ACADEMIC SESSION 2022/2023

SCHOOL OF ELECTRICAL AND ELECTRONIC ENGINEERING

EEE424/ EEK425/ EEM425 – Engineering Design

Capstone Project Proposal

Lonely Champion Winner - Badminton Robot Trainer

Group 8

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Submission Date

27 November 2022

Table of Contents

CHAPTER 1

INTRODUCTION

1.1 Background

Malaysia has entered a global advancement in sports. There are many reasons that people choose to play sports. Not only is good for your health, but it promotes teamwork and sportsmanship. These are both transferable skills which can be taken into different aspects of life, such as in the workplace and when studying. The discipline learnt when playing a sport is also a great life-skill to have. Sports is also a great way to socialize and make friends, that will most than likely have similar interests. This can be very helpful when trying to make friends, such as when starting university, as you will be able to meet people that already have a common interest to you. Furthermore, it can help individuals to learn to focus and to manage their time efficiently. This again is another transferable skill that is very valuable in places such as the workplace and when completing studies.

Over the last century, technology has affected sports for both officials and athletes, changing the way sports are prepared for, played, and reviewed by officials. Technology is utilized by almost everyone involved in a modern sporting event. Games can be prepared for by using technology that tracks the athlete's diet and workouts, giving them precise information, they need to appropriately prepare for a game. Practicing monitored, and safe training habits allows athletes to increase their efficiency in the game and potentially prolongs their careers. For example, during the game, players can be tracked by chips embedded into jerseys and mounted on helmets. Sensors in Jerseys and on helmets are utilized by team staff to monitor the athlete's performance.

One of the advancements in sports as done in badminton using the badminton robot trainer. This research involved the prototyping of a shuttlecock robot that enables a badminton player to practice independently. First, a three-dimensional model of the badminton robot was designed using Solidworks. Subsequently, the dynamics of the mechanism were evaluated. Next, the hardware was designed using. Finally, the trajectory of the badminton shuttlecock was determined using a series of experimental tests.

1.2 Problem Statement

In the current global era, problems arise when a player is self-training. When a player is conducting self-training, the person needs someone else to feed them the ball. If the person doesn't have anyone to play with, most probably the player would quit badminton. Next, is the competition among players these days. Humans have become very competitive in badminton every year because they want to excel and be the best. Coaches cannot offer high-intensity or high-accuracy training all the time because they are humans too and they are prone to make mistakes and also get tired in between sets.

1.3 Proposed solution

Our proposed solution is a badminton trainer robot. The robot can constantly shoot the shuttlecock with high intensity at random or specific places inside the badminton court for the player to counter. The robot can also shoot different types of shots which are high ball(lobby), netball(netting), and also drop ball (dropshot). Players have the option to choose the intensity of their game.

1.4 Objectives

The objectives of carrying out this project are:

1. To design and implement an IoT-based badminton robot trainer for training purpose for beginner badminton players.
2. To design a badminton robot trainer which can feed the ball in multiple directions and positions.
3. To design a badminton robot trainer with high accuracy in ball feeding.
4. To design an economical and high-quality badminton robot trainer for badminton players.

CHAPTER 2

LITERATURE REVIEW

Badminton is a common indoor sport in Southeast Asia. Generally, it requires two or four opposing players to hit a shuttlecock in opposite directions at varying speeds. However, at least two players are needed for training, which in some cases has been difficult. In such cases, players need a device that allows them to train independently. While there are no such resources for badminton players to practice badminton, this issue can be solved using an automatic machine designed to support badminton training. This device would be beneficial for talented players who cannot afford professional coaching or imported machinery. In addition, it provides an opportunity to practice and master the crucial skills required for the game. A machine would launch shuttlecocks at varying speeds and directions, providing the player with a practice session that mimics a real badminton game with an expert or experienced partner. Furthermore, because of its simple design, the machine could be manufactured locally, and the cost would be considerably reduced. Therefore, it could be used to train several players at a given location.

Several studies have been conducted to prove the capability of robots or machines in badminton training. Sun et al. proposed a new mobile badminton training robot with a pneumatic batting mechanism. Stoev et al. presented a mechatronics design approach and related technologies for a badminton-playing robot. Yamakawa et al. developed a fully automatic badminton-playing robot that served as a substitute for a human badminton player. Sakai et al. developed a shuttlecock-launching machine using two turn rollers for badminton exercises. Their research used a shuttlecock tracking algorithm for the badminton robot. Yousif et al. developed a new shuttle shooter machine with an impact mechanism for badminton training purposes. Sakai and Shirayama proposed a badminton launching machine using a revolving launch arm with a new launcher mechanism that can discharge at high speeds to reduce damage to the shuttlecock feathers. New insertion equipment and motion control systems were proposed by Sakai et al., and a training machine for badminton that project shuttlecocks at high speeds were developed. Two types of shuttlecocks made of different materials (feathers and plastic) were used for a new badminton robot by Tan et al.

According to PHILIP OSAMENDE OMOREGIE University of Education, Winneba GHANA technology increasingly is playing a leading role in the development of sports and enhancing performance in all faces. Thus, applications of technology allow for more effective training, stimulations, management, and tracking of athletes, accuracy of results, enhanced spectator viewing, developing performance, and preventing injuries, amongst many more functions (Busch, 1998). Technology in sports is a technical means by which athletes attempt to improve their training and competitive surroundings in order to enhance their overall athletic performance. It is thought of as a technical means or instrument utilized to pursue chosen ends. Hence, the paper investigates the impact of technology on sports performance.

Moreover, based on Jun Xie 1, Guohua Chen and Shuang Liu ,School of Physical Education, East China University of Technology, Nanchang, China, explored the role of the intelligent badminton training robot(IBTR) to prevent badminton player injuries based on the machine learning algorithm. An IBTR is designed from the perspectives of hardware and software systems, and the movements of the athletes are recognized and analyzed with the hidden Markovmodel (HMM) under machine learning. After the design was completed, it was simulated with the computer to analyze its performance. The results show that after the HMM is optimized, the recognition accuracy or data pre-processing algorithm, based on the sliding window segmentation at the moment of hitting reaches

96.03%, and the recognition rate of the improved HMM to the robot can be 94.5%, showing a good recognition effect on the training set samples. In addition, the accuracy rate is basically stable when the total size of the training data is 120 sets, after the accuracy of the robotics analyzed through different data set sizes. Therefore, it was found that the designed IBTR has a high recognition rate and stable accuracy, which can provide experimental references for injury prevention in athlete training.

There are many approaches to increasing the accuracy and effectiveness of badminton machines. This project is primarily done to benefit three parties which are the player, the coach and the court owner.

CHAPTER 3

METHODOLOGY

3.1 Survey Method

In order to pinpoint and comprehend the issues as well as requirements of the project, a survey form has been created to collect user feedback on the title of our capstone project, badminton robot trainer. This survey contains data on the users' interest in our product and their relationship to it. The prepared survey form is divided into four sections: section 1 asks about the respondents' demographic profile; section 2 inquiries about users' perspectives on the topic of why humans are superior to robots in badminton training; section 3 inquiries about the desired robot specification and cost, and section 4 gathers users' opinions on the tendency to experience badminton robot trainers. The survey was conducted using a Google form for 11 days, starting on November 7, 2022, and ending on November 17, 2022. There are 50 responders in all.

3.1.1. Respondents' Demographic Profile

3.1.1.1 Respondents' Gender

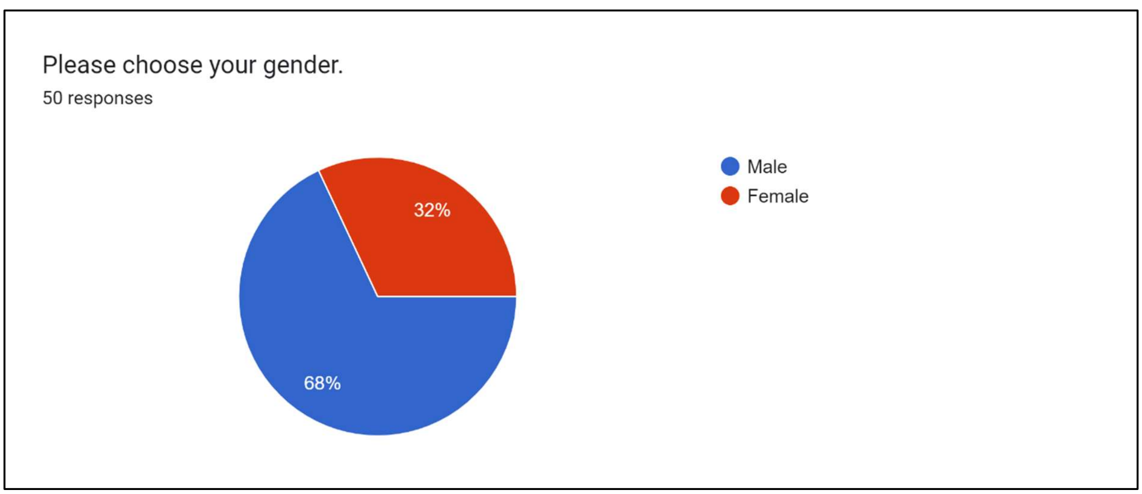

Figure 3.1.1.1.1: Gender of respondents.

According to the data presented above, the majority of respondents are males, with 34 out of 50 respondents accounting for 68 percent. Female respondents, on the other hand, account for 32 percent of all respondents, or equivalent to 16 out of 50 respondents. Based on the result of the survey obtained, we discovered that the number of male respondents who are interested in our product outnumbers the number of female respondents. This may be due to the fact that most of the males are sports lovers as they have always been naturally competitive. This survey reveals that, despite gender, there were a significant number of responses from females as well. This demonstrates that both genders are interested in and satisfied with our product.

3.1.1.2 Respondents' Age Group

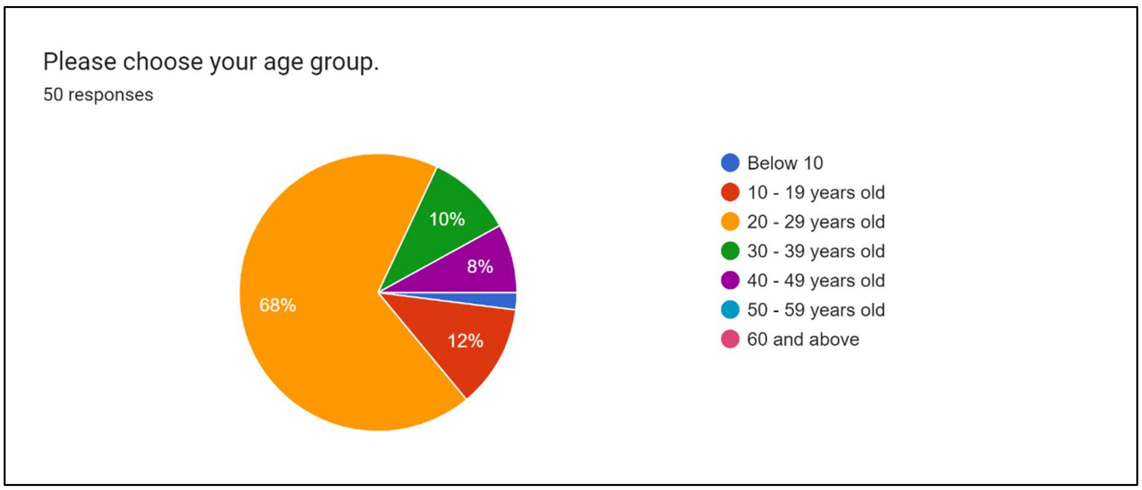

Figure 3.1.1.2.1: Age group of respondents.

According to the data, the pie chart reveals that 34 out of 50 respondents, or 68 percent, are between the ages of 20 to 29 years old, which represents the majority of our respondents. The respondents who are between the ages of 10 and 19 account for 13 percent of the total respondents. Only 5 out of 50 responders, or 10 percent, are between the ages of 30 and 39. Furthermore, just 8 percent of responders are between the ages of 40 and 49. Lastly, there is only 1 respondent who is below 10 years old, accounting for 2 percent of the total. Moreover, we noticed that there is no respondent who is in the range of 50 to 59 years old or above 60 years old. As a result, this statistic suggests that the majority of responders are young because they are more physically active than the older generation and have an interest in playing badminton. Another reason there may not be any elderly adults to respond to our survey is that the older age group is not engaged on social media or is not familiar with modern technology.

3.1.1.3 Respondents' Occupation

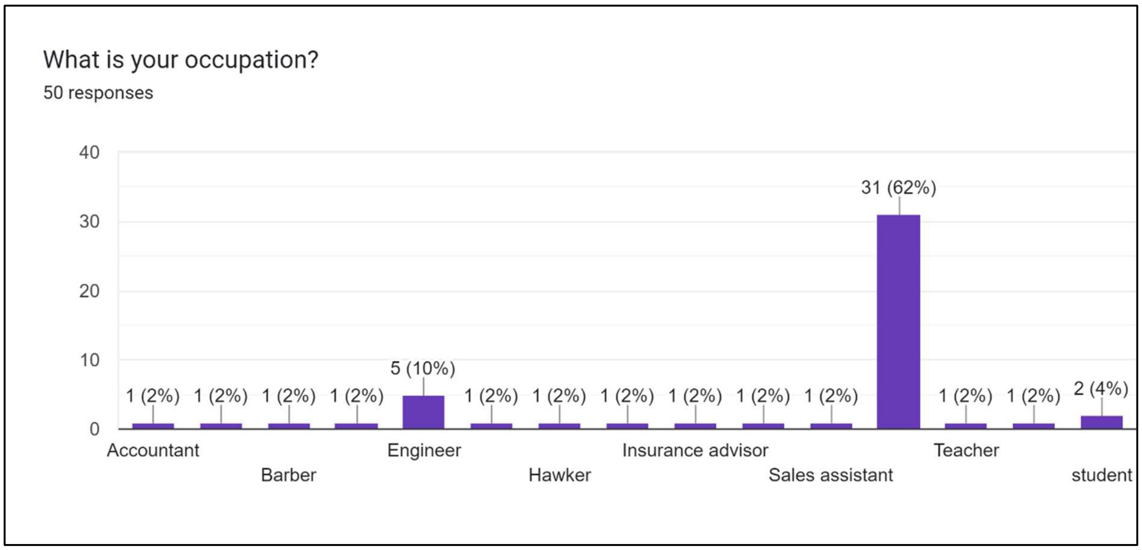

Figure 3.1.1.3.1: Occupation of respondents.

Based on the above data, there are 34 out of 50 respondents are students, accounting for 68 percent of the total. Followed by 5 respondents who are engineers that account for 10 percent of the total. However, it was discovered that the remaining occupations, such as accountant, barber, hawker, insurance advisor, teacher, auditor, financial planner, housewife, promoter, and technician, each only had one respondent equivalent to 2 percent of the total respondents. Since the majority of our respondents are students from the younger generation, the occupation findings really matched the respondents' age group that we previously identified. This suggests that our product is drawing in students or younger individuals who enjoy badminton and are more physically active.

3.1.1.4 Frequency of Playing Badminton

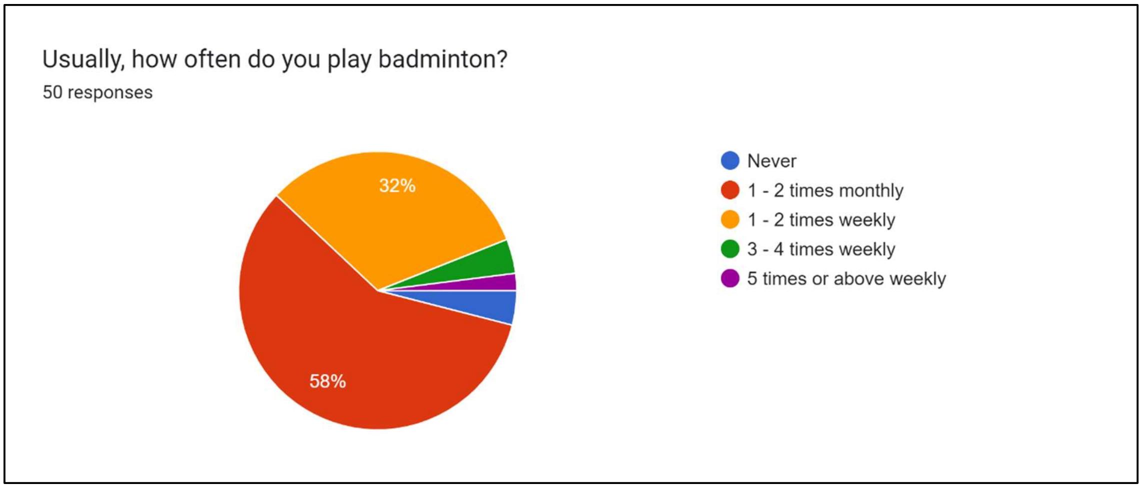

Figure 3.1.1.4.1: Frequency of playing badminton by respondents.

The pie chart shows that 58 percent of our total respondents (29 out of 50 respondents) play badminton 1 to 2 times monthly. Following closely after are 16 out of 50 respondents, or 32 percent, who play badminton once or twice a week. Besides, we also found out that there are 2 respondents (4 percent) who play badminton 3 to 4 times weekly. In contrast, there are also 2 respondents (4 percent) who have never badminton before. Lastly, we have only 1 respondent (2 percent) who plays badminton almost every day which is 5 times or above weekly. According to the results, we have a healthy community that takes care of its own health because the majority of the respondents play badminton at least once or twice a month. This shows that our product is beneficial to our responders in terms of training to improve their skills and motivate other people to play badminton as well.

3.1.1.5 Professionalism as a Badminton Player

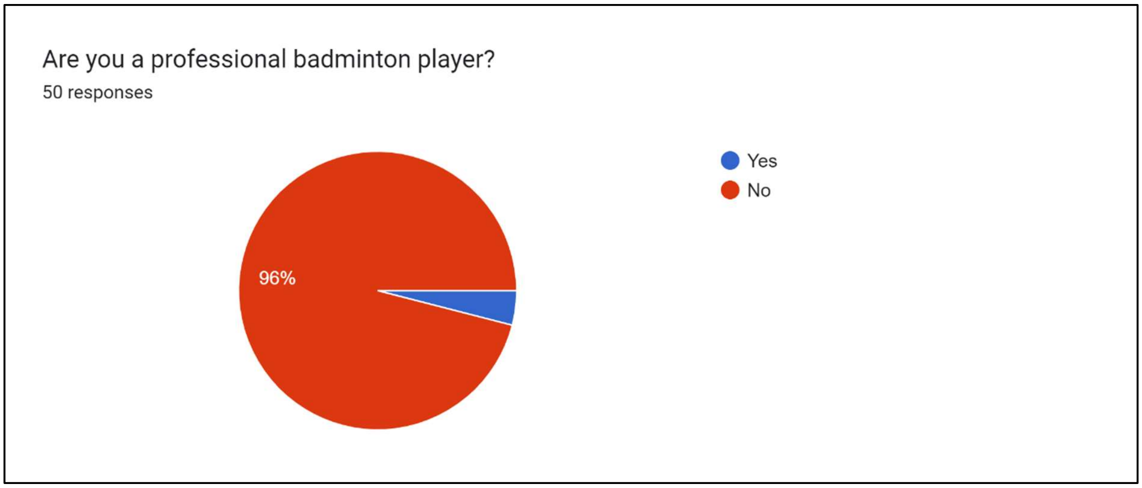

Figure 3.1.1.5.1: Professionalism of respondents as badminton players.

The data above shows the professionalism of the respondents as badminton players. It was discovered that 96 percent of the total respondents which is equivalent to 48 respondents are not professional badminton players. There are only 2 respondents who are professional badminton players. This is due to the fact that the majority of our responders are not athletes but rather students who are primarily from the engineering faculty.

3.1.1.6 Opinion on Having a Proper Badminton Training

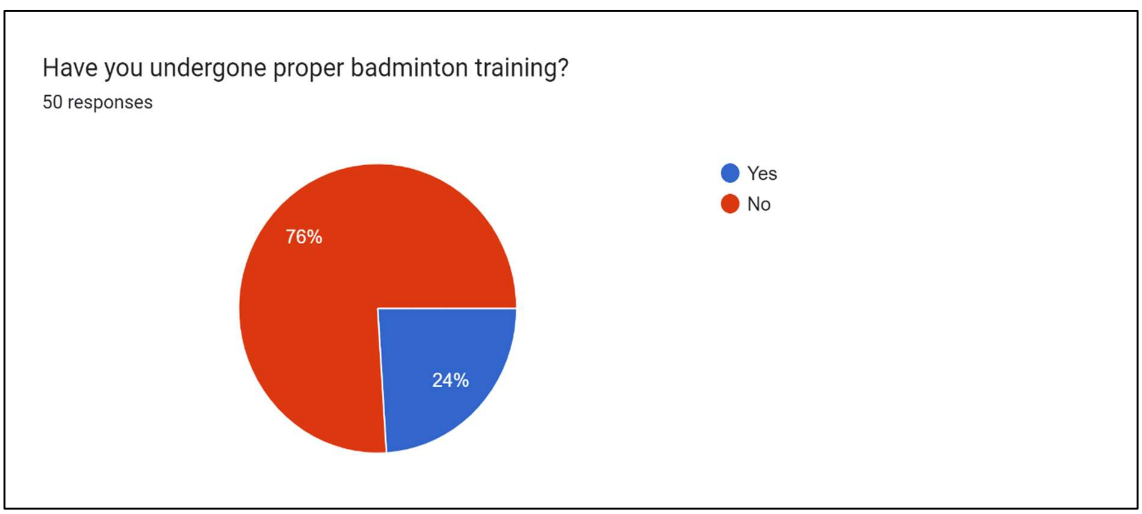

Figure 3.1.1.6.1: Respondent's opinions on having proper badminton training.

Based on the pie chart above, it was found that 38 out of 50 respondents (76 percent) did not undergo proper badminton training before. Meanwhile, only a minority of respondents which is 12 out of 50 respondents equivalent to 24 percent had undergone proper badminton training before. This can be the result of the inconvenience of scheduling badminton coaches' appointments around the free time of our respondents.

3.1.1.7 Opinion on Having Trained with Badminton Robot Trainer

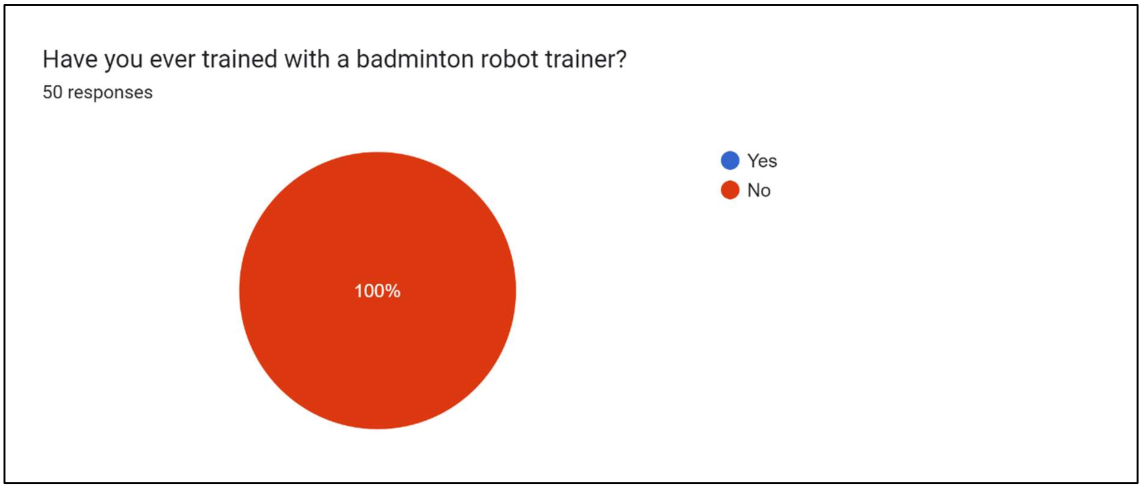

Figure 3.1.1.7.1: Respondents' opinions on having trained with a badminton robot trainer.

The results of the data above show whether or not our respondents have ever used a robot trainer for badminton. Based on the pie chart above, it can be clearly seen that all the respondents (100 percent) never trained with a badminton robot trainer before. This could be as a result of the badminton robot trainer being a relatively new product on our market and being an expensive product.

3.1.1.8 Opinion on Preference to Train with either Human or Robot

Figure 3.1.1.8.1: Respondents' opinions on preference to train with either humans or robots.

The data above shows the preference of our respondents to train badminton with humans, robots, or both. Based on the results obtained, the majority of the respondent which are 44 out of 50 respondents (88 percent) want to have their training sessions with both humans and robots. On the other hand, only 3 respondents (6 percent) want to train with either humans or robots respectively. As a result, we can draw the conclusion that our product is well-received by the majority of our respondents and may be commercially viable.

3.1.2. Respondents' Opinions on the Topic "Human Better Than Robot"

3.1.2.1 Opinion on Advantages of Training with Human Trainer over Robot Trainer

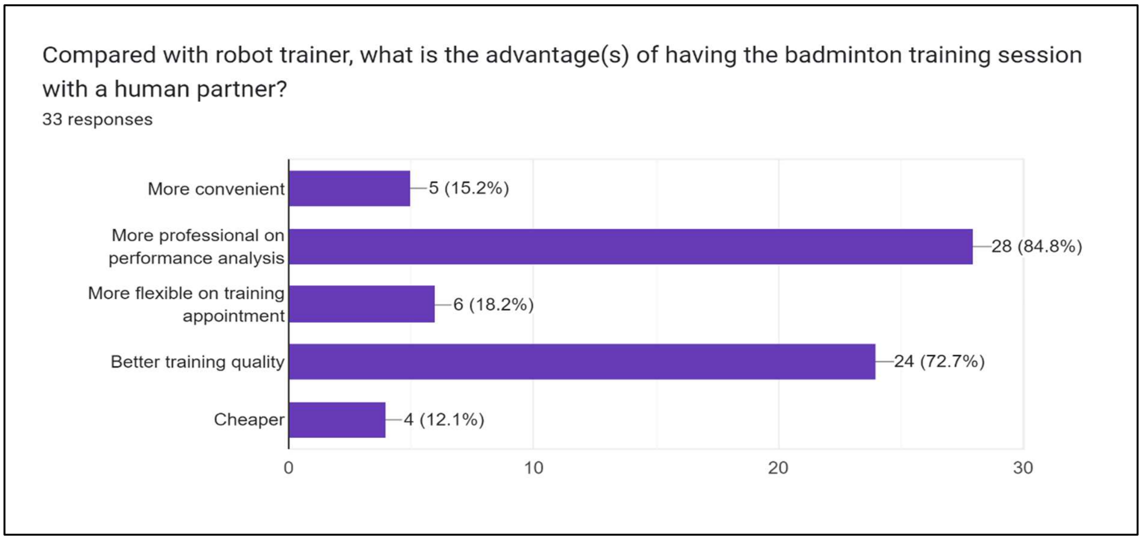

Figure 3.1.2.1.1: Respondents' opinions on the advantages of training with a human trainer over a robot trainer.

The data above shows the opinions of respondents on the advantages of training with a human trainer over a robot trainer. Based on the bar chart above, the majority of the respondents account for 84.8 percent think that human trainers are more professional in performance analysis as compared to robot trainers. Besides that, there are 24 respondents (72.7 percent) believe that human trainers will provide better training quality as compared to robot trainers. A total of 6 respondents (18.2 percent) believes that scheduling training sessions with human trainers are more flexible, and a total of 5 respondents (15.2 percent) believe that training with human trainers is more convenient than with robot trainers. Finally, only 4 respondents (12.1 percent) believe that the benefit of training with human trainers is due to a lower cost. Therefore, we may draw the conclusion that the majority of respondents think human trainers are better because the market's current robot trainers are still unable to deliver the same level of training quality and professional performance analysis as supplied by professional badminton coaches.

3.1.2.2 Opinion on Disadvantages of Training with Robot Trainer over Human Trainer

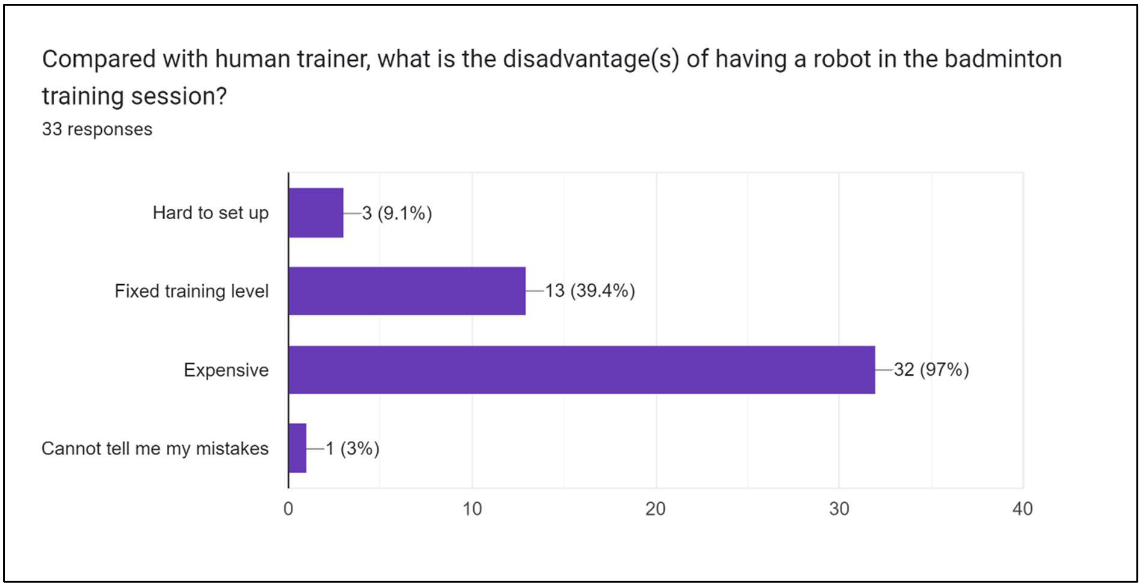

Figure 3.1.2.2.1: Respondents' opinions on the disadvantages of training with a robot trainer over a human trainer.

The data above shows the opinions of the respondents on the disadvantages of training with robot trainers over human trainers. Based on the survey result, it was discovered that the majority of the respondents which are 32 out of 50 respondents (97 percent) believe that having trained with badminton robot trainers is expensive. Followed by 13 respondents (39.4 percent) who think that robot trainers will only provide a fixed training level. Meanwhile, there are 3 respondents (9.1 percent) who think that it is hard to set up a badminton robot trainer. Finally, only 1 responder (3 percent) believes that a robot trainer cannot identify the mistakes made by the player during the training session, which is a disadvantage compared to a human trainer.

3.1.3. Respondents' Desired Robot Specification and Cost

3.1.2.3 Opinion on Expected Features of the Badminton Robot Trainer

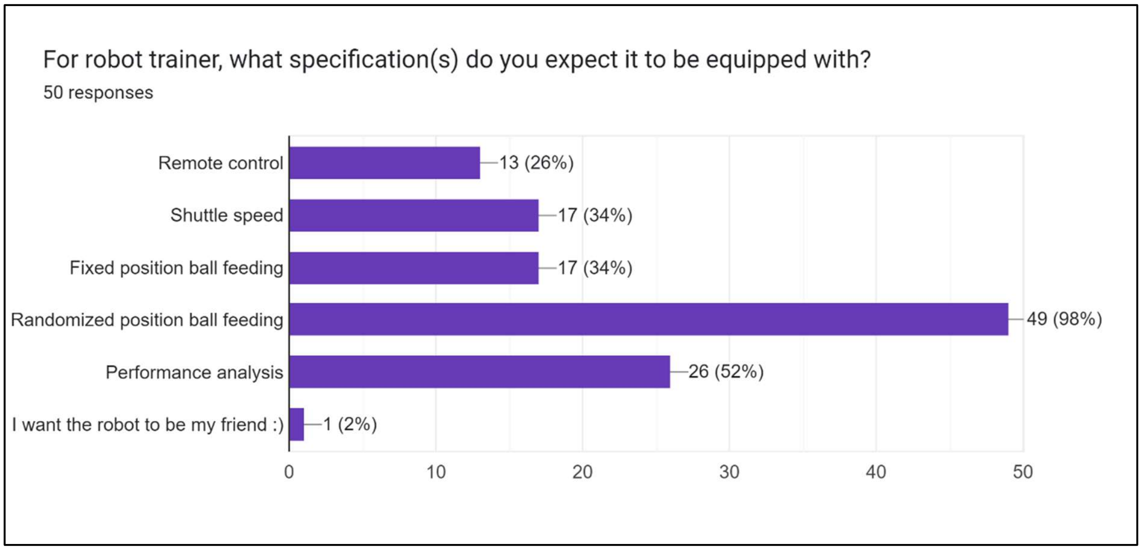

Figure 3.1.3.1.1: Respondents' opinions on the expected features of the badminton robot trainer.

The data above displays the respondents' thoughts on what they expected the badminton robot trainer to be equipped with. According to the bar chart, it can be clearly seen that majority of the respondents which are 49 out of 50 respondents (98 percent) hope that the badminton robot trainer is equipped with a randomized position ball feeding function. Followed by 26 out of 50 respondents want the badminton robot trainer to have the performance analysis function, accounting for 52 percent of the total. Moreover, there are an equal number of respondents which are 17 respondents (34 percent) expressed the wish that the badminton robot trainer is equipped with fixed position ball feeding and different shuttle speed respectively. There are 13 respondents (26 percent) who want the robot trainer can be controlled remotely. Finally, only one responder (2 percent) expects that the robot trainer will communicate with him or her as a friend or partner during the training session. Therefore, this indicates that our product should be equipped with a randomized position ball feeding function.

3.1.2.4 Opinion on Expected Cost of the Badminton Robot Trainer

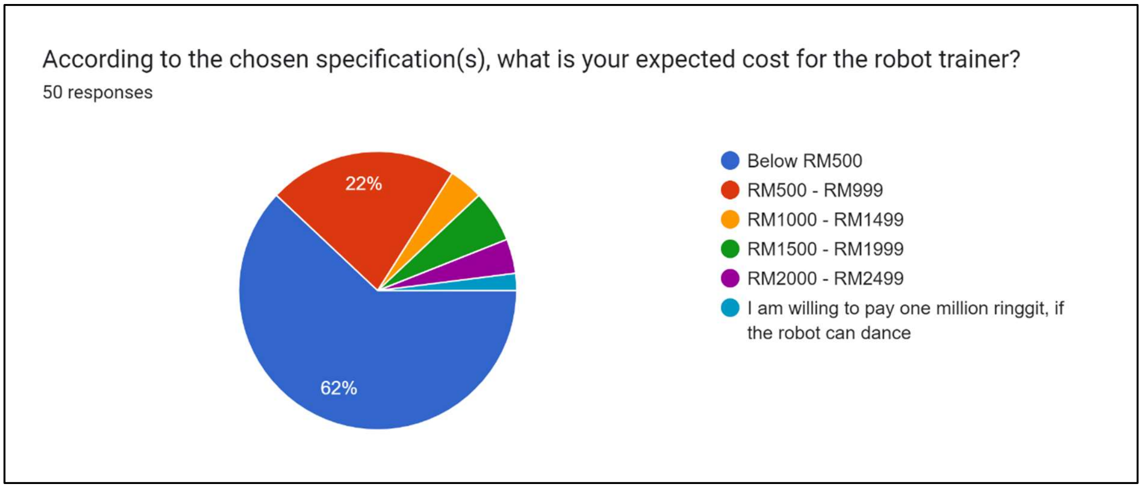

Figure 3.1.3.2.1: Respondents' opinions on the expected cost of the badminton robot trainer.

The data above shows the respondents' opinions on the expected cost of the badminton robot trainer. Based on the pie chart, the majority of respondents which are 31 out of 50 respondents (62 percent) expect that the robot trainer should cost less than RM500 because it will be more affordable for them. Followed by 11 respondents equivalent to 22 percent of the total respondents expect the cost of the robot trainer will be between RM500 and RM999. There are 3 respondents (6 percent) predict that the robot would cost between RM1500 and RM1999, while 2 respondents (4 percent) predict the robot trainer will cost between RM1000 and RM1499 and RM2000 to RM2499, respectively. Finally, only one respondent (2 percent) does not care how much the robot trainer costs as long as it is sophisticated and has excellent mobility. This demonstrates that our product should cost less than RM500 in order to attract more people to purchase it.

3.1.4. Respondents’ Opinions on the Tendency to Experience Badminton Robot Trainer

3.1.4.1 Opinion on Willingness to Buy a Badminton Robot Trainer

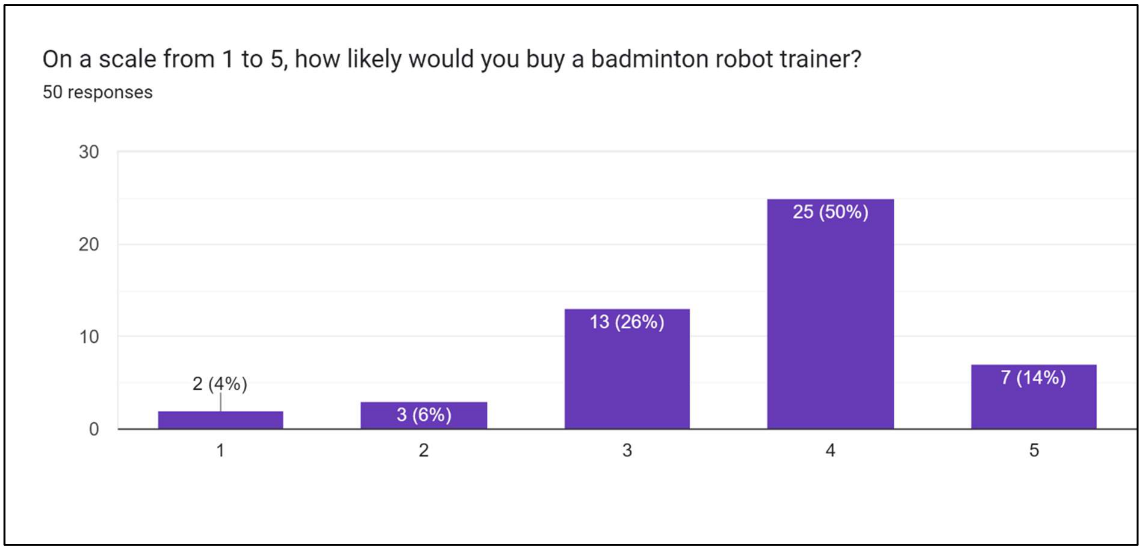

Figure 3.1.4.1.1: Respondents’ opinions on the willingness to buy a badminton robot trainer.

The information above illustrates what respondents thought about their willingness to purchase a badminton robot trainer. Based on the bar graph, it was determined that 25 respondents (or 50 percent) are likely to try to get a badminton robot trainer, while 7 out of 50 respondents (or 14 percent of the total) are extremely eager to do so. There are now 13 respondents, or 26 percent of the total respondents, who are still debating whether they should buy it or not. On the other hand, there are only 5 respondents (10 percent) are not interested in purchasing a robot trainer. We can conclude that the majority of survey respondents appear to be generally enthusiastic and interested in our goods.

3.1.4.2 Opinion on Replacement of Human Trainer by Robot Trainer in the Future

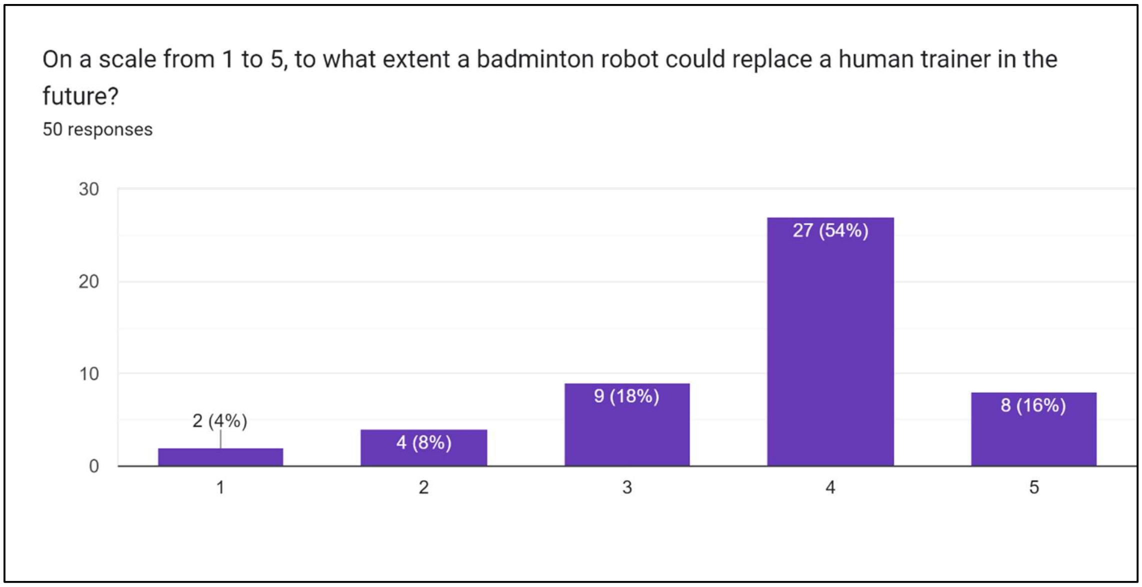

Figure 3.1.4.2.1: Respondents' opinions on the possibility replacement of a human trainer by a robot trainer in the future.

The data presented above shows how respondents felt about the possibility of a robot trainer taking the place of a human trainer in the future. According to the results, 8 respondents (16 percent) are convinced that a robot trainer might replace a human trainer in the future, while 27 respondents (54 percent) think that a badminton robot could replace a human trainer in the future. In the meantime, there are 9 out of 50 respondents are debating on whether a badminton robot trainer could possibly replace a human trainer in the future. Last but not least, 6 respondents which is accounting for 12 percent of the total respondents believe that robot trainers are not likely to replace human trainers very soon.

3.1.4.3 Opinion on Likeliness to Visit a Sports Arena Equipped with Badminton Robots

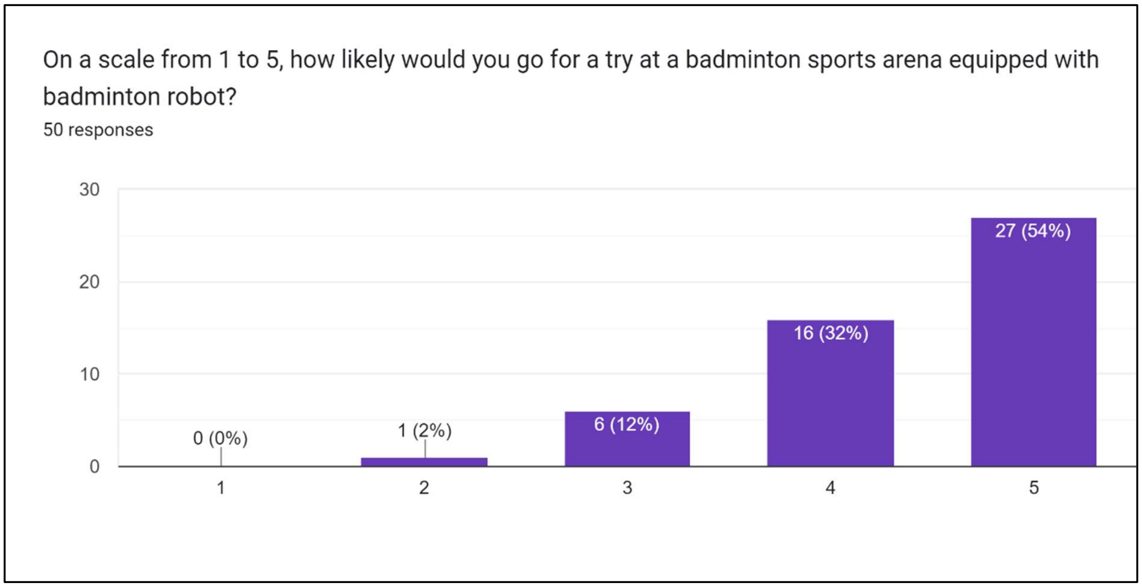

Figure 3.1.4.3.1: Respondents' opinions on the likeliness to visit a sports arena that is equipped with badminton robot trainers.

The information above shows how respondents felt about the likelihood of visiting a sports complex containing badminton robots. According to the bar chart, the majority of respondents (27 respondents, or 54 percent) would unquestionably give a badminton robot sports arena a try. Additionally, there are 16 out of 50 respondents (32 percent) who are likely to visit the sports arena with badminton robots. Meanwhile, there are 6 respondents accounting for 12 percent of the total respondents are still considering whether want to give it a try at the sports arena with the equipment of badminton robot trainers. Lastly, only 1 respondent (2 percent) does not want to visit the sports arena that is equipped with robot trainers. As a result, we can conclude that most people are attracted to the sports arena that is equipped with the robot trainers as they are willing to pay a visit for it.

3.1.4.4 Opinion on Convenience and Flexibility Provided by Badminton Robot Trainer

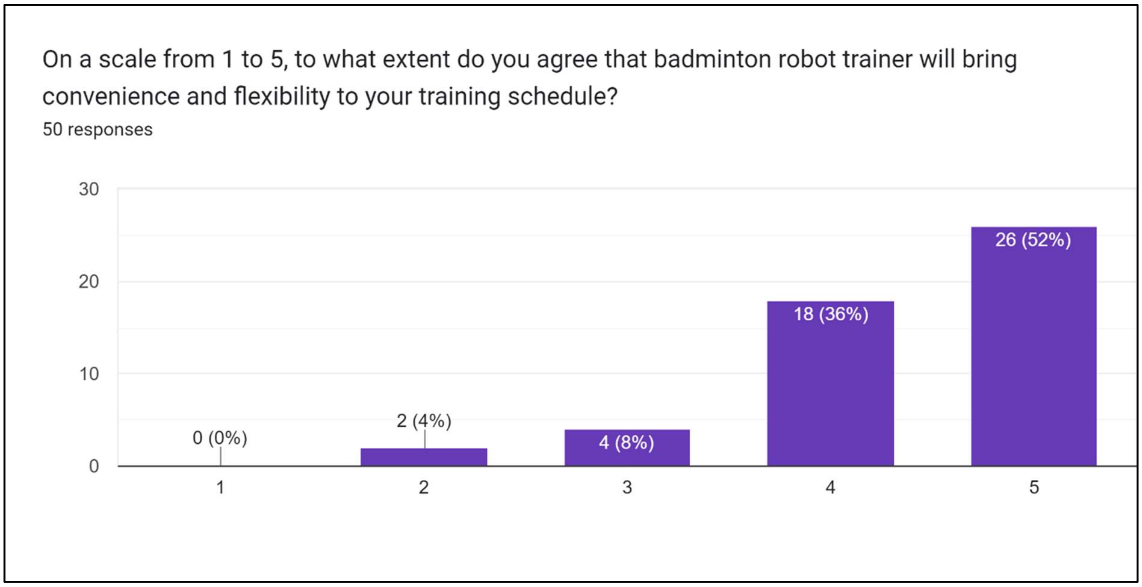

Figure 3.1.4.4.1: Respondents' opinions on the convenience and flexibility provided by the badminton robot trainer.

The data presented above shows how respondents felt about the flexibility and convenience that the badminton robot trainer offered. Based on the result obtained, there are 26 out of 50 respondents (52 percent) totally agreed that the badminton robot trainer will bring convenience and flexibility to their training schedule, while there are 18 respondents accounting for 36 percent of the total respondents partially agree with this statement. Meanwhile, there are 4 respondents (8 percent) who are still debating this issue. Finally, only 2 respondents (4 percent) think that the badminton robot trainer will not bring convenience and flexibility to the training schedule. As a result, most end users think that the badminton robot trainer is beneficial to them for their training.

3.1.4.5 Opinion on Effectiveness of Training Brought by Badminton Robot Trainer

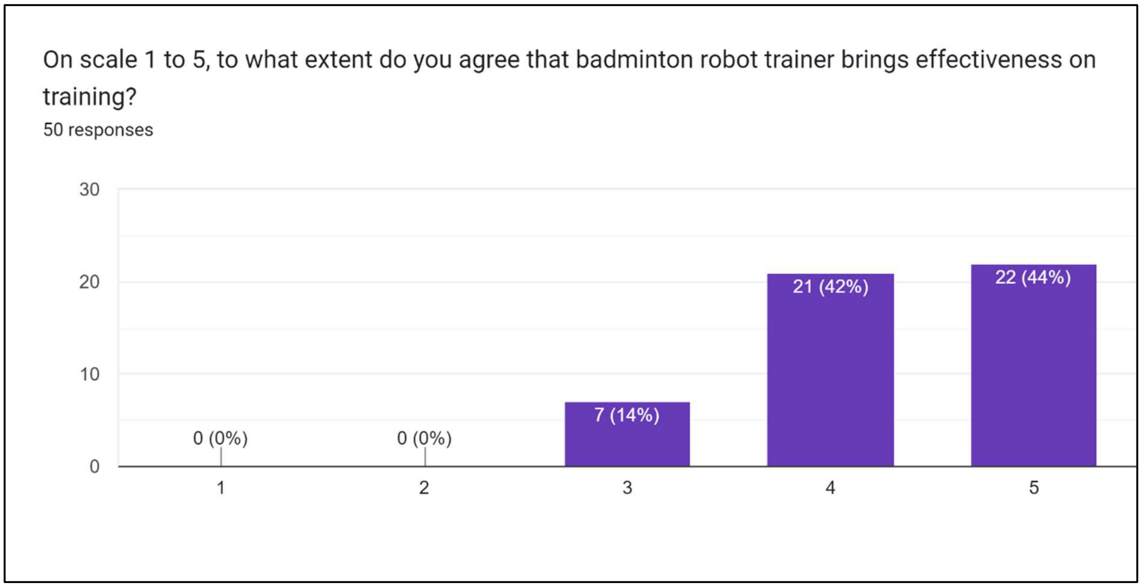

Figure 3.1.4.5.1: Respondents' opinions on the effectiveness of the training brought by the badminton robot trainer.

The statistic above displays the opinions of the respondents on the effectiveness of the training brought by the badminton robot trainer. Based on the bar chart above, 22 out of 50 respondents (44 percent) totally agree that the badminton robot trainer will bring effectiveness to the training, while there are 21 respondents accounting for 42 percent of the total respondents partially agree with this statement. On the other hand, there are only 7 respondents (14 percent) are still undecided on this issue. There is no respondent that disagrees with this statement. We may therefore draw the conclusion that everyone believes the badminton robot trainer will undoubtedly improve one's training.

3.2 Implementation of Project

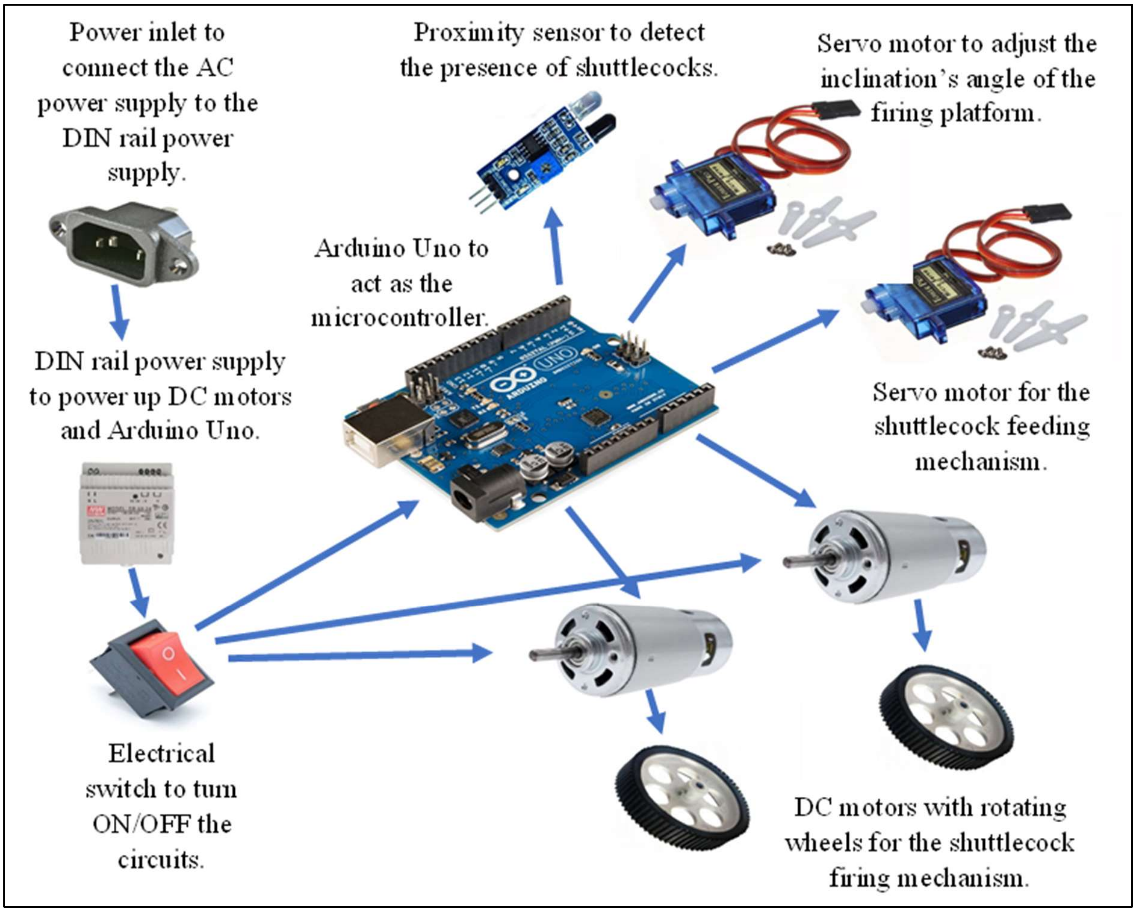

Figure 3.2.1: Implementation of project's design.

The badminton robot trainer is designed to aid the badminton player in being able to train independently whenever it is convenient without having to worry about the issue of difficult-to-make appointments with a badminton coach. Additionally, this badminton robot trainer is made to overcome the limited functionality of the badminton robot trainers currently on the market because it has two firing mechanisms: fixed-position and randomized-position shuttlecock firing mechanisms. Both firing mechanisms will be extremely helpful to one's training especially for the beginner-level and intermediate-level badminton players. Furthermore, the badminton robot trainer is made to be as portable and small as possible, making it easier to carry and providing users and sports complex owners with convenience.

There are two main mechanisms in the badminton robot trainer which are the shuttlecock feeding and firing mechanisms.

The hardware components used in this project are Arduino Uno, DIN rail power supply, 24V DC motors, DC servo motors, rubber wheels, MOSFETs, electrical switch, resistors, diodes, capacitors, voltage regulators, power inlet, proximity sensor, and LED. Whereas the software that will be used in this project is Arduino IDE and SolidWorks. The whole system is controlled by the Arduino Uno microcontroller. The C or C++ coding for the microcontroller to perform the required tasks is uploaded to the Arduino Uno through the Arduino IDE so that it can make sure the shuttlecock feeding and firing mechanisms work perfectly. The SolidWorks software is used to design the frame, feeding part, motor housing, etc.

For the shuttlecock feeding mechanism, it requires three main components which are the proximity sensor, LEDs, and DC servo motor. The proximity sensor is used to detect the presence of shuttlecocks in the shuttlecock storage place. If the storage has been emptied, the proximity sensor will notify the user by lighting an LED to indicate that a refill is necessary. Meanwhile, the servo motor is used to control the movement of the feeding part which acts as a 'stopper' for controlling the feeding rate of the shuttlecocks.

For the shuttlecock firing mechanism, it requires components such as the 24V DC motors, rubber wheels, and servo motors. In order to fire the shuttlecock when the shuttlecock head contacts the rubber wheels, 2 DC motors with attached rubber wheels are required. These motors are placed side by side with a predetermined distance between them. Meanwhile, the servo motor is used to adjust the angle of inclination of the shuttlecock firing platform in order to fire the shuttlecock with different trajectories like low serve and high serve which will improve the quality of training.

Since the DC motors used are rated for 24V, which will drain a significant amount of current when operating, and the Arduino Uno can only generate 5V and 40mA, it is not possible to operate them at full speed. Therefore, an external power supply must be used. In the meantime, Metal Oxide Semiconductor Field Effect Transistor (MOSFET) can be used to control the voltage received by the DC motors for speed control using Arduino. The MOSFET will act as a switch that controls if current is conducted from the power supply to the motors and the Arduino Uno will control the switch (MOSFET). This is because the voltage can be easily controlled between 0V to the maximum voltage by using the pulse width modulation (PWM). Since the wall socket serves as the external power source for the DC motors, a DIN rail power supply is required to convert the 240V AC power source to the 24V DC power source and to stabilize the voltage.

3.3 Block Diagram

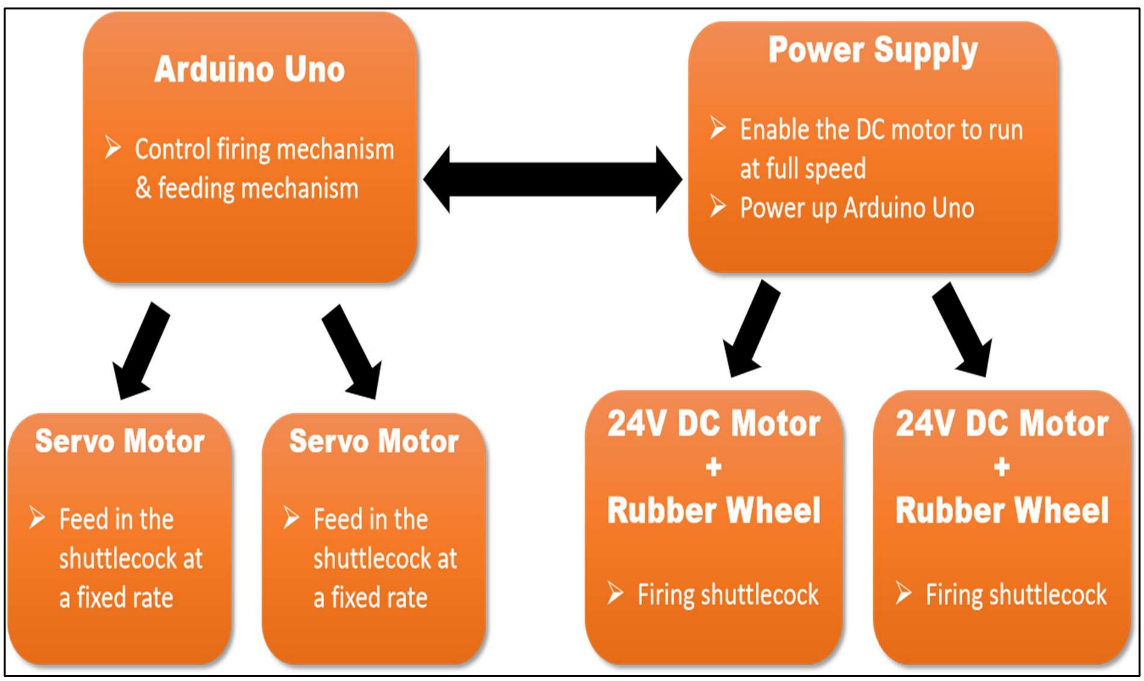

Figure 3.3.1: Block diagram of the project implementation.

3.4 Components Description

No.	Components	Description
1.	Arduino Uno	• Act as the controller to receive data, process the data, and provide the signal to output.
2.	DIN Rail Power Supply	• Convert the 240V AC power supply from the wall socket to a 24V DC power supply.
3.	24V DC Motor	• Spin the rubber wheel attached to it for the shuttlecock firing mechanism.
4.	Rubber Wheel	• Provide the firing mechanism.
5.	DC Servo Motor	• Control the movement of the moving part (bracket) for feeding in the shuttlecock at a fixed rate. • Adjust the angle of inclination of the shuttlecock firing platform to provide different firing trajectories.
6.	MOSFET	• Act as a switch to control the rotor angular velocity using pulse width modulation (PWM).
7.	Electrical Switch	• Disconnect or connect the conducting path in the circuit.
8.	Resistor	• Limit and regulate the flow of electrical current.
9.	Diode	• Control the voltage that flows through the DC motor.
10.	Capacitor	• Prevent the rush changes in voltage.
11.	Voltage Regulator	• Further drop the voltage.
12.	Power Inlet	• Connect the electric cables and power cables.
13.	Proximity Sensor (Infrared Sensor)	• Detect or sense the presence of shuttlecocks in the shuttlecock storage place to give an alarm if the storage is empty.
14.	Light Emitting Diode (LED)	• Light up to inform the users if there is no shuttlecock detection in the storage place.
15.	Toggle Switch	• Select different modes of firing mechanism.

Table 3.4.1: Components list with its description.

3.5 Project Operational Flow Chart

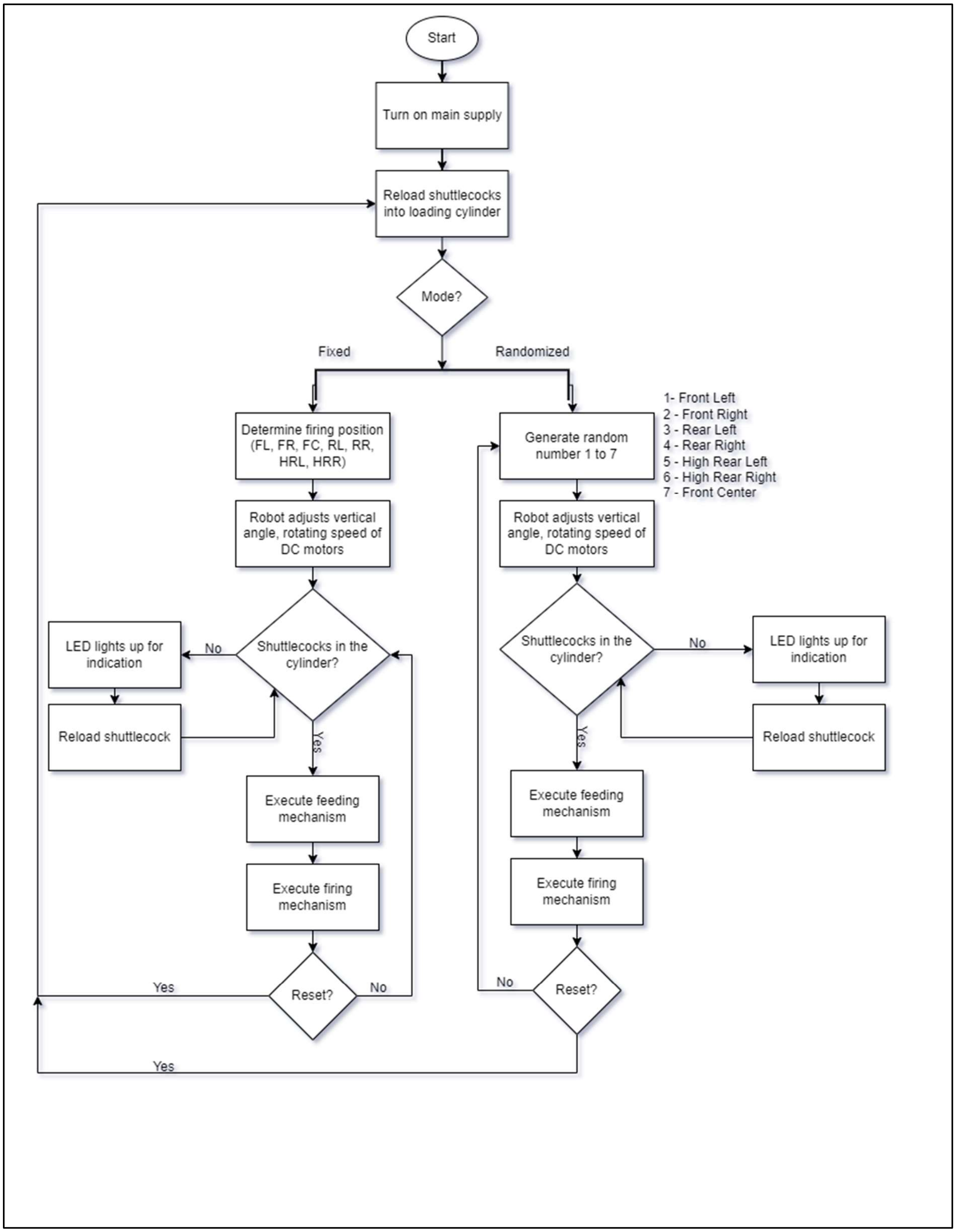

Figure 3.5.1: Flowchart of the badminton robot trainer.

When the badminton robot trainer is powered up, the end user needs to reload the shuttlecocks into the loading cylinder before he/she can start the self-training. After that, the end-user needs to choose the mode of training he/she wants which is either the fixed-position or randomized position shuttlecocks feeding training mode. If the fixed-position shuttlecock feeding mode is selected, the end user needs to determine the firing position that he/she desired. There are 7 positions for the end user to choose from which are the front left, front right, rear left, rear right, front center, high rear left, and high rear right service positions respectively. Thus, the badminton robot trainer will adjust the vertical angle and the rotating speed of the DC motors automatically based on the firing position chosen. In the meantime, the badminton robot trainer will detect whether there are shuttlecocks in the loading cylinder. If there is no shuttlecock detected by the proximity sensor, LED will light up to notify the end user that reloads action is required. On the other hand, if the shuttlecock is detected by the proximity sensor, then the robot trainer will execute the feeding mechanism, followed by the execution of the firing mechanism. If the reset button is pressed, the badminton robot trainer will stop functioning and the end user can change the mode of training he/she wants. Meanwhile, if the reset button is not being pressed, the badminton robot trainer will continue to function as usual and the proximity sensor will help to sense the presence of shuttlecocks in the loading cylinder throughout the training session.

If the randomized-position shuttlecock feeding mode is selected, the badminton robot trainer will randomly generate 1 number between 1 and 7 where number 1 represents the ‘front left serve’, number 2 represents the ‘front right serve’, number 3 represents the ‘rear left serve’, number 4 represents the ‘rear right serve’, number 5 represents the ‘high rear left serve’, number 6 represents the ‘high rear right serve’, and number 7 represents the ‘front center serve’. Then, the badminton robot trainer will adjust the vertical angle and rotating speed of the DC motors according to the random number generated in order to provide different firing trajectories and positions for better training quality. Similar to the fixed-position shuttlecock feeding mode, the proximity sensor will detect whether there are shuttlecocks in the loading cylinder. If no shuttlecock is detected, the LED will light up to give an indication to the end user for the shuttlecock reloading action. If a shuttlecock is detected, then the badminton robot trainer will execute the feeding and firing mechanisms. So that, the end user can start the training. Again, if the reset button is pressed, then the badminton robot trainer will stop functioning and this allows the end user to change the mode of training. If the reset button is not pressed, then the robot trainer will continue to provide the same mode of training.

3.6 Theoretical Calculation

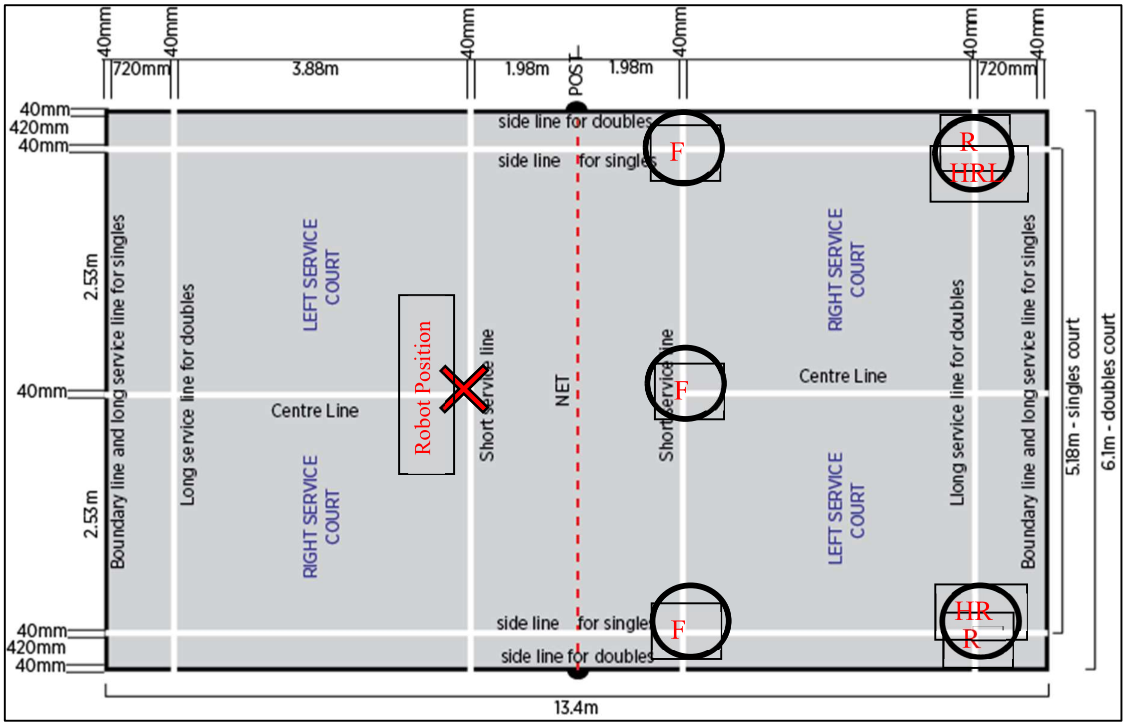

Figure 3.5.1: Dimension of a standard badminton court.

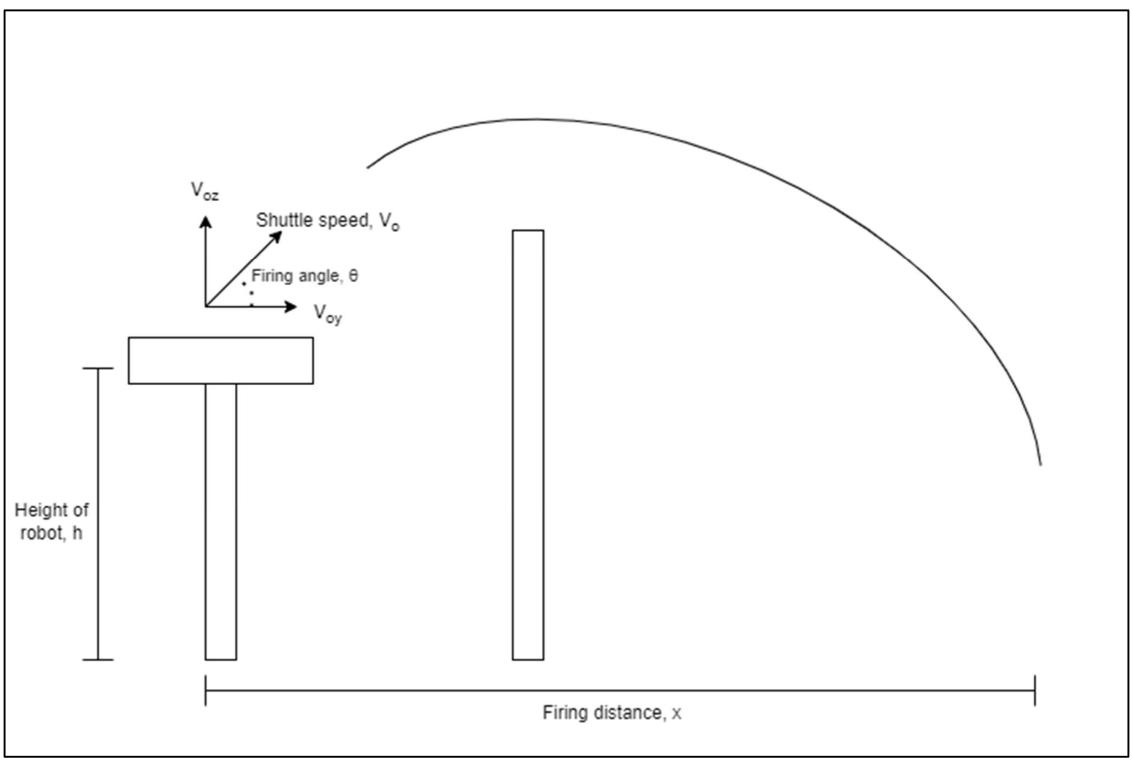

Figure 3.5.2: Projectile motion of the shuttlecock.

Finding y-component,

$x = v_{oy}t$

$x = v_o \cos\theta\, t$

$t = \frac{x}{v_o \cos\theta}$ -- Eq. 1

Finding z-component,

$y = y_o + v_{oy}t - \frac{gt^2}{2}$

Taking the robot base as the origin, thus making y = 0, y_o = h,

$0 = h + v_o \sin\theta\, t - \frac{gt^2}{2}$ ------------------------------ Eq. 2

Substituting Eq. 1 into Eq. 2,

$0 = h + \frac{x v_o \sin\theta}{v_o \cos\theta} - \frac{gx^2}{2v_o^2(\cos\theta)^2}$

Multiplying $(\cos\boldsymbol{\theta})^2$ into the equation,

$0 = h(\cos\theta)^2 + \mathrm{x}\sin\theta\cos\theta - \frac{gx^2}{2v_o^2}$

Let $\frac{gx^2}{2v_o^2} = \boldsymbol{a}$ and $(\cos\boldsymbol{\theta})^2 = \mathbf{1} - (\sin\boldsymbol{\theta})^2$,

$0 = h - h(\sin\theta)^2 + \mathrm{x}\sin\theta\cos\theta - a$

Since $\mathbf{2}(\sin\boldsymbol{\theta})^2 = \mathbf{1} - \cos\mathbf{2}\boldsymbol{\theta}$ and $\mathbf{2}\sin\boldsymbol{\theta}\cos\boldsymbol{\theta} = \sin\mathbf{2}\boldsymbol{\theta}$,

$0 = h\cos 2\theta + x\sin 2\theta + h - 2a$

Since A $\sin\boldsymbol{\theta} +$ B $\cos\boldsymbol{\theta} = \boldsymbol{C}\cos(\boldsymbol{\theta} - \emptyset)$,

$0 = \sqrt{h^2 + x^2}\cos(2\theta - \emptyset) + h - 2a, \emptyset = \tan^{-1}\frac{x}{h}$

Re-substituting a back into equation and rearranging,

$$\theta = \frac{\cos^{-1}\left(\frac{\frac{gx^2}{v_o^2} - h}{\sqrt{h^2 + x^2}}\right) + \tan^{-1}\frac{x}{h}}{2}$$

To determine the optimum firing angle, robot height, h shall be assumed at a reasonable value which is around the net's height, 1.52m to 1.55m. The shuttle speed, v_o can be obtained from the DC motor's angular velocity which will be shown in the following section. Firing distance, x can be calculated based on the firing position P_{FL}, P_{RR}, etc. based on Pythagoras' Theorem $\sqrt{A^2 + B^2} = C$.

In the following part, maximum height of the shuttlecock is determined.

To determine maximum height,

$v_z = v_o \sin\theta - gt$

At maximum height, $v_z = 0$

$t = \frac{v_o \sin\theta}{g}$

Let firing platform be origin,

$z_{max} = -\frac{gt^2}{2} + v_o t \sin\theta$

Where z_{max} = maximum height of shuttlecock above robot height, h.

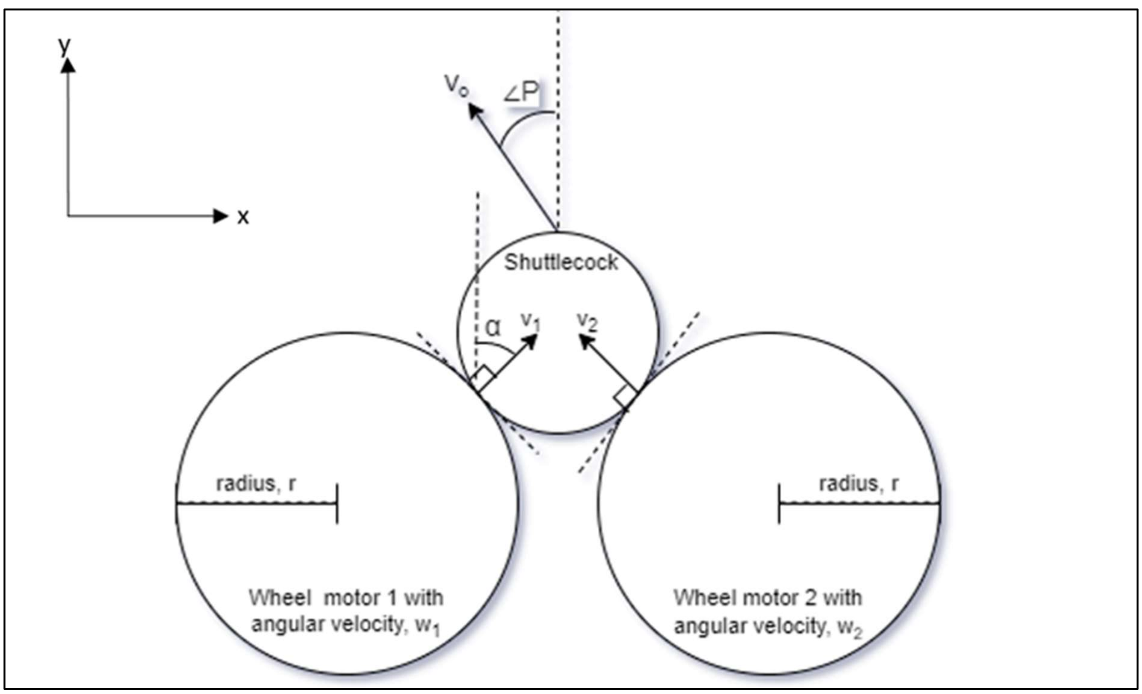

Figure 3.5.3: Illustration of the body diagram of spinning wheels and shuttlecock.

From DC motor's datasheet, angular velocity, w_i is known. Radius of the roller wheel can also be determined through measurement. Therefore, to find linear velocity, v_i,

$v_1 = rw_1$

$v_2 = rw_2$

$v_x = v_1 \sin\alpha - v_2 \sin\alpha$

$v_y = v_1 \cos\alpha + v_2 \cos\alpha$

$v_o = \sqrt{v_x^2 + v_y^2}$

$\angle P = \tan^{-1}\frac{v_x}{v_y}$

$\frac{v_x}{v_y} = \tan\angle P$

In this context, radius, r and angle α is constant since the spinning wheels and the feeding position of the shuttlecock are always fixed. Also, ∠P can be determined based on the firing position such as position FR, RL, and etc. where $\angle P = \tan^{-1}\frac{width\ between\ robot\ and\ firing\ position}{length\ between\ robot\ and\ firing\ position}$. Obtaining ∠P, the $\frac{v_x}{v_y}$ ratio, as well as $\frac{w_x}{w_y}$ ratio can then be determined. Since v_o must be strong enough to send the shuttle to the designated position, either angular velocity, w_i shall be set at maximum volume. Having all these done, v_o can then be procured for further calculation of vertical firing angle as mentioned above.

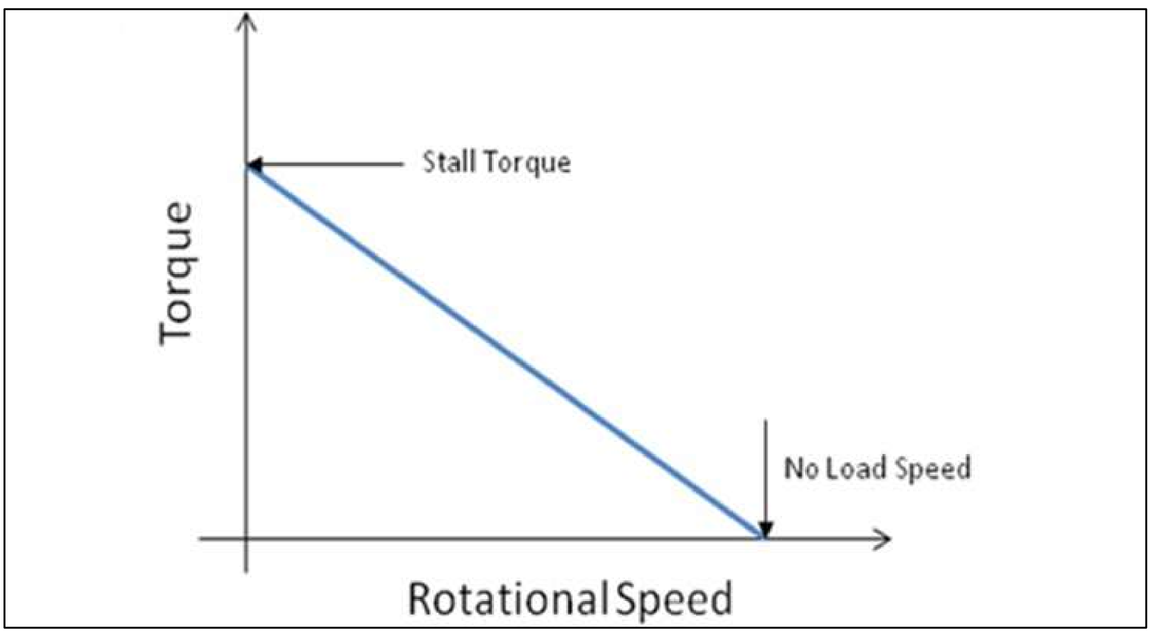

Figure 3.5.4: Illustration of DC motor's torque speed characteristic.

The datasheet of the DC motor shall be studied in order to understand its torque speed characteristic before buying compatible roller wheel for setup. The speed-torque gradient $\frac{\Delta n}{\Delta T}$ is an indicator of motor's performance. The smaller the value of the gradient, the less the motor varies with load variations. This aspect must be taken into consideration so that the rotating speed of the DC motor is ample to send the shuttlecock to every corner of the badminton court. The load torque, T_L induced by the weight of the spinning wheel is determined in such a way that

$$\boldsymbol{T_L = Fr} \textbf{ where } \boldsymbol{F = mg}$$

(The symbol r refers to the wheel's radius whereas m refers to the weight of the wheel.)

3.7 Limitation of Project

- The designed badminton robot trainer is unable to move around the badminton court to serve the shuttlecock from different positions which will improve the standard of the training. Instead, it is fixed at the center of the opposition’s court to provide the fixed and randomized shuttlecock feeding training from a fixed position.
- The designed badminton robot trainer is unable to provide all kind of shots during the training session such as smash shot and drop shot. Instead, it is just able to provide high and low serves to the player by the adjustment of the angle of inclination of the shuttlecock firing platform.
- The designed badminton robot trainer is not wireless as it still requires connection to the wall socket to support the operation of the high-rated DC motor.

The limitations of the project are due to the time constraint as we are only given about 5 weeks to come out with the prototype before the demo session. Besides, we need to take into account the total cost of the components needed before the project is implemented because the budget allocation is limited (RM300). As a result, our product is only suitable for independent training for badminton players at the beginner and intermediate levels.

3.8 Project Viability

3.8.1. Economical

Our design is considered economical because the design cost of the components and materials used were taken into account due to our budget is limited. We have conducted related research to get the most cost-effective supplies to build our design using lower-cost materials with better performance. Therefore, consumers are encouraged to purchase the badminton robot trainer at an affordable and reasonable price. As the quantity demanded increases, the price of the product can be sold at a cheaper price.

3.8.2. Sustainability

According to the Global Sustainable Development Goals list by the United Nations, our focus in this project aims on SDG 3 Good health and well-being. This goal states to ensure healthy lives and promote well-being for all at all ages. Our project is designed to ensure everyone can play badminton even if they do not have partners. Our design tends to help in improvements in health, increasing life expectancy for all and reducing the most common and preventable causes of death.

3.8.3. Manufacturability

Our design is using flexible and scalable mechanisms. This can provide lower upfront investment for manufacturing. Besides, the materials and components used in this badminton robot trainer are low enough while maintaining high quality. Higher-priced materials are not always superior to lower-priced materials in terms of performance. As a result, our design has the readiness for replication and can be produced in large quantities.

CHAPTER 4

PROJECT AND FINANCIAL PLANS

4.1 Project Management Plan

4.1.1. Project role

The figure below shows the organization chart and responsibilities of each role in group 8.

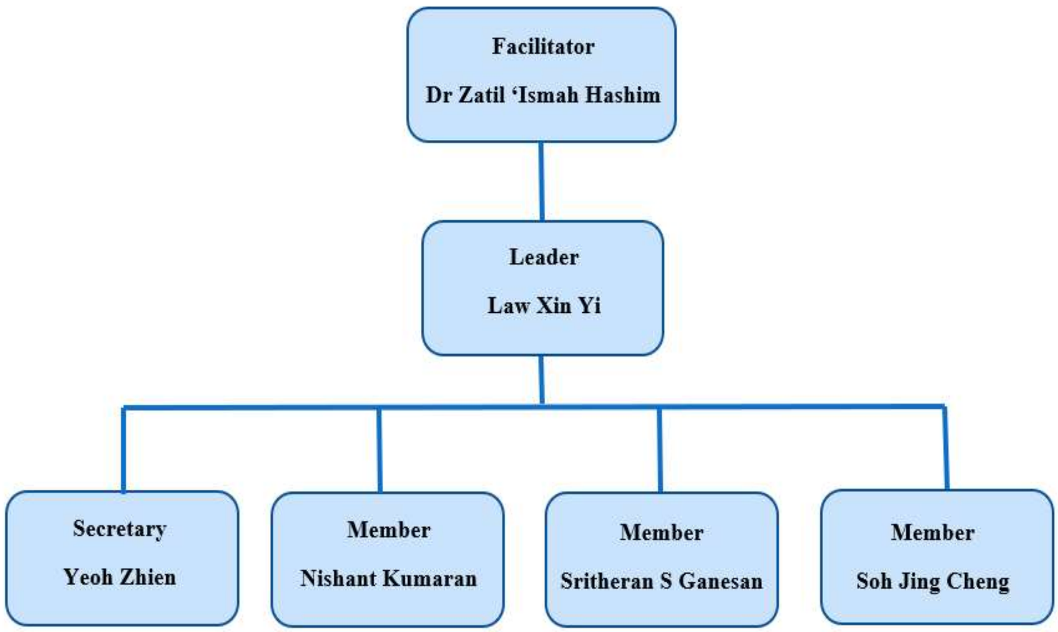

Figure 4.1: Organization chart of Group 8

This is the organizational chart of group 8. All of the members in this chart are assigned to a specific job to ensure the workload is properly distributed and also to make sure the work is carried out smoothly. Every member in this team has been provided a role throughout this whole project development. The roles and tasks are shown in the table below.

Name	Task assigned	Description
Law Xin Yi	Leader	• Manage and distribute tasks to all team members. • Monitor project progress and performance. • Compile proposal and report.
Yeoh Zhien	Secretary/software programming	• Summarise meeting content. • Prepare minute meeting report. • Handle software-related works for the project • Manage project cash flow
Nishant Kumaran	Software programming	• troubleshoot and solve critical issues faced during project development. • Handles software programming related to the project
Sritheran S Ganesan	Hardware handling/ Technical	• Prepare overall design for the project. • Design the hardware for the project. • Take care of the technical aspect
Soh Jing Cheng	Hardware handling/ Technical	• Prepare overall design for the project. • Come up with the idea to make the project work. • Communicate with the end-user.

Table 4.1 Project Role of Team Members

Based on the above table, the project has been equally divided into a few parts and distributed to each member. There are technical and also software perspectives of the project as well as the leadership and secretary tasks that are assigned to each member. These tasks were distributed based on each team on strength and potential to work on their provided task. Therefore, the end product will be based on the capabilities of each member to finish the project successfully.

4.2 Project Schedule

4.2.1. Gantt Chart

The capstone project is planned to be completed within one semester with a duration of 15 weeks. Thus, the progress of the project has to be planned properly by considering various kind of factors including budgets, time, and environmental issues. The time schedule for this project is presented as the Gantt Chart as shown in the table below.

Task/Week	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Team forming and Project discussion															
Project survey and end-user															
Pitching Session															
Discussion on Project Improvement															
Proposal Preparation and Submission															
Buying Components															
Project designing and construction															
Software development															
Project testing															
Project debugging															
Project demonstration & Individual Presentation															
Report & Logbook submission															

Table 4.2.1 Gantt Chart

4.2.2. Milestone

Milestone	Details	Completion of week	Status
Group forming	• Briefing on Capstone Project • Confirm group members and group leader • Research based on the theme given	Week 1	Done
Project discussion and submission of project title	• Discuss a project based on: 1. Problem statement 2. Objectives 3. Possible outcomes • Meeting with facilitator to confirm the project	Week 2	Done
Conduct marketing survey and look for end-user	• Prepare a google form to conduct a survey • Finding an end-user	Week 3 – Week 4	Done
Pitching	• Conduct an online pitching session with facilitator and end-user	Week 5	Done
Submission of proposal	• Modify design based on feedback from survey and end-user • Submit the finalized proposal	Week 6	In-pending
Designing and testing project	• Design project including hardware and software • Testing and debugging the project	Week 7 – week 11	In-pending
Final report preparation	• Prepare a final report • Record details about the project and its application	Week 12 – week 13	In-pending
Demonstration	• Demonstrate the working project	Week 14	In-pending
Submission of all reports	• Submit the finalized report	Week 15	In-pending

Table 4.2.2 Milestone

4.3 Project cost estimation

Our project consists of a few hardware that requires to be good ones for the badminton robot trainer to work efficiently. The badminton robot trainer must be capable of shooting the shuttlecock precisely therefore good roller wheels are required. The shuttlecock must also be able to move and be in place before shooting therefore the mechanism that is involved must work properly. To ensure this, we have come up with an estimation of the costs of the materials and components required, with minimal money as per budget, and also have the capability to make the project work without any failure.

Components	Quantity	Price per unit (RM)
Arduino Uno	1	40.00
External power supply	1	60.00
24V DC Motor	2	25.00
DC servo motor	2	10.00
MOSFET	4	4.00
Other materials, appearances, motor housing, feeding part	1	100.00
GRAND TOTAL		288.00

Table 4.3 Cost Estimation of Prototype

CHAPTER 5

CONCLUSION AND CONTRIBUTION OF PROJECT

5.1 Conclusion

In conclusion, this paper introduced an IoT-based shuttlecock launcher that acts as a standalone badminton trainer which could help badminton players at beginner levels conduct their self-training. Our badminton robot trainer has a high functionality that mainly works in two modes which are ball feeding with high accuracy at a fixed position and random positions. The hardware for this design cost RM288, which is much cheaper than the badminton robot trainer in the market now due to our design using lower-cost materials while maintaining its performance and quality. By having this badminton robot trainer, players do not need to rely on partners or coaches as the speed of shuttlecock feeding of the robot operates supersedes humans and also prevents typical human errors in terms of technique, and positioning whilst improving the overall quality of training.

5.2 Contributions

This project will provide significant positive effects on the society and health. People can buy our badminton robot trainer with a cheaper price for training or learning purposes as the price of materials and components used in this design is affordable and reasonable. Besides, the mechanism and technology used in this design has the readiness for replication. As the quantity of demand of product increases, our design is manufacturable as it has low upfront investment. As the design are produced in larger quantities, it can be sold in cheaper price per unit to the market. Moreover, our project will also benefit the health aspect of the community. More people are able to afford to have a badminton robot trainer to have self-training even without partners or coaches. In short, this project is creating a product that will provide numerous benefits and crucial solutions especially for beginner-level badminton players, since the badminton robot trainer is necessary during learning and self-training.

REFERENCE