Engineering students have created a robot capable of evading incoming balls using Arduino, motor drivers, and ultrasonic sensors. Additionally, the main body of the robot has been constructed by Electrical-Electronics Engineering students.

3.1.1. Requirements

The expected outcome from the robot is its ability to evade 9 out of 10 incoming balls. The created Dodgeball Robot possesses the capability to dodge incoming objects. To detect incoming objects, the robot is equipped with 4 ultrasonic sensors. These sensors are positioned side by side on the robot's lower side with the help of a T-shaped attachment. The sensors are ultrasonic distance sensors, with the HC-SR04 code. They draw power directly from the Arduino UNO. The Arduino is connected to an L298N motor driver, which is powered by a total of 12V batteries. Additionally, to prevent power loss in the sensors, a 9V battery is directly connected to the Arduino using a 9V DC adapter. Given that the robot's main task is to evade incoming balls, its rectangular main body features four wheels on each side and each wheel is connected to a 6V 250 RPM DC motor. To enable the robot to move left or right upon detecting an incoming object, a code has been written for the Arduino using the C++ programming language. In this context, the robot emerges as a Dodgeball Robot.

3.1.2. Technologies and Methods

The dodgeball robot operates using a combination of advanced technologies and methods to detect and evade incoming balls effectively. Central to its functionality is an Arduino microcontroller, which serves as the brain of the robot, orchestrating its movements based on sensory input. The Arduino communicates with an L298N motor driver, enabling precise control over the robot's movement mechanisms. For detecting approaching balls, the robot is equipped with HC-SR04 ultrasonic sensors strategically positioned to cover its surroundings. These sensors detect motion within their range, prompting the robot to move left or right accordingly to evade the detected object. Powering the robot are 12V batteries, providing the necessary energy for sustained operation. Additionally, there is a 9V battery directly connected to the Arduino using a DC Barrel Adapter for additional power supply. The code governing the robot's behavior is written in the C++ programming language, meticulously crafted to ensure optimal performance and responsiveness in dynamic dodgeball scenarios. Through the integration of these cutting-edge technologies and methods, the dodgeball robot demonstrates its capability to autonomously navigate its environment and successfully evade incoming projectiles.

3.1.3. Conceptualization

Various circuit elements were used in creating the robot. Some of these components were essential without equivalent or alternative options, such as the Arduino UNO. During the robot's assembly, the selected motor driver was unavailable, leading to the use of an alternative. Initially, a green L298N dual motor driver board was used, but it proved incompatible after testing. To resolve this issue, the red L298N voltage-regulated dual motor driver, initially planned for use, was employed, allowing the circuit to operate smoothly. The project initially planned and implemented the use of three HC-SR04 ultrasonic sensors. However, testing revealed that each sensor's 15-degree field of view was insufficient. Therefore, an additional sensor was added, totaling four sensors used in the robot's construction. Additionally, there were power supply issues encountered as the number of sensors increased to four, causing the 12V battery to become inadequate. To address this, a 9V battery was directly connected to the Arduino using a DC Barrel Adapter.

3.1.4. Physical Architecture

At the top of the robot, you'll find the Arduino UNO, L298N motor driver, and battery holder. To allow for easier movement, the Arduino and motor driver were positioned on top of a breadboard. On the robot's side bottom, a custom part designed in AutoCAD, resembling a 'T' shape, was created to fit snugly underneath the robot's lower section, specifically in front of the designated direction where the ball comes from. This piece was then 3D printed. The purpose of this part is to house the four HC-SR04 distance sensors used for detecting incoming objects. These four sensors are securely positioned on the T-shaped part on the robot's side bottom. Additionally, to ensure sturdiness, this additional piece was fastened to the robot's main body using plastic clamps. For the robot to move, wheels were placed at the four corners of the rectangular-shaped main robot skeleton. Each wheel is attached to a separate 6V 250 RPM DC motor. The entire system operates using a total of 12V battery power source with 9V direct power supply to Arduino.

3.1.5. Materialization

During the creation of the robot, we followed the initial plan that was drafted. The upper and lower parts of the robot's main body were combined, housing four 6V 250 RPM DC motors inside. Each motor was connected to a wheel. The command center of the robot is positioned on top, featuring an Arduino UNO on a breadboard. An L298N motor driver was connected to this Arduino to control motor torque and speed. This driver was also linked to the total 12V battery. Additionally, due to the need for additional power, a 9V battery was connected directly to the Arduino via a DC Barrel Adapter. For detecting incoming objects, four HC-SR04 ultrasonic distance sensors were positioned on the robot's side bottom. These sensors have a 15-degree field of view each and are mounted on the part resembling a 'T' shape, which was initially designed in AutoCAD and then 3D printed. Throughout the robot's creation process, experiments were conducted using various balls such as tennis, handball, and volleyball-sized balls. Based on the robot's operation principle, it was decided that the ideal ball size for the robot would be that of a handball. Additionally, the robot was initially planned to have three sensors, but due to inadequate field of view, it was increased to four sensors based on experimental findings.

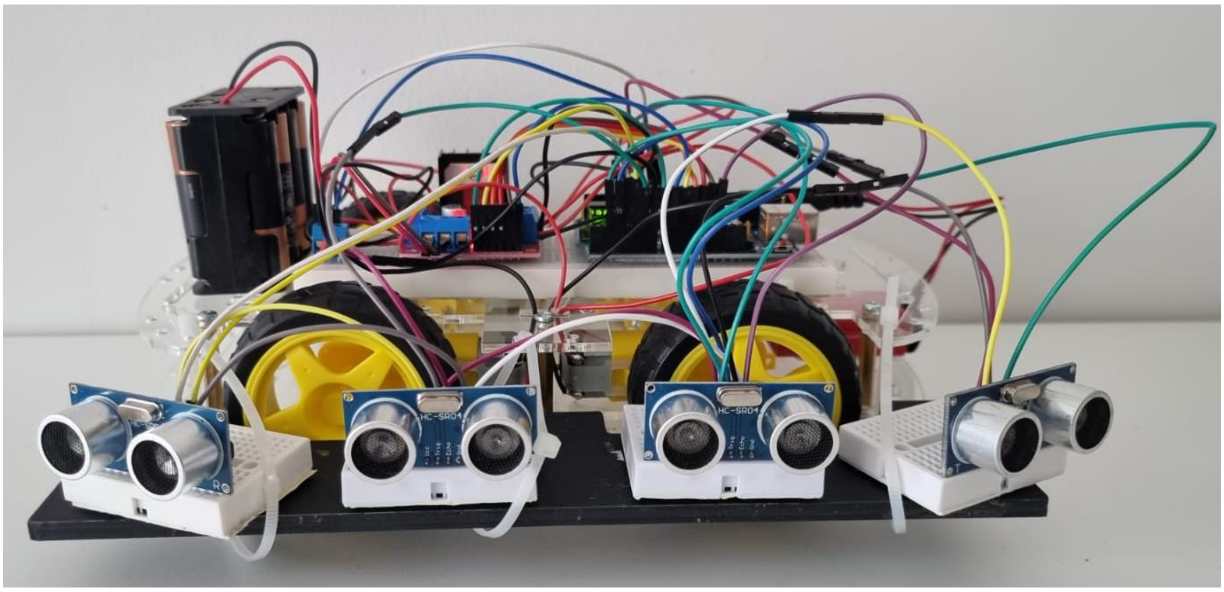

Figure 5. Front view of robot design

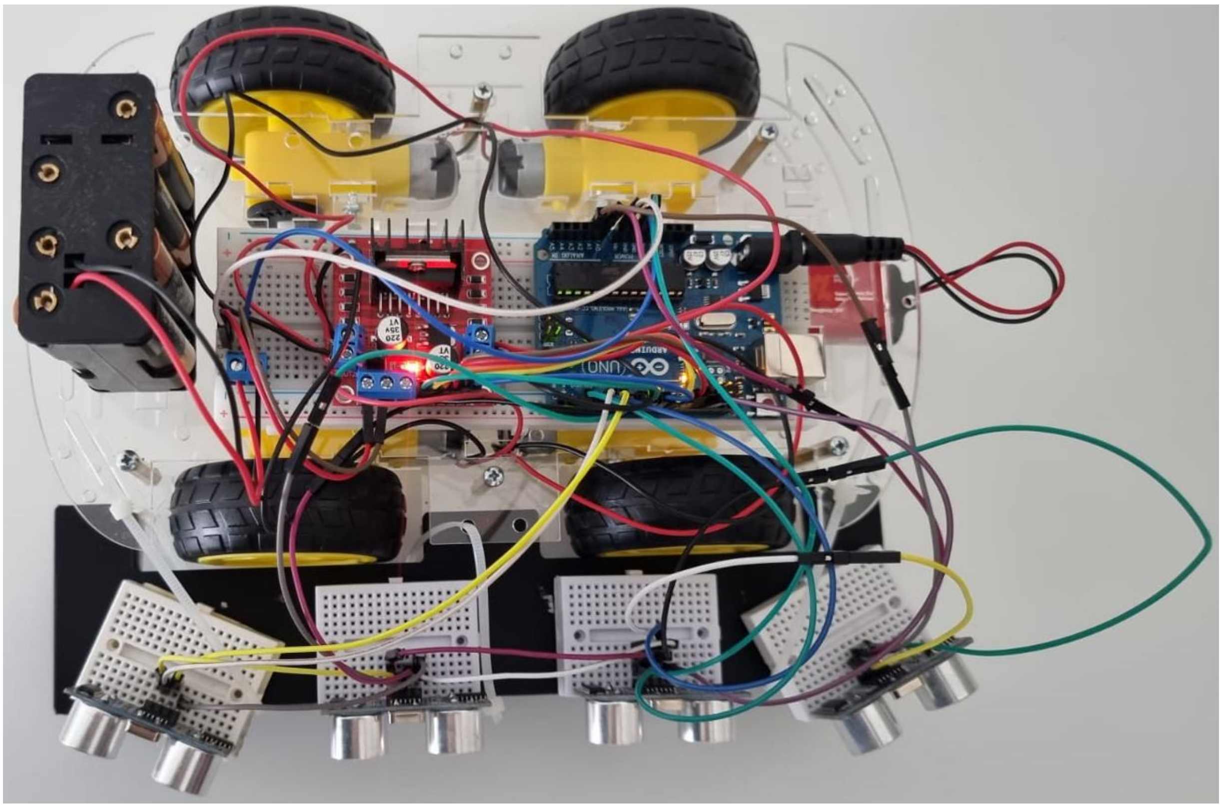

Figure 6. Top view of robot design

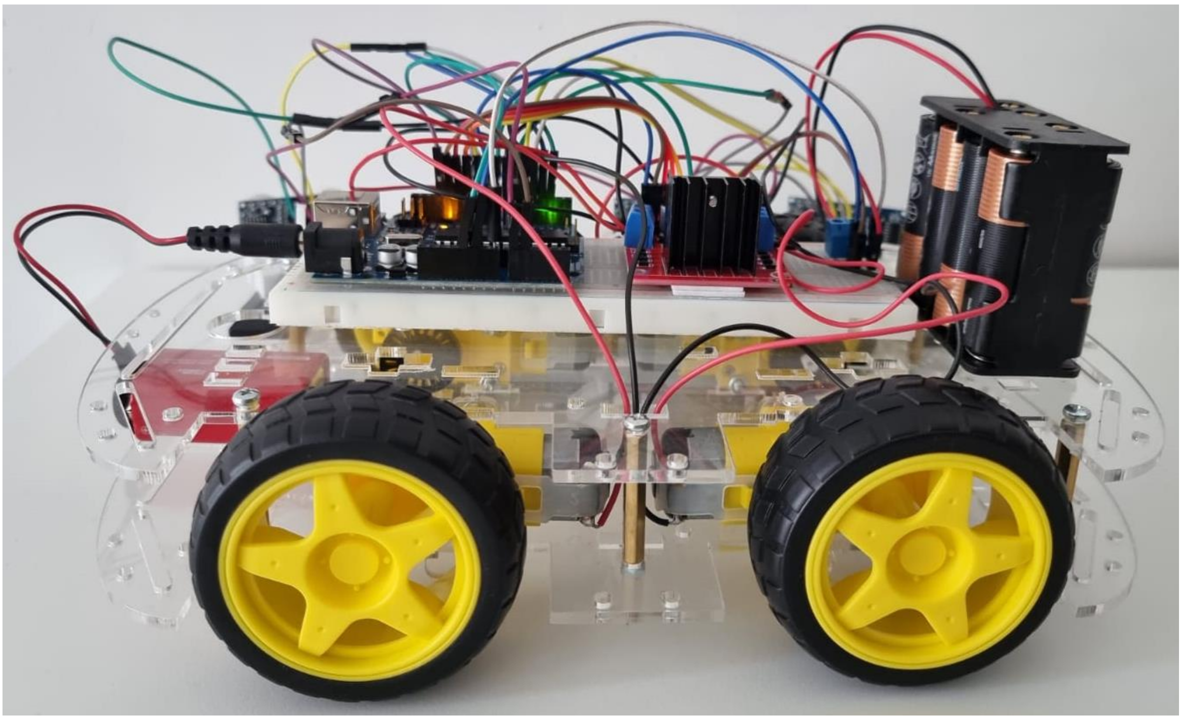

Figure 7. Rear view of robot design

3.1.6. Evaluation

During the formation process of the robot, several changes and updates were made. One of these changes involved the choice of distance sensor, specifically the HC-SR04 sensors, each having a limited 15-degree field of view. Initially designed with three sensors, experiments revealed the need for an additional sensor. As a result, the robot was finalized with a total of four HC-SR04 distance sensors. Another change was the inclusion of a motor driver, which was not originally planned in the initial stage. It was decided that a motor driver was necessary to control the speed and direction of the DC motors. Initially, attempts were made to set up the circuit using a green L298N dual motor driver board, but this was unsuccessful. Subsequently, it was anticipated that the issues could be resolved, and an alternative approach was taken by using a red L298N voltage-regulated dual motor driver board. Additionally, during the planning phase of the robot with three sensors, there were no anticipated battery issues. However, providing power for four sensors with the existing batteries proved challenging. Therefore, a 9V battery was directly connected to the Arduino UNO to provide additional power support. In its final form, the robot was constructed with an Arduino UNO, L298N motor driver, four HC-SR04 distance sensors, four wheels, four 6V 250 RPM DC motors, and additional battery support, enabling it to evade incoming balls effectively.

3.2. The Name of the Sub-system 2

The camera and software sub-system developed by Computer Engineering students is designed to provide real-time tracking and trajectory prediction of incoming balls. This system uses image processing techniques to enhance the robot's dodging capabilities.

The camera system continuously captures video feed of the environment, which is processed to detect the balls and calculate their trajectories. The software updates the robot's movement strategy in real time, ensuring quick and accurate responses to avoid collisions. This sub-system works in conjunction with the ultrasonic sensors, providing a comprehensive solution for the robot's evasion maneuvers.

3.2.1. Requirements

The camera and software sub-system must provide real-time video processing to detect and track incoming balls accurately. The system should be able to handle various lighting conditions and ensure low latency in processing the visual data.

The software must be capable of predicting the ball's trajectory and updating the robot's movement strategy accordingly. It should integrate seamlessly with the ultrasonic sensors and the robot's control system, providing a reliable and efficient solution for dodging the balls. The system should also be robust and adaptable to different types of balls and speeds.

3.2.2. Technologies and Methods

The camera system uses advanced image processing techniques to detect and track the balls. The software processes the video feed in real time, calculating the ball's speed and direction to update the robot's movement strategy.

The system leverages Python and OpenCV, an open-source computer vision library, for image processing and trajectory prediction. The processing is done on a laptop, which is connected to the robot via a serial connection. The Python code captures the video feed from the camera, processes the images to detect the balls, and uses algorithms to predict their trajectories. The real-time data is then sent to the robot to adjust its movements accordingly. This setup ensures efficient and accurate performance, providing low-latency responses and reliable operation. The integration with the ultrasonic sensors and the robot's control system ensures a comprehensive solution for evasion maneuvers.

3.2.3. Conceptualization

The camera and software sub-system was conceptualized to enhance the robot's dodging capabilities by providing additional data for trajectory prediction. This system complements the ultrasonic sensors, ensuring a more comprehensive understanding of the environment.

The design process involved selecting a suitable camera, developing the image processing algorithms, and integrating these components with the robot's control system. Extensive testing was conducted to ensure the system's reliability and accuracy, with adjustments made based on experimental findings to optimize performance.

3.2.4. Physical Architecture

The camera used for the system is integrated with the laptop rather than being mounted on the robot. The laptop captures the video feed, which is then processed in real time to detect and track incoming balls. The data from the camera is processed using Python and OpenCV, and the results are sent to the robot via a serial connection.

The laptop is positioned to have a clear view of the environment where the robot operates. The processed data, including the detected positions and predicted trajectories of the balls, is communicated to the robot's microcontroller. This setup ensures that the camera system can effectively monitor the surroundings and provide accurate real-time data to the robot's control system for making evasion maneuvers.

3.2.5. Materialization

The camera system was integrated with a laptop, with the software developed to process the video feed in real time. The image processing algorithms were optimized for performance, ensuring low latency and high accuracy.

Extensive testing was conducted to ensure the system's reliability under various conditions. Adjustments were made to the camera's positioning and the software's parameters based on experimental findings. The data from the laptop's camera was processed using Python and OpenCV, and the results were sent to the robot via a serial connection. The integration with the robot's control system was completed, providing a robust solution for evasion maneuvers.

3.2.6. Evaluation

The camera system was evaluated through a series of experiments to ensure its accuracy and reliability. The system's ability to detect and track balls in real time was tested under different lighting conditions and environments.

During these evaluations, several challenges were encountered, particularly related to lighting and ball color. Inconsistent lighting conditions sometimes caused the camera system to have difficulty detecting the ball accurately. Similarly, balls with colors similar to the background or with reflective surfaces posed additional detection challenges. To address these issues, the image processing algorithms were adjusted, and additional filtering techniques were implemented to improve detection accuracy. Despite these challenges, the integration with the ultrasonic sensors provided a fallback mechanism, ensuring the robot could still make effective evasion maneuvers. The final results demonstrated that, with these adjustments, the camera system significantly enhanced the robot's dodging capabilities.

4. INTEGRATION AND EVALUATION

The project consists of two main subsystems. The first is led by Electrical and Electronics Engineering students, focusing on circuit design and system-oriented robot development. This involves assembling necessary components, integrating electronic and mechanical parts, programming Arduino, and designing a robot capable of evading incoming balls using sensors.

The second subsystem is led by Computer Engineering students, primarily focusing on the software aspect, specifically developing a camera system that operates on the same principle. The final stage involves integrating these separately developed subsystems into a cohesive system with a common goal.

4.1. Integration

The project consists of two main subsystems, with the primary goal of integrating these two systems that operate on the same principle. The responsibilities of Electrical and Electronics Engineering students included creating the robot's main body, handling the electronic and mechanical components, and writing code for Arduino. Accordingly, the robot was constructed using various circuit elements, including Arduino UNO, L298N motor driver, four HC-SR04 distance sensors, a breadboard, four wheels each driven by a 6V 250 RPM DC motor, and a 9V battery connected to both the battery holder and directly to Arduino.

Once the electronic and mechanical components were completed, the robot needed to be integrated with the other subsystem. The integration process involved connecting the Arduino UNO to a laptop using a USB A to USB B Arduino programming cable. To enable data retrieval from the camera system, an additional C++ code was written for Arduino, complementing the previously written C++ programming language. This facilitated the integration of the two subsystems.

The Computer Engineering students developed a camera system and software using Python and OpenCV to process the video feed from a laptop camera. The laptop captures the video feed, which is processed in real-time to detect incoming balls and predict their trajectories. The processed data is then transmitted to the robot's microcontroller via a serial connection. This integration ensures that the robot receives accurate and timely information about the ball's position and movement, allowing it to make precise evasion maneuvers. The integration process involved extensive testing and adjustments to ensure seamless communication between the laptop and the robot.

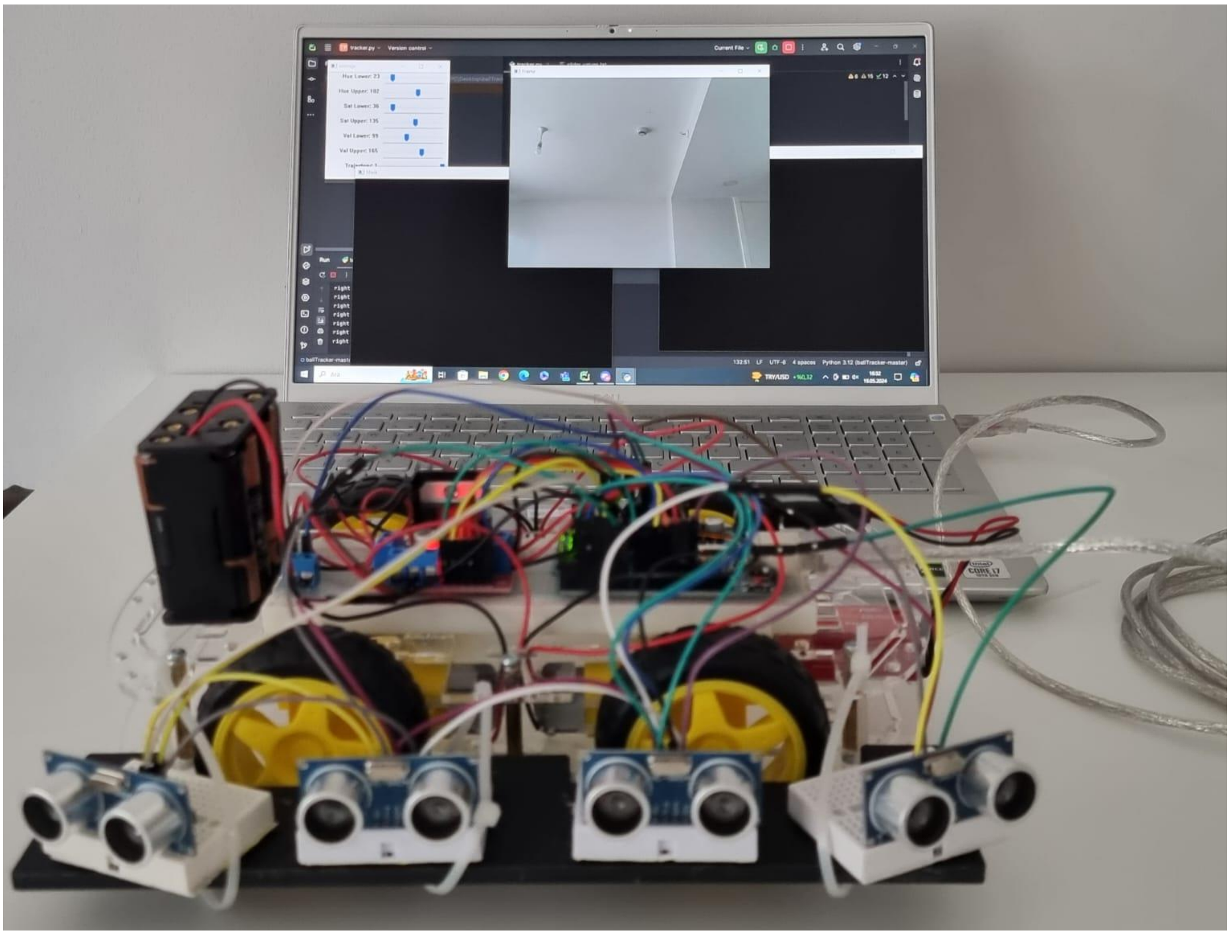

Figure 8. Integrated robot design

4.2. Evaluation

After integrating the two subsystems, various experiments were conducted to calculate the error margin. These experiments, involving an average-sized handball, were conducted after the initial experiments performed on the electronic and mechanical parts. During these experiments, the code written to retrieve data from the camera system was revised multiple times to ensure efficient data collection. To observe the working principles of the systems separately and in an integrated manner, activations of the subsystems were alternately disabled. This approach allowed for comprehensive testing both independently and in conjunction.

During the evaluation phase, the integration of the camera system with the robot was thoroughly tested. Several challenges were encountered, particularly with detecting the ball under different lighting conditions and against various backgrounds. Adjustments were made to the image processing algorithms to improve accuracy and reliability. The camera system's ability to track the ball's trajectory was evaluated by conducting multiple tests with balls of different colors and sizes. The robot's evasion maneuvers were also tested under these conditions to ensure it could effectively dodge incoming balls. Despite initial difficulties, the system's performance improved significantly with these adjustments, demonstrating its effectiveness in real-world scenarios.

5. SUMMARY AND CONCLUSION

In summary, a Dodgeball Robot capable of evading at least 9 out of 10 incoming balls was developed. The development process of this robot involved two main subsystems. The first subsystem focused on the development of the electronic and mechanical components, while the second subsystem centered around the camera software. The electronic part of the robot primarily consisted of Arduino UNO, L298N motor driver, HC-SR04 ultrasonic sensors, and 6V 250 RPM DC motors. A code was written in C++ programming language for Arduino to instruct the robot to move right when warnings were detected from the left and left when warnings were detected from the right. The motor driver was used to control the torque and speed of the motors. Ultrasonic sensors were employed to enable the robot to detect incoming objects. This electronic and mechanical part was integrated with the other subsystem. The integration was achieved using a USB A to USB B Arduino programming cable, allowing data retrieval from the developed camera software to be incorporated into the existing code. This updated code, written in C++ on Arduino, facilitated simultaneous operation of both sensors and the camera system, resulting in the successful integration of the two subsystems.

The camera system and software were developed using Python and OpenCV. The laptop camera provided real-time video feed, which was processed to detect and track the balls. Challenges such as varying lighting conditions and ball colors were addressed by optimizing the image processing algorithms. The data from the camera was transmitted to the robot via a serial connection, enabling precise evasion maneuvers. This integration significantly enhanced the robot's ability to dodge incoming balls.

In conclusion, the Dodgeball Robot, designed using Arduino, sensors, and a camera system, can effectively evade incoming balls by moving left or right. Future development of this project could involve creating a robot capable of 360-degree movement. For this purpose, a robot body resembling a sphere or a robot body with outward-facing wheel positions could be used. Depending on the robot's shape, sensor placement could be adjusted to align with each wheel position. Additionally, higher RPM DC motors could be employed to enable faster movement. Using high RPM DC motors would provide significant advantages in robot mobility and agility. To eliminate the wired system, the integration of the two sub-systems could be achieved using a wireless setup with the help of a Bluetooth module. As an alternative to a standard Bluetooth module, HC05 or HC06 Bluetooth modules could be used.

Further improvements can focus on enhancing the image processing algorithms to handle a wider range of environmental conditions, such as varying lighting and background complexities. Additionally, exploring advanced machine learning techniques could improve the system's ability to predict ball trajectories more accurately. These enhancements would contribute to the robot's overall performance and reliability, making it more versatile and effective in different applications. By continuing to refine both the hardware and software components, the Dodgeball Robot can evolve into a more sophisticated and capable autonomous system.

ACKNOWLEDGEMENTS

We would like to express our gratitude to our adviser, Assist. Prof. Evrim Tetik and Assist. Prof. Selin Nacaklı, for her invaluable contributions to our project, her guidance, mentorship, and boundless patience. We would also like to extend our thanks to another esteemed adviser, Assist. Prof. Zafer İşcan, for his guidance and mentorship during the initial stages of the Dodgeball Robot project.

REFERENCES

[1] R. W. Fransiska, E. M. P. Septia, W. K. Vessabhu, W. Frans, W. Abednego and Hendro, "Electrical power measurement using Arduino Uno microcontroller and LabVIEW," 2013 3rd International Conference on Instrumentation, Communications, Information Technology and Biomedical Engineering (ICICI-BME), Bandung, Indonesia, 2013, pp. 226-229 [Online]. Available:https://ieeexplore.ieee.org/abstract/document/6698497?casa_token=d6DUDfvpxpwAAAAA:k1stXiY1kz73BzokhsgDidhI8-X7nNRIqfUbeExd5DWcwee-uy6fqYE_pJLXwV6gbkEKpu_mhho [Accessed: April 4, 2024].

[2] A. Aiman, P.pirah, L. Wasi, "DC Motor Speed Control Through Arduino and L298N Motor DriverUsingPIDController",2022[Online].Available:https://www.researchgate.net/publication/361763175_94-Article_Text-198-1-10-20211204 [Accessed: April 4, 2024].

[3] Arifin, Adam & Nurpulaela, Lela & Rahmadewi, "Implementation Of Ultrasonic Sensor HCSR04 Based on Arduino UNO as a Social Distance Tool in The New Normal Era". Power Elektronik:JurnalOrangElektro,2022[Online].Available:https://www.researchgate.net/publication/371046224_IMPLEMENTATION_OF_ULTRASONIC_SENSOR_HCSR04_BASED_ON_Arduino_UNO_AS_A_SOCIAL_DISTANCE_TOOL_IN_THE_NEW_NORMAL_ERA [Accessed: April 12, 2024].

[4] A. Ma'arif, Iswanto, N. M. Raharja, P. Aditya Rosyady, A. R. Cahya Baswara and A. Anggari Nuryono, "Control of DC Motor Using Proportional Integral Derivative (PID): Arduino Hardware Implementation," 2020 2nd International Conference on Industrial Electrical and Electronics(ICIEE),Lombok,Indonesia,2020,[Online].Available:https://ieeexplore.ieee.org/abstract/document/9277258?casa_token=y7S6_lA7bOkAAAAA:mlkOBQs8ypxJ13UYh4oubsgFrCR-qy8ayJXs19OjRnsiUQK-tFMwtutcznDplnNgFhfgORGcsiM [Accessed: April 12, 2024].

[5] Y. A. Badamasi, "The working principle of an Arduino," 2014 11th International Conference on Electronics, Computer and Computation (ICECCO), Abuja, Nigeria, 2014, pp. 1-4 [Online].Available:https://ieeexplore.ieee.org/abstract/document/6997578?casa_token=Xp6C1CaI5_kAAAAA:tHUZYbQXhiUOiNE15OqvGEMkvXdhM4DfayVb9naujpd-YZzi1MQ8w3tQrENC0_2-S8lglV4VPE4 [Accessed: April 28, 2024].

[6] A. M. Kamal, S. H. Hemel and M. U. Ahmad, "Comparison of Linear Displacement Measurements Between A Mems Accelerometer and Hc-Sr04 Low-Cost Ultrasonic Sensor," 2019 1st International Conference on Advances in Science, Engineering and Robotics Technology (ICASERT), Dhaka, Bangladesh, 2019, pp. 1-6 [Online]. Available:https://ieeexplore.ieee.org/abstract/document/8934569?casa_token=droaOK2-JAsAAAAA:p_q76L_osuuYMfKzhTQi5UVv8tarZCxbztonAzKqgNZe86aNewrEKDuJegbypEORPQ9rPUYTk0 [Accessed: April 28, 2024]

[7] S. Rajesh, G., Anita and S. Bhupendra, "Arduino Interfacing with Sensors", 2019 [Online]. Available:https://www.researchgate.net/publication/332458775_Arduino_Interfacing_with_Sensors [Accessed: May 8, 2024].

[8] K. A. Raza and W. Monnet, "Moving objects detection and direction-finding with HC-SR04 ultrasonic linear array," 2019 International Engineering Conference (IEC), Erbil, Iraq, 2019, [Online].Available:https://ieeexplore.ieee.org/abstract/document/8950639?casa_token=u8Khxex7O0sAAAAA:9wpj9Sl76G9vAbXQDVgFbOpU5RIUyf59xTlpgu4pmIpvBNomuDC3SHGK6BcQKTXBOw8RGdiH3MU [Accessed: May 8, 2024].

[9] K. Ren, J. Lin and S. Cai, "The design of networked DC motor speed control platform based on WiFi," 2017 Chinese Automation Congress (CAC), Jinan, China, 2017, [Online]. Available: https://ieeexplore.ieee.org/document/8243783 [Accessed: May 15, 2024].

[10] M. Mutava and K. Paul., "Arduino Uno, Ultrasonic Sensor HC-SR04 Motion Detector with Display of Distance in the LCD", International Journal of Engineering Research, 2020, [Online].Available:https://www.researchgate.net/publication/341871272_Arduino_Uno_Ultrasonic_Sensor_HC-SR04_Motion_Detector_with_Display_of_Distance_in_the_LCD[Accessed: May 15, 2024].