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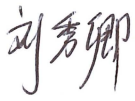

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DEVELOPMENT OF TABLE TENNIS LAUNCHER

LIEW XIU QING

Thesis submitted in fulfillment of the requirements
for the award of the degree of
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ABSTRAK

Pelancar ping pong adalah sesuatu alat latihan yang memberi tumpuan untuk meningkatkan kemahiran pemain. Objektif projek ini adalah untuk membangunkan alat latihan elektronik yang boleh dipasang di atas meja ping pong. Keperluan reka bentuk bermula dari pengambilan kelajuan pelancaran bola ping pong dan trajektori semasa sesi latihan dengan menggunakan Yawcam dan GIMP serta webcam diperolehi pada 8 bingkai sesaat. Prototaip ini terdiri daripada dua Brushless DC (BLDC) motor, dua Pengawal Kelajuan Elektronik (ESC), Pengawal Kelajuan PWM, sistem penghantaran bola dan peralatan momentum pelancaran bola, serta konsol pengawal. Semua ini mendapat kuasa dari 11.1V 2200 mAh litium polimer bateri. Aci motor dilengkapi dengan roda elastomer yang berputar kaunter untuk meningkatkan sentuhan permukaan antara penggelek dengan bola. Kelajuan sudut penggelek dikawal oleh pengawal kelajuan PWM. Tempoh diperlukan untuk menggantikan bola diukur dengan perintang bergantung cahaya (LDR), dan pemancar laser. Arduino Mega 2560 digunakan untuk memperoleh tempoh serta mengawal sistem penghantaran bola ping pong. Modul Bluetooth digunakan sebagai protokol wayarles untuk membolehkan pelaksanaan kawalan suara dengan menggunakan telefon bimbit Android dan sumber terbuka Aplikasi BT Kawalan Suara. Prestasi pelancar ping pong dinilai berdasarkan pelancaran jarak, konsistensi, kebolehulangan dan kajian kepuasan produk. Ia telah mendapati bahawa 10m/s pelancaran kelajuan dan mencapai jarak yang boleh diterima iaitu 2m. Ia juga menunjukkan bahawa sistem penghantaran bola ping pong berfungsi dengan baik. Kawalan dengan suara membolehkan pengguna mengawal kekerapan penghantaran bola dari jarak tertentu. Hasil kajian juga menunjukkan bahawa sistem boleh digunakan sebagai alat alternatif untuk latihan sukan.

ABSTRACT

Table tennis launcher is a training tool which focuses to enhance and improve player skills. The object of the project is to develop an electronic controlled training tool that can be retrofitted on a standard table tennis table. The design requirement starts with acquisition of launching speed and trajectory during a training session using Yawcam and GIMP as well as webcam acquired at 8 frame per second. The prototype consists of two Brushless DC (BLDC) motors, two Electronic Speed Controller, PWM speed controller, ball feeding system and momentum launching instrumentation, as well as controller console. All of these is powered by 11.1V 2200 mAh lithium polymer battery. The motor shaft is fitted with counter rotating elastomer wheels to increase the contact surfaces of rollers and balls. The angular speed of the rollers are controlled by the PWM speed controller up to nominal launching speed of 10m/s. The duration required to displace the ball is measured by the Light Dependence Resistor (LDR), laser emitter and optical arrangement instrumentation. An Arduino Mega 2560 is used to acquire the duration as well as the controlling the servo control feeding system. A Bluetooth module was used as a wireless protocol to allow implementation of voice control by using Android hand phone and open source BT Voice Control Applications. The performance of the table tennis launcher was evaluated on the basis of launching distance, consistency, repeatability and product satisfaction survey. It was found that the 10m/s launching speed reached acceptable length with 2m. It also showed that the feeding system works fine. The voice control application can remotely control the frequency of ball feeding from certain distance. The survey result also showed that the system can be used as an alternative tool for training.

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LIST OF SYMBOLS

λ	Grab Angle
μ	Contact Coefficient
η	Friction Angle

LIST OF ABBREVIATIONS

PWM	Pulse Width Modulation
BLDC	Blushless DC Motor
CATIA	Computer Aided Three-Dimensional Interactive Application
ESC	Electronic Speed Controller

CHAPTER 1

INTRODUCTION

1.1 Introduction

Table tennis is a sport that played by two or four players struck a small lightweight ball over the net with plastic rackets on a hard table (Hojatighomi 2013). Table tennis is accepted to have been originated at Europe in the 1880s (Yong 2014). It started as an emulation of the traditional lawn tennis played on the dining table as miniature versions. In 1926, the International Table Tennis Federation (ITTF) was formed for the purpose of governing the worldwide table tennis associations (Jenny Heaton, 2009). Until now, ITTF has more than 220 member associations and up to 300 million table tennis players from all around the world. In other words, table tennis is gaining more popularity nowadays.

Table tennis consists of various types of strokes such as push, drive, loop, chop, and block as well as multiple types of serves such as long serve, short serve and medium serve where each of this techniques is important for defining an athlete in terms of winning or losing (Ponnusamy et al. 2015). Therefore, honing and training are a must if anyone has to master these table tennis skills. Training in a systematic manner is crucial for a person to excel in a particular sport, regardless the people are playing it on a leisure basis or professionally. Indeed, the most effective training method in table tennis is multi ball training (Zheng & Jin 2016). Multi-ball training with various method for rotation, intensity, speed, position, arcs, mixes of various innovations and nonstop ball striking can adjust for the less forward and backward times, more space in order to enhance the practice efficiency and make players get a handle on and improve an assortment of difficult movements. Furthermore, continuous striking in multi-ball training can viably enhance the density and intensity of the training, which not just helps players improve their techniques and tactics, but also strengthen player's quality and will.

However, there are some problems to be aware of when feeding multi-ball. The feeder or coach is standing on the other side of the table which oppose the trainee and this is not ideal for viewing the trainee's lowers body and subsequently some technical mistake made by trainee might be missed (D. Seemiller 2009). If the coach stand directly behind the trainee, he or she can see the trainee's footwork whether they are in the right footstep. Meanwhile, if the coach is focusing a lot on his or her feeding and not viewing the trainee then he or she cannot point out the mistake right at the moment trainee did and the trainee is accordingly practicing a fault. It could likewise be contended that a multi-ball feed is not thoroughly repeating the stroke and its position if feeding by a human coach. Therefore, table tennis launcher is a high demand device now for training especially multi-ball training (Yong 2014). Table tennis launcher is a device that can shoot the table tennis ball in the specific position that player desired over and over again until player masters the skills. In addition, if player miss the ball or hit the ball to the wrong direction, the table tennis launcher will still shoot the ball to the same position player had set earlier. This is something that a human partner or human coach unable to do.

Moving on, it is hard to find a good sparring partner who can play a table tennis game in different level. Although table tennis game is playing with multiple players but when it comes to practice or training, it usually done by solo (Williams 2011). Therefore, a plenty number of table tennis launcher being commercialized in all around the world. These launchers consist of two types such as recreational type and high-end type (Yong 2014). Recreational type launcher use for recreation purpose at home or leisure sport centre while high-end type use at professional sport training centre. For example, one of the launchers is called Newgy Robo Pong. Newgy Robo Pong can handle many types of drills, no matter is serve return, backspin, high ball and so forth. Newgy Robo Pong not only allow people to do technical and physical training but also reaction training. There is one interesting part of this launcher which is ball recycling part. The recycling net will block the ball which is off to table and the ball will drop to the ball dam to be recycled. Without doubt, table tennis launcher becomes a perfect partner when training or just playing a simple table tennis game.

Hence, in this project, a table tennis launcher with launching system and feeding system will be designed and fabricated for the need and demand. However, the fabricated

table tennis launcher may not accurate and consistence as coaches and players expect while doing the repeating ball shot (Norris et al. 2012). This is hard for player to focus on his or her tactic and technique while performing on a practice or training exercise. With this intention, the control system has to be designed with voice controller for obtaining better manipulation. The system will be capably using by player from all ages.

1.2 Problem Statement

The problem statements as shown follows:

1. Launching a table tennis ball needs better motor abilities to accomplish the proper spin.
2. Better manipulation of the ball feed is crucial to making a functional prototype.

1.3 Objectives

The objectives as shown follows:

1. To determine the kinematics of table tennis ball by using images acquisition method.
2. To fabricate a table tennis launcher with launching system and feeding system.
3. To integrate a voice control algorithms for ball feeding frequency with microcontroller.

1.4 Scope of Project

The project scope as listed follows:

1. System integration for table tennis launching system and feeding system.
2. A trajectory control system that can control the ball trajectory for table tennis launcher in fixed angle and direction.

CHAPTER 2

LITERITURE REVIEW

2.1 Introduction

This chapter provides thematic review on experimental and computational investigation on table tennis. These reviews include previous research findings in sport science and mechatronics engineering fields. The main purpose behind this chapter is to give a clearer point of view to the issues and scope of this project. It additionally plans to seek for better strategies which will be applied in this project. The information included historical perspective, past study and past research works that have been accomplished for table tennis training, coaching, table tennis launcher, and stages of ball.

2.2 Conventional or Traditional Training System

In traditional training, practices and exercises of coaches are depended on coaches' beliefs, experiences and behaviours to determine the way in which their trainees learn or have to learn (Harvey et al. 2013). In other words, life story or life history of coaches will affect the route in training is arranged and structured. This culture is strong and continuous using in every coach's training. These trainings and practices mostly tied to the method of 'trial and error' and of instinctive knowing which mean that without the use of any analysing research data, imitating others' training patterns rather than on rational objective data. Consequently, coaches tend to train their trainee from a simple way to a complicated way. For instance, the forehand drive of table tennis can be split into four phases such as the ready position, the backswing, the strike, and the follow through to ease the training. But, human coaches tend to follow their thought and may mess up all the steps in just single practise. This may cause the player fail to master the skills with the complex training style.

Meanwhile, coaches generally did not have self-awareness and did not realise that their behaviour are affecting the structure or the arrangement of practices and of training sessions. They are still using their traditional style in the training sessions rather than understanding and considering the needs of the trainees (Harvey et al. 2013). In this case, important instruction like what, how and why are implemented would be ignored because of the different training styles. In effect, the trainees would not understand with the important concepts and skills to reflect upon the objectives of their training sessions. Therefore, the robot trainer is needed for the trainees to achieve the goals of their training session and the broader environment to process the given practices and trainings. In the meantime, human trainers' coaching styles do not have a constant manner for each coach. Without doubt, human coaches tend to employ the training style or practice type of world class athletes' coaches because they successfully trained the world class athletes. Those trainings and practices of the world class athletes do not mean that it will suitable for a normal people or a beginner. Thus, the coaches should structure the training or the practice according to the needs of the learners and applicable and effective for a normal people or a beginner.

Table 2.1 Detail of the three collegiate coaches and the results on the long season study

Coach	Sport	Experience	Background	Trainee	Time used	Five behaviours
Stuart	Field hockey	11 years of coaching in clubs	• Degree level education • Level two field hockey National Governing Body (NGB) coaching qualification	Women's 1st team	1000	80%
Martin	Volleyball	4 years coaching experience	• Level one volleyball coaching qualification • Engaged in postgraduate study in sports coaching	Men's 1st team	533	75%

Will	Basketball	15 years coaching experience	• Degree level education and held Level three NGB basketball award	Men's 1st team	905	85%

Source: (Harvey et al. 2013)

After reviewing the traditional training, the reason why a table tennis launcher is needed for training or practice is determined. With this intension, Harvey et al., 2013 carried out a research on the relationship between practice state and coach behaviour in three collegiate coaches over the course of a season. Three male collegiate coaches as shown in Table 2.1 are chosen in this long season research study. These coaches must be in full time coaching to ease the progress of this study. This study implemented systematic observation and interpretive interview for data collecting methods. This study also analysing the data on time spent in each training, coaching behaviours which are instruction, general feedback positive, silence, specific feedback positive, questioning, and interview data. From the results above, the five coaching behaviours obtained high percentage from 75% to 85%. Thus, the practices sessions' structures are employed from the coaches' behaviour and experiences is one of the reasons why table tennis launcher is demanding nowadays.

2.3 Modern Training System

In today's era of advanced technology, efficiency and accuracy are very much needed. Human coach may not feed every single ball in the same speed, same trajectory and same direction. Also, their coaching are mainly depend on their behaviors and beliefs in the conventional training system. These problems may affect trainee's practice and training progress. Thus, table tennis launcher and humanoid robot are fabricated for the need and demand. Table tennis launcher is a perfect sparring partner during multi-ball training while human-like humanoid robot can interact with the players and the environment. These two innovations are the best equipment in this modern training system.

2.3.1 Multi-Ball Training

Practicing with multi-ball is an effective way of table tennis training. First, techniques correction is one of the functions of multi-ball training (Zheng & Jin 2016).

The density and intensity of multi ball training is stronger than the single ball training. Multi-ball practicing with coaches' instructions, advices and tips will ease the trainees in correcting movement techniques. Second, multi-ball training can improve footwork pattern. For instance, this is hard for a trainee to run continuously for about 30 balls in the single ball training to familiar with the particular footwork. Moreover, there are different types of footwork pattern can be practice with multi-ball training, including side to side footwork, in and out footwork, and crossover footwork (Jenny Heaton 2009). Trainee can focused practice on their weak techniques and need not to focus on other player. Last but not least, multi-ball also can enhance the combination ball techniques especially for the advanced players. Elite player often focus on combination ball practice because it is very important in the match. Due to plate time's increment, multi-ball training method is chosen rather than single ball training. Trainee can practice variety of table tennis techniques or footwork with multi-ball training method by different placements and different speeds of the ball.

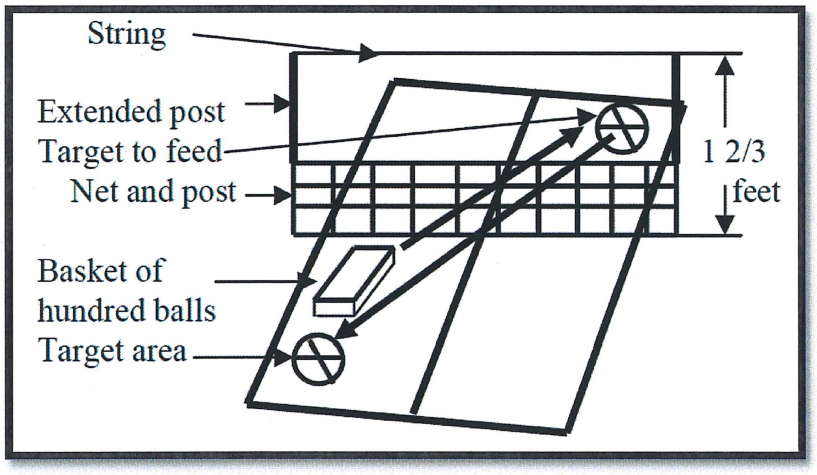

Figure 2.1 Schematic example of right-handed feeder multi-ball training set up
Source: (Flores et al. 2010)

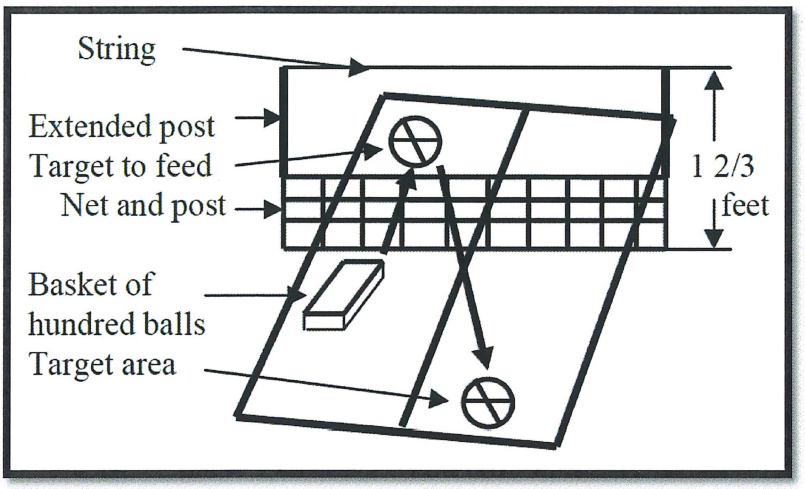

Figure 2.2 Schematic example of left-handed feeder multi-ball training set up
Source: (Flores et al. 2010)

Table 2.2 Heart rate statistical table in different phases in multi ball training

	Average value of heart rate
Before multi ball training	70
Before single ball training	69
In multi ball training	190
In single ball training	131
Recovery in multi ball training	86
Recovery in single ball training	71
Hitting times in multi ball training	232
Hitting times in single ball training	155

Source: (Zheng & Jin 2016)

From Table 2.2, compare the influence of both trainings on the heart rate with the same training content and training time, multi-ball training has higher density and intensity than one to one single ball training. Recovery heart rate in single ball training is 15 less than in multi-ball training. This showed that the recovery of multi-ball training is faster compared to one to one single ball training. At the same time, hitting times in multi-ball training is higher which means that the density of multi-ball training also higher. Therefore, multi-ball training is not only helpful for the improvement and strengthens of

table tennis techniques and movements, but also maintaining the cardiovascular and respiratory systems.

2.3.2 Semi-Autonomous Training

Table tennis launcher is equipment for semi-autonomous training. It is needed for better training because coach is usually standing on the other side of the table which oppose the trainee in traditional training and this is not ideal for viewing the trainee's lowers body. Figure 2.3 showed that table tennis launcher has high potential to be the practice partner for athletes at all levels especially in multi-ball training (D. Seemiller 2009). The effect of the use of table tennis launcher on multi-ball training is evaluated in the research which done by Jayabalakrishnan and Achanta. The research consist of two steps. The first step was surveying a group of coaches from national level on the effectiveness of table tennis launcher training and getting valuable feedback from them. The second step was collecting quantized data from the chosen sample during multi-ball training. The experiment was set up as shown in Figure 2.4. This information is to verify multi-ball training is the essiential method for table tennis training and it had higher effectiveness while apply with table tennis launcher.

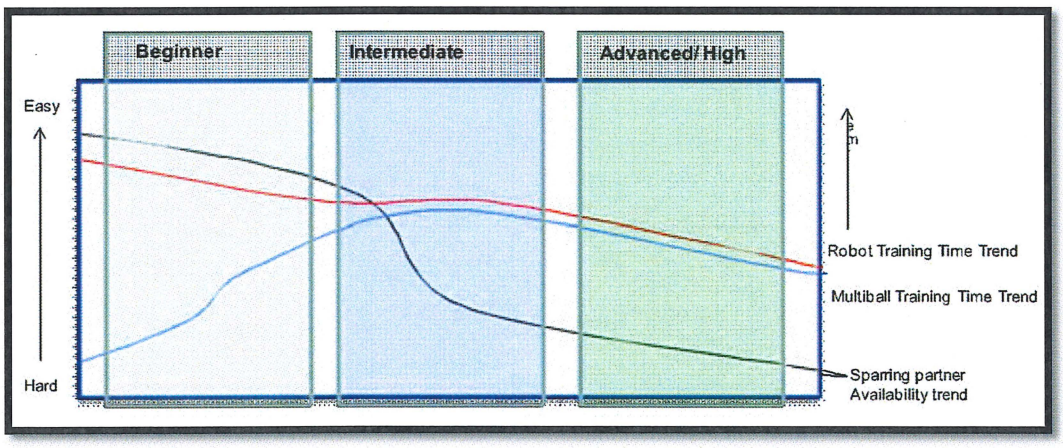

Figure 2.3 Multi-ball training, robot training and sparring partner availability across the levels of play

Source: (Jayabalakrishnan & Achanta 2013)

Table 2.3 Synopsis of findings from overview among table tennis launchers

	Percentage
Reason for robot	
Technique correction	62.5%
Footwork	75%
Consistency or Accuracy	75%
Level of athletes for robot training	
2 - 5 years training	46%
More than 5 years training	15%
District or State level	46%
High level	23%
Limitations for utilizing for advanced athletes	
Predictable randomness	28%
Lack of variations	71%
Lack of match simulation	28%
Serve or receive sequence	28%
Measures to overcome above limitations	
Multi-ball training	40%
Sparring partner	60%
Restrict usage of robot	20%

Source: (Jayabalakrishnan & Achanta 2013)

It is hard to find a suitable level sparring partner at every single training or practice time. From Table 2.3, there is high percentage of the coaches agreed that table tennis launcher is perfect partner for helping the athletes in simulated training and performance enhancement of athletes. In this intension, the technique correction is in high percentage for the coaches can easily pointed out the mistakes players made by standing behind them. At the same time, feeding a high repetition of balls with table tennis launcher is

effectively enhancing the skills of the athletes. Table tennis launcher is a great partner for the trainees when the coach is coaching them.

2.3.3 Fully Autonomous Training

Fully autonomous training is carried out by using humanoid robot which its human-like outlook and design gives it favourable circumstances in working in human-interactive environment. There are several configurations which involve in humanoid robot (Sun et al. 2011). First, its mechanism is designed to be flexible. In table tennis game, it is fundamental to build up a robust and flexible humanoid robot for walking. Second, the control system of humanoid robot is real time control. It not just concern on the efficiency of the arranging and control algorithm, additionally on the control process duration because of the quick respond requirement. In this intension, minimizing the process duration is essential to control the humanoid robot. Third, humanoid robot has accurate recognition that includes detecting the moving table tennis ball, predicting its direction and localizing the robot itself decisively in real time. Last but not least, humanoid robot can keep itself balances dynamically while its arm moving in high speed. Currently, Y. Sun et all., 2011 built a humanoid robot named Kong can play the table tennis game with a human player in real time which shown in Figure 2.4. Humanoid robot with their human-like form can interact with the players and the environment.

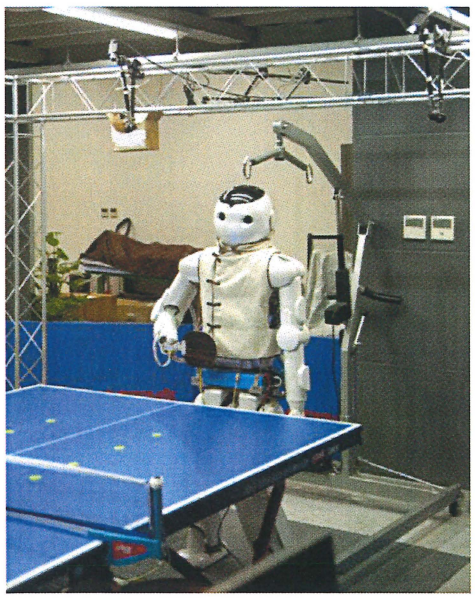

Figure 2.4 Humanoid robot Kong is in stand by position
Source: (Sun et al. 2011)

2.4 Table Tennis Launcher

Table tennis ball launcher is not a new invention these days. The launching mechanism of it is generally using same idea as the tennis launcher. Where the two motors are installed parallel to each other of different rotating direction and launching a table tennis ball through the attached wheels at the exit hole (Yousif & Yeh 2011). Nowadays, there are many table tennis launchers were marketed to satisfy the request and need of the players to improve their skills. Recreational type and high-end type are the two fundamental sorts of table tennis launcher (Yong 2014). Furthermore, table tennis launcher also can be divided into two design which are table attachment launcher design and vertical ball launcher design (Williams 2011).

2.4.1 Pneumatics Ball Launch System

Pneumatics launching system fundamentally utilizes compressed air to shoot the ball. The air is packed utilizing compressor and put away as a part of a chamber. The pressure of this compressed air is vital to guarantee great direction of ball. This is on account of the initial velocity of the ball contingent upon the compressed air pressure. While the ball is put away in a tube and this current tube's elevation angles can be changed in accordance with get certain sorts of trajectories. The elevation angles can be adjusted manually or automatically utilizing electronic framework (Kassim 2013).

This pneumatic launching system can deliver spin ball direction by introducing connector toward the end of the outlet tube. This connector backing off one side of the ball and makes the ball turns at required pivot. The connector should be moved about the tube's pivot to get various sorts of ball twists, for example, top spin, back spin and side spin ball. Be that as it may, the turn velocity cannot be adjusted separately as it relies on upon the initial velocity of the launching ball.

Pneumatics launching system is typically powered by 230/110 V mains voltage. The benefits of pneumatics launching system are high strength, unwavering quality and imperviousness to different climate conditions. However, this kind of framework just elevates basic strokes to the players and no advanced training can be promoted. It is most appropriate to beginners and not for expert players.

2.4.2 Mechanical Ball Launch System

Mechanical ball launching system fundamentally utilizes two rollers or wheels which rotate in different direction to launch the ball (Minnich et al. 2011). These wheels are typically controlled by electrical motors to turn. The initial velocity of the ball relies on upon the turning velocity of the wheels. The wheels have little opening between them where they influence the approaching ball. The ball originating from ball feeder is then crushed under colossal speed and pressure applied by the wheels. At that point the tennis ball is shot by means of gigantic speed and pressure of the wheels.

The elevation angles can be adjusted by moving the wheels left and right or moving wheels here and there. Spin ball trajectory can be performed by adjusting the turning velocities of both wheels. If the upper wheel is turning quicker than lower wheel, it will deliver top spin ball. While if the lower turning wheel is turning quicker than upper wheel, the ball launches with back spin (Kassim 2013).

Mechanical launching system is generally powered by accumulators as it can be utilized at courts with no electrical supply or if there may be an occurrence of its breakdown (Minnich et al. 2011). Yet, there is likewise weakness of utilizing accumulators since them limits the use time despite the fact that there is no uninterruptible operation. In any case, mechanical launching system can perform better as it gives high accuracy and more extensive scope of the conceivable strokes. So it can be utilized as a part of advanced training and reasonable for expert players.

2.4.3 Ball Feeder Mechanism

In light of the surveys of the distinctive frameworks, one of the primary elements which can recognize the creation of a launcher framework would be the continuous feeding system. This element controls the frequency of the balls feed to shoot from the launcher. A ball server provided by a mechanized ball feeder contained a trough and turning propeller plate that feeds balls in every rate (Ahmad 2013). The Robo-Pong robots have a narrow base which permits the balls to move due to gravity as a feeding framework where the table tennis balls fall into it. The balls then move into a vertical

tube which holds and turns the balls vertically into the place that it will be propelled (Williams 2011).

2.4.4 Recreational Type

Recreational type of table tennis launcher is suitable for the player who plays table tennis as a recreational sport. It focuses on home user and leisure sport centre. This type of table tennis launcher only consists of simple features such as adjustable speed, spin, shooting position and so forth. The comparison of some recreational type table tennis launcher was done by Yong as shown in Table 2.4 and.

Table 2.4 Features of various example of recreational type table tennis launcher

	Newgy Robo-Pong 2050	**Newgy Robo-Pong 1050**	**Newgy Robo-Pong 540**	**iPong TOPSPIN**	**iPong PRO**
Price	RM2108.80	RM1276.80	RM636.80	RM319.44	RM728.40
Controller	Wired remote	Wired remote	Wired remote	Wired remote	Wired remote
Power Source	AC adapter	AC adapter	AC adapter	9V battery	AC adapter
Ball recycling	Yes	No	No	No	No
Spot selection	21	21	8	No	3
Head angle adjustment	Yes	Yes	No	No	No
Spin selection	Yes	Yes	Yes	Topspin only	Top and bottom only
Speed selection	Yes	Yes	Yes	No	No
Ball frequency	Adjustable	Adjustable	Adjustable	Adjustable	Adjustable
Programmable	Yes	Yes	No	No	No

Source: (Yong 2014) (Williams 2011)

2.4.5 High-end Type

High-end type table tennis launcher was intended for elite athlete and sport training centre. The design was utilized to improve table tennis technique and enhance the effectiveness and efficiency of practice. Thus, there is some adding on features but the main features of high-end type are similar with recreational type. For instance, remote arc adjustment by Killerspin Throw Robot and twofold turn innovation by AMDT Y&T V-989H Robot. The comparison of several high-end type table tennis launchers was done by Yong is shown in Table 2.5.

Table 2.5 Features of various example of high-end type table tennis launcher

	Butterfly SmartPong	**Killerspin Throw Robot**	**Oukei TW-2700-S9**	**AMDT Y&T V-989H Robot**	**AMDT Y&T V-981 Robot**
Price	RM5405.97	RM2699.82	RM5084.82	RM4423.35	RM1589.97
Controller	Wireless remote	Wireless remote	Wireless remote	Colour LCD touch screen	Wireless remote
Power Source	AC adapter	AC adapter	AC adapter	AC adapter	AC adapter
Ball recycling	Yes	Yes	Yes	Yes	No
Spot selection	-	-	18	11	2
Head angle adjustment	Yes	No	Yes	Yes	Yes
Spin selection	Yes	Top and bottom only	Yes	Yes	Yes
Ball speed selection	Yes	Yes	Yes	Yes	Yes
Shooting frequency	Adjustable	Adjustable	Adjustable	Adjustable	Adjustable
Programmable	Yes	Yes	Yes	Yes	Yes

Source: (Yong 2014)(Williams 2011)

2.4.6 Table Attachment Launcher Design

This system takes after the style of the launching systems which are appended to toward one side of the table. The base of this launching machine will be composed with a wheel connection structure which permits the system to move on a level plane along one end of the table. The table tennis balls will be held and shot by the accumulation of a hopper and a swivel track system. The ball will exit the hopper, go along the swivel track all through the system, hit the shooting wheel then be shot from the system. On the back upper casing of the launcher will attach a net which table tennis balls will drop into the dam and then returning to the feeding system. (Williams 2011)

2.4.7 Vertical Ball Launcher Design

This design varies from the style of the table attachment design because of the way that this concept will be composed with a vertical wheel base. This base will permit the system to be maneuverer from one range of the table tennis table to another. The table tennis ball will launched from a hopper by a continuous feeding ball system. The ball will go along a vertically slanted tracking system which prompts to the shooting motor wheel. Once the table tennis ball hits the shooting wheel the ball will be shot out. This launcher will be attach with a rotational net appended to the back of the casing of the launcher to improve a players returning accuracy and also get the table tennis balls which are shot from the machine. (Williams 2011)

2.5 Stages of Ball

In order to launch the ball using two motors which are rotating in different direction three conditions should be met. The first is the pre-launching stage for pulling the ball in between the wheels. The second is the launching stage for launching the ball away through the wheels. Last one is the post-launching stage.

2.5.1 Pre-Launching Stage

At the point when the ball is started to pulled by the wheels, two primary forces show up at the contact focuses between the ball and the wheels. These are the pressure force N, which is normal to the surface which contact with the ball, and the tangent friction force T as appeared in Figure 2.5. In order to pull the ball, the horizontal component T_h, of the contact constrain T is equivalent or more noteworthy than the horizontal component N_h of the pressure force N (Wusatowski, 1960).

$$T\cos\lambda \geq N\sin\lambda \qquad 2.1$$

Where λ can call as "grab angle" which appear in between the surfaces contain the wheels' axes as well as the surfaces contain the pivot of wheel and the contact point between the ball and the wheel. As T=μN, where μ is the contact coefficient (Wójcicki et al. 2011), then:

$$\mu \geq tg\lambda \qquad 2.2$$

But

$$\mu = tg\eta \quad (2.3)$$

As η is friction angle, the equation below can represent the condition for dragging the ball in between the wheels.

$$\lambda \leq \eta \quad (2.4)$$

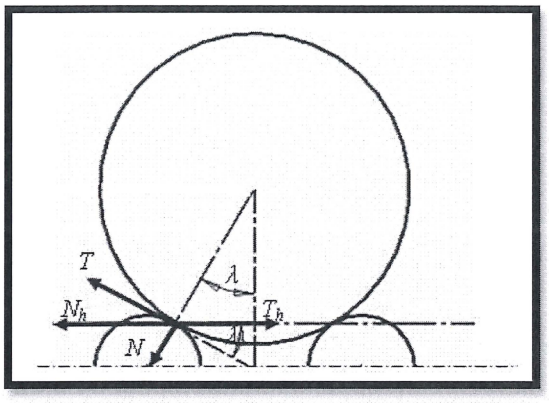

Figure 2.5 Forces and geometry at the contact between the ball and the wheels during pulling the ball in between the wheels

Source: (Wójcicki et al. 2011)

2.5.2 Launching Stage

For launching the ball through the wheels, the friction force between the ball and the wheels ought to be equivalent or more noteworthy than the inertia force of the ball as appeared in Figure 2.6. This condition guarantees that there is no slip between the wheels and the ball:

$$F_w \geq 2T \quad (2.5)$$

The acceleration ought to be transmitted from the wheels to the ball to acquire the required initial velocity of the launch. The friction force between the wheels and the ball relies on upon the friction coefficient and on the pressure constrain between the wheels and the ball (Wójcicki et al. 2011). The pressure constrain can be acquired from the meaning of Young's modulus for the ball:

$$N = \frac{Es\Delta l}{2r} \quad (2.6)$$

with Young's modulus E, ball deformation Δl and the area at the deformation surface s.

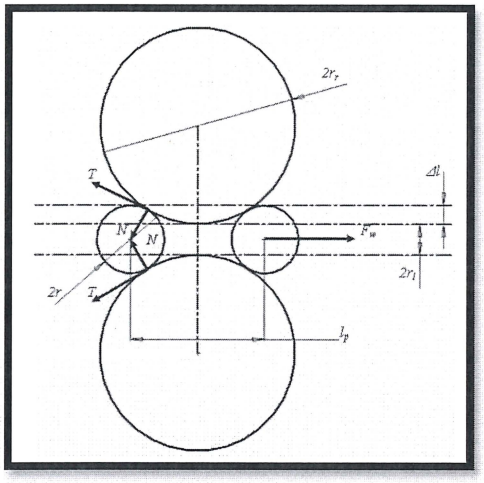

Figure 2.6 Forces and geometry at the contact between the ball and the wheels during launching the ball away

Source: (Wójcicki et al. 2011)

2.5.3 Post-Launching Stage

The flying ball is affected by three principle powers: gravity, drag and lift as appeared in Figure 2.7. Just the drag force coming about because of the translational movement of the ball is considered. The impact of the drag coming about because of the rotation is ignored. During the stroke at the court the rotational velocity of the ball is practically the same as soon after the serve that is the rotational velocity drop amid the flight is negligible. This implies the moment of the air drag constrain amid the turn does not impact the flight of the ball in a detectable way (Wójcicki et al. 2011).

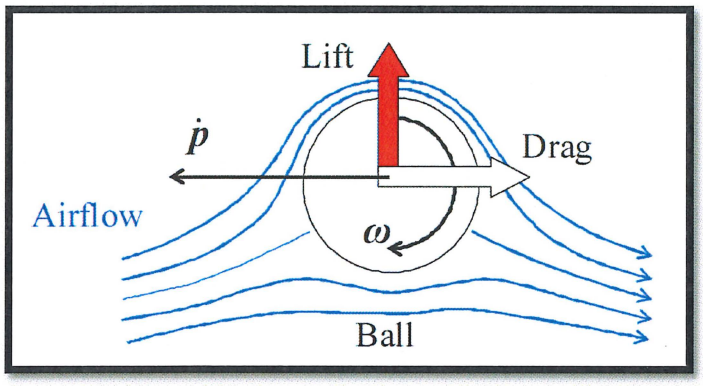

Figure 2.7 The drag and lift forces of the rotated flying ball

Source: (Nakashima et al. 2011)

2.6 Pulse Width Modulation (PWM)

PWM gives the distinctive way to deal with controlling the speed of a brushless DC (BLDC) motor. Power is provided to motor as square wave with steady peak voltage however changing in width of pulse or cycle of duty. The duty cycle of PWM is controlled by the pulse width because the frequency is consistent while the on-off time is fluctuated, in this manner the power builds duty cycle in PWM. Figure 2.8 showed the higher the average voltage, the higher the value of duty cycle or pulse width (Singh & Pandey 2013).

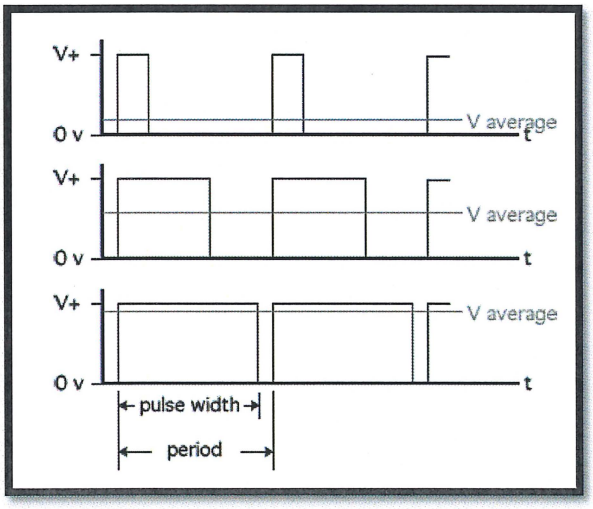

Figure 2.8 The square wave of PWM

Source: (Yong 2014)

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter explains the technique adopted to build up a table tennis launcher with launching system and feeding system. Details of imaging system for identifying the kinematics of table tennis ball will be clarified in the upcoming section. Moreover, the following section covers the explanation of the system block diagram.

3.2 Stage of Literature Review

In this stage, articles, books, past research papers and journals that identified with the implementation of launching system, feeding system and ball recycling system in table tennis launcher are reviewed. This is fundamental to increase and refined the information as well as knowledge on the project that will be led later on. Fields of study in this stage can be classified into two main categories which are the sport science in table tennis and the implementation of mechatronics engineering knowledge on the launcher. By looking into the past discoveries, it will be help in identifying the problem statements, objective, and scope of the project.

3.3 Project Flow Chart

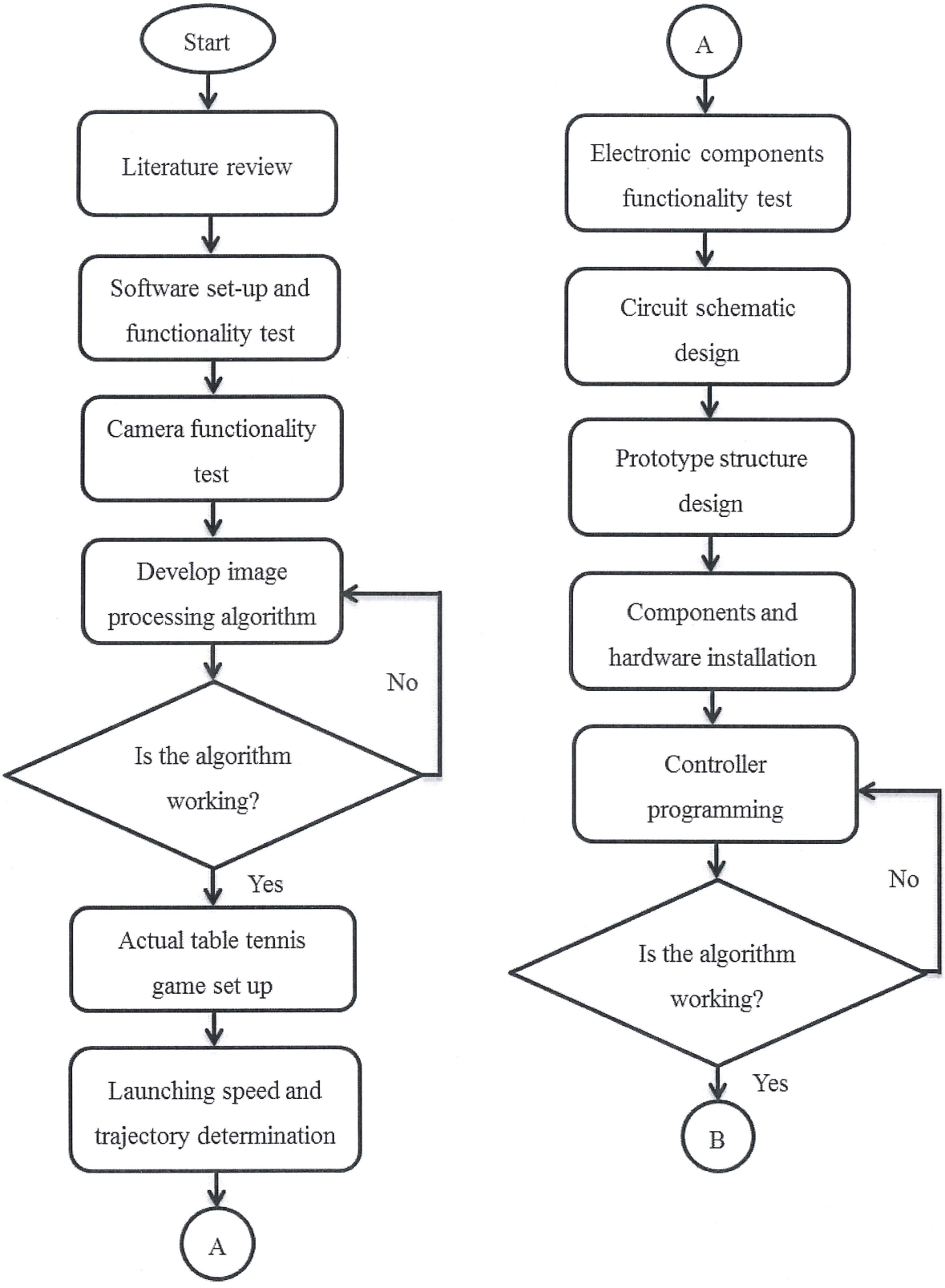

Figure 3.1 Project flow chart

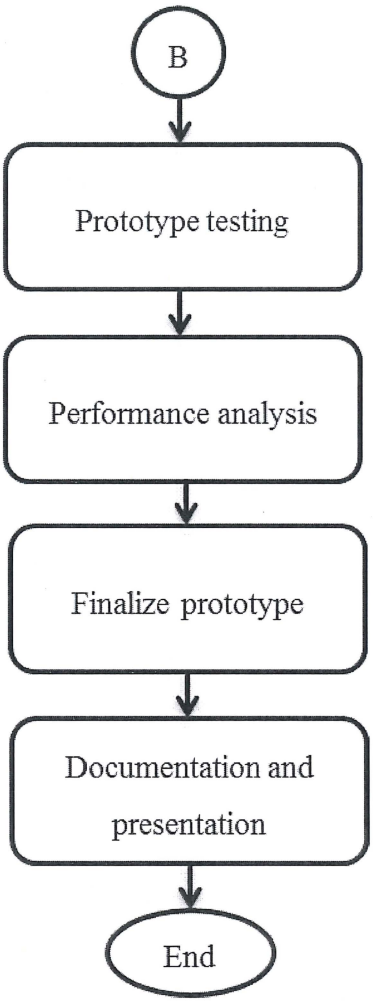

Figure 3.2 Project flow chart (continued)

Figure 3.1 and 3.2 shows the flow chart of project tasks. The ball's launching speed and trajectory of table tennis launcher is done by using Yawcam software motion detection method. A webcam is used to take the pictures of the actual table tennis game. The pictures are then processed by image processing algorithm. The image processing algorithm is developed in GIMP (GNU Image Manipulation Program) incorporating with AutoCAD 2016. The prototype hardware design is done by using CATIA. The Arduino Mega 2560 is used as the microcontroller of the table tennis launcher. The details of the integration work will be further discussed in the following sections.

3.4 Proposed Solution

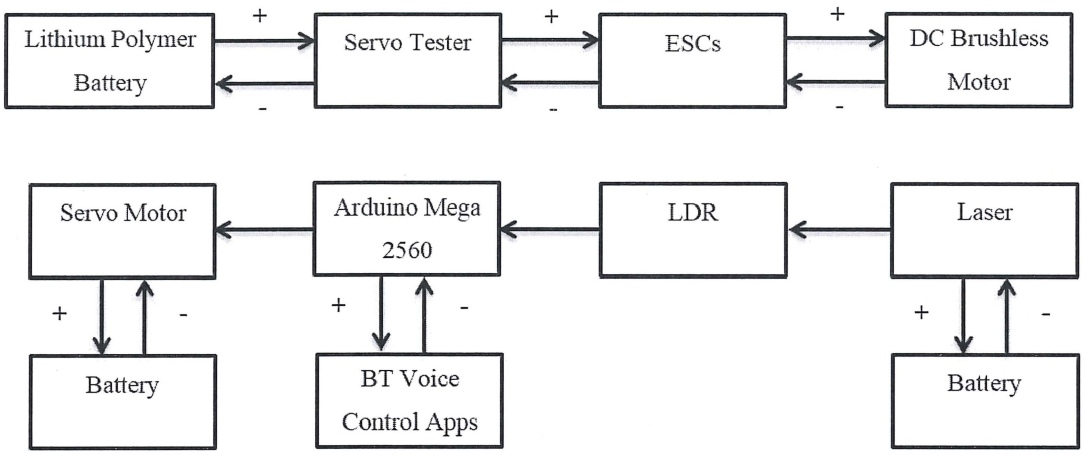

Figure 3.3 System block diagram

In this study, a standard table tennis table will be used. Before starting with the work of system development, a primary launching speed and launching trajectory needs to be determined. An experiment is believed to be the most appropriate determination with reasonable prove. With a proper image processing algorithm, it can be used to estimate ball launching speed and ball's flight trajectory. The block diagram of the proposed system is illustrated in Figure 3.3.

The system is manually started to initialize the ball feeding system. The feeding system will be used for the continuous feed feature. The Arduino Mega 2560 will control and turn on the motors to feed the balls towards the launching motor. The launching motor will then launch the balls out of the exit. In order to create a robust system, the fabricated launcher is being test to keep the dc brushless motors at the most possible identical speed for every same trajectory. This is done by using the LDR and laser pair for detecting the ball launching speed.

Furthermore, guards will cover the component which launches the table tennis balls and every part would be screwed or bolted to the frame to ensure no loose components within the device. These are the safety features that must not be forgotten to be implemented because in real world, there are dynamic changes in the surrounding that someone may not be able to foresee. In this case, the table tennis launcher must be featured with some safety function to prevent any unwanted events.

3.5 Imaging System

This project uses an image based ball launching speed and ball trajectory determination in real time rather than in broadcast video. This is because there are much challenge when detecting and tracking ball in broadcast video such as the small size of the ball and the moving camera. It is hard to compare the changes in between the current and consecutive images. Thus, an actual table tennis game will first be set up in order to carry out the image based ball launching speed and ball trajectory determination in real time. In this experiment, a laptop camera is used and it is placed at a distance from the side of table tennis table to allow it to capture and acquire the image of the ball with better field of view. The set up and the view of the laptop camera for the proposed system are illustrated in Figure 3.4 and 3.5.

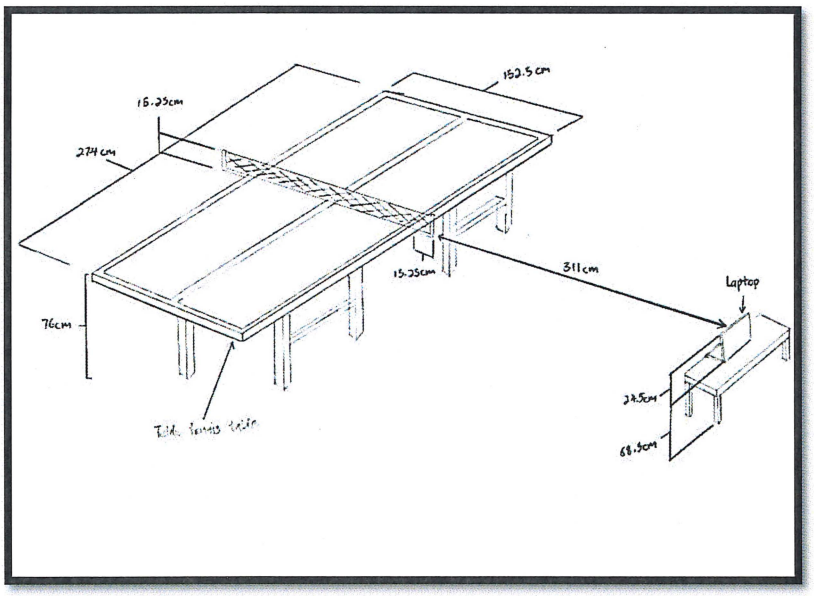

Figure 3.4 Schematic diagram of set up of the laptop camera

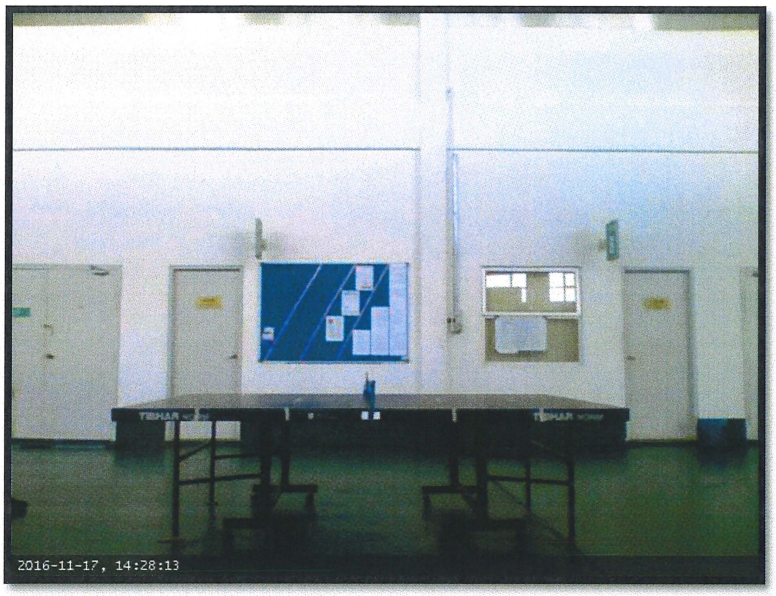

Figure 3.5 View of the laptop camera

3.5.1 Image Acquisition Mechanism

This section reveals the details of development of the image acquisition algorithm for ball launching speed and ball trajectory determination. Yawcam 0.6.0 (*Yet Another WebCAM)*, GIMP 2.8 (*GNU Image Manipulation Program*) and AutoCAD 2016 are the main tools of developing this algorithm.

3.5.2 Imaging Acquisition Algorithm

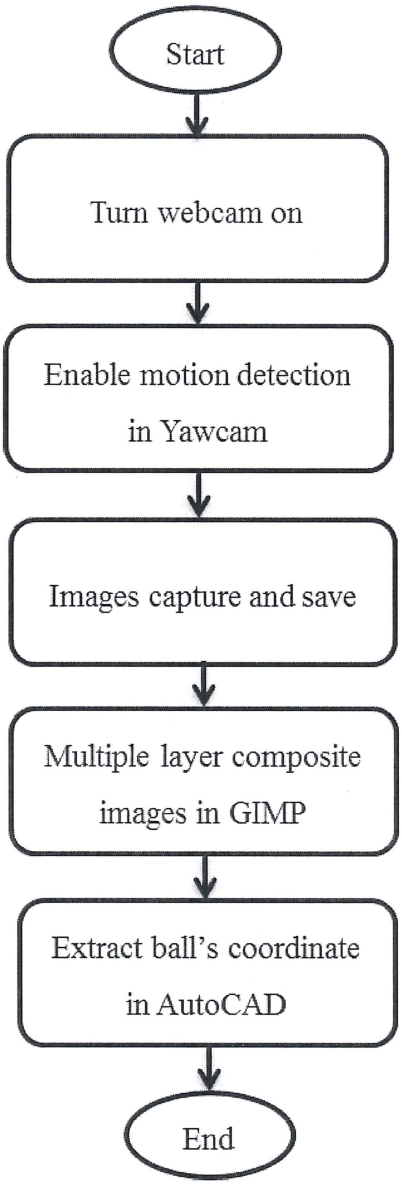

Figure 3.6 Image acquisition algorithm's flow chart

From the flow chart above, Yawcam is clicked to start to detect motion after turn on the webcam. But, before setting up the parameters of the motion detection, it needs to carry out an experiment with the settings to get the right conditions for this project. There is high percentage that the software is detecting excessively few motion events or recognizing an excessive number of false positive motion events. Unfortunately there is no enhancement setting that works for everyone. Experiment should be taken to discover what works for the conditions. Therefore, a swing table tennis ball pendulum is detected

and capture by using Yawcam in order to identify whether these conditions are right for this project.

First condition is to minimize the detect area to avoid detecting the constant moving objects or unwanted moving objects. Reference image is chosen in the detection algorithm. The reason is it develops a reference image by mixing some percentage of new images into the reference images. The motion detection is finished by contrasting the reference image by the present image. In this experiment, the default value 8% of the blending percentage is used. The new image will be blended into new reference image in every 100ms. Since the image array is activated, variable filename {tstampMS} which mean the current millisecond is used to save a sequence of images with 2ms interval.

After all the possible setting, the experiment is started with letting got the pendulum. The saved images will then proceed to the GIMP multilayer compositing. Firstly, make the first one of the images as the base. Then in this image go to file open as layers and that is the next followed images that are going to add on top of this image. Second, add black full transparency layer mask on the top image. This is probably the most important thing people ever do in Photoshop adding layer mask. This whole image will disappear become transparent and then paint on the black layer mask with white. It does bring the image in the background back up. The steps are repeated for every followed image. The composite image will import to AutoCAD 2016 to extract the coordinates in order to verify whether the right conditions are using for this image acquisition system. Several formulas are used in calculating the averaged velocity at x-axis and y-axis as follow:

$$\text{Ball size} = 40\text{mm} = \text{pixel coordinate} \tag{3.1}$$

$$\text{Frame rate} = 8 \text{ per second} \tag{3.2}$$

$$x_{mm} = \frac{x_{pixel}}{\text{pixel coordinate}} \times 40mm \tag{3.3}$$

$$y_{mm} = \frac{y_{pixel}}{\text{pixel coordinate}} \times 40mm \tag{3.4}$$

$$Vx = \frac{x_2 - x_1}{\frac{1}{8}} \quad 3.5$$

$$Vy = \frac{y_2 - y_1}{\frac{1}{8}} \quad 3.6$$

$$Vr = \sqrt{Vx^2 + Vy^2} \quad 3.7$$

$$tan\theta = \frac{Vy}{Vx} \quad 3.8$$

The ratio of the ball size in actual and in pixel coordinate are compared in order to convert the coordinate in x-axis and y-axis from pixel to mm. Displacement between the balls in the images will be calculate with the frame rate to get the velocity in x-axis and y-axis. The displacements between the balls have very small time stamp so that linear motion can be assumed. Lastly, the averaged velocity will be calculated in the squared root of sum of the squared velocity of x-axis and of y-axis respectively.

3.6 Mechanical Construction

CATIA V5R20 software was used as Computer Aided Design (CAD) tool in this project. The final concept structure of table tennis launcher is shown in Figure 3.7. Polystyrene was used as the main material for table tennis launcher due to its light weight. Table tennis launcher was controlled by two Brushless DC Motors (BLDC) and one servo motor. These motors controlled each of their mechanical part of the system which are launcher and feeder.

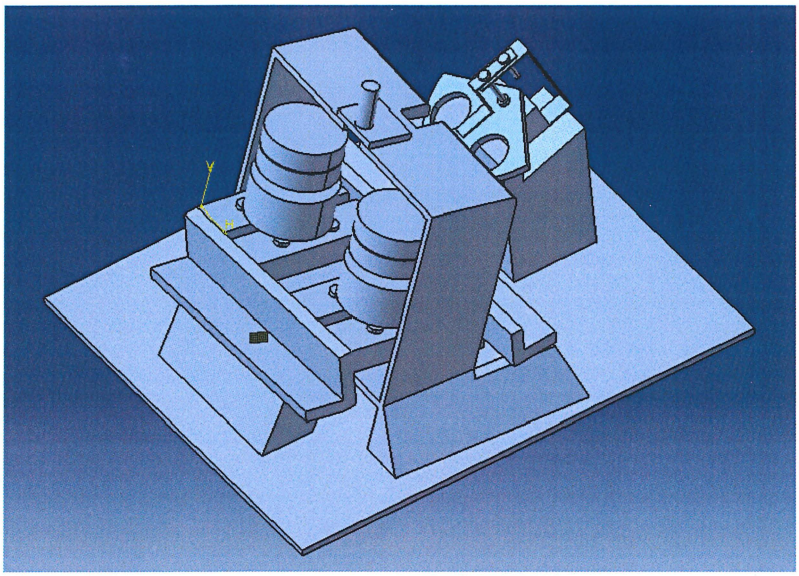

Figure 3.7 Final concept structure of table tennis launcher

3.6.1 Draft Design

By referring to the literature reviews and online tutorial with homemade table tennis launcher, some of the conceptual ideas of table tennis launcher design were done before finalize the final structure as shown in Figure 3.8 and Figure 3.10.

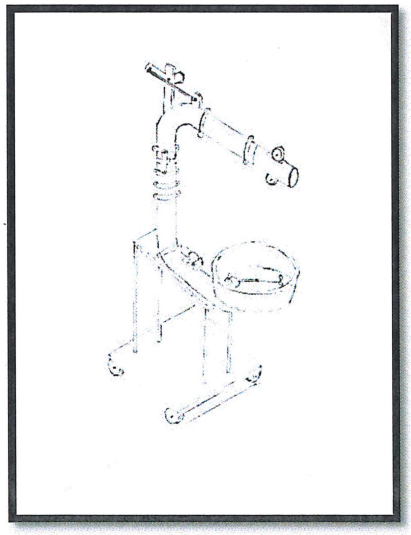

Figure 3.8 First draft design

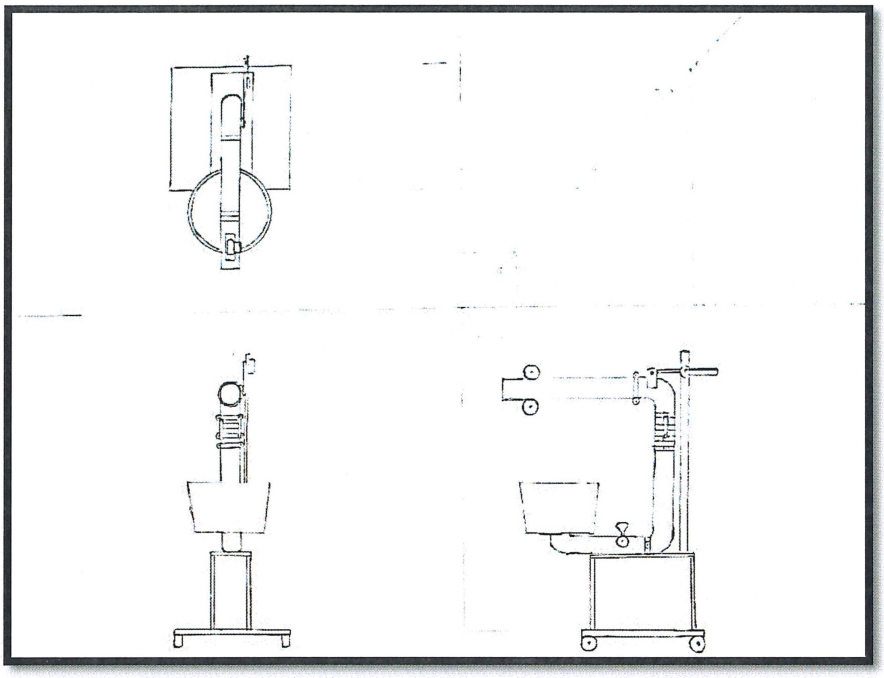

Figure 3.9 Three views of the first draft design

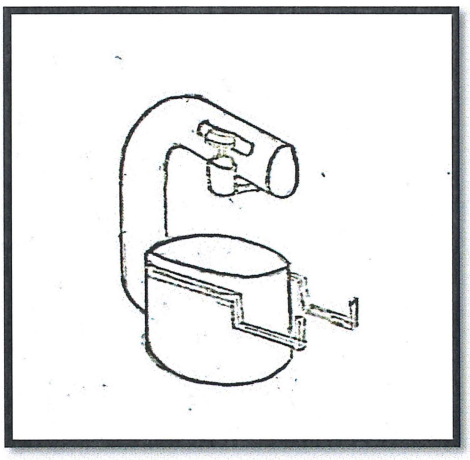

Figure 3.10 Second draft design

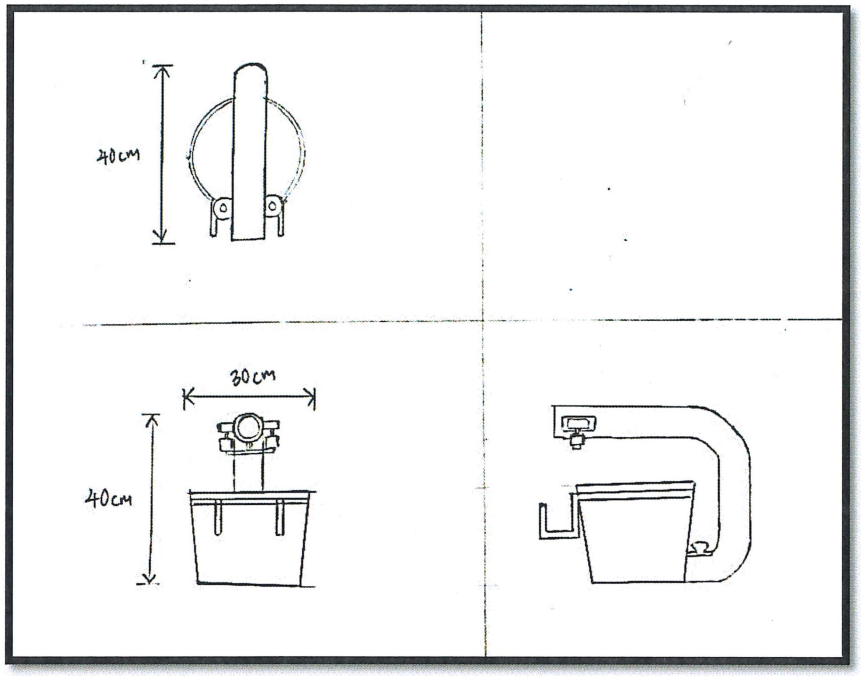

Figure 3.11 Three views of the second draft design

3.6.2 Ball Launcher

After both sorts of table tennis launching system are analysed, it demonstrates that mechanical launching system gives better parameters and more prominent control potential measure up to pneumatics launching system. As the preferences, mechanical launching system furnishes launching component with good repeatability, improve the initial velocity and the ball is flying with smooth and precise velocity. Additionally, it can control the launch better and turn the ball in a required way. The hindrance of utilizing pneumatics launching system is the table tennis ball hits by the compacted air moves inside the outlet tube in an unusual way. As it is hard to control, this will bring about numerous issues, for example, more terrible exactness and repeatability. Thus, two Brushless DC (BLDC) Motors will be used in the launching mechanism.

The motors will be installed parallel to each other horizontally on a motors holder to launch the ball with counter rotating rubber wheels. The motors holder was made by aluminium due to its light weight and robust characteristic. There is a 35mm gap between the motors to allow the table tennis ball to launch through them. The gap made in 35mm but not 40mm is because there must be a contact between the ball and the rubber wheels.

For launching the ball through the rubber wheels, the friction force between the ball and the wheels ought to be equivalent or more noteworthy than the inertia force of the ball. The acceleration will be transmitted from the rubber wheels to the ball to acquire the required initial velocity of the launch. Thus, the ball would be launched. To generate a trajectory launch, the system was installed in an angle of 20 degree. The launching mechanism was shown in Figure 3.12.

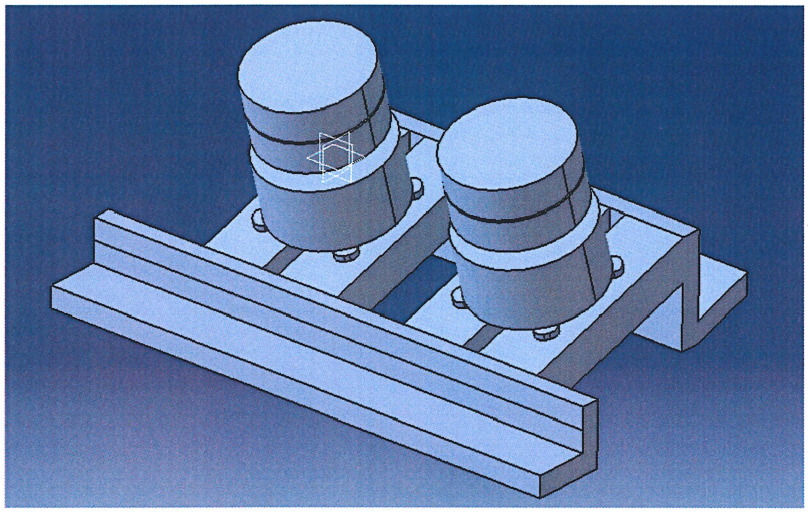

Figure 3.12 Launching mechanism

3.6.3 Ball Feeder

Ball feeder was designed to control the frequency of table tennis ball launch from the launcher. One servo motor was used in this mechanism with one 60 degree of rotation, one table tennis ball will be pushed to the launcher. Frequency of ball shoot will increase as servo motor rotate faster. One semi-circle plate was attached on the servo horn to function as the table tennis ball holder. Two holes were made in diameter of 35mm which is smaller than 40mm actual table tennis ball size on the semi-circle plate to prevent the ball falling through the plate and it was functioning as the ball holder. Next, two L-shape aluminium bracket were joint as the stand for the ball feeder and one screw was used as the axis of rotation of the semi-circle plate. Thin aluminium sheets were cut into small size and made them into curve and fixed them on the screw next to the axis screw as the pusher. The pushers were stationary, when the semi-circle plate rotate, the pusher will act as a blocker to block and push the ball toward the launcher. The feeder was installed in

an angle 20 degree to ease the table tennis ball roll towards the launcher after push by the pusher. Figure 3.13 showed the ball feeder mechanism.

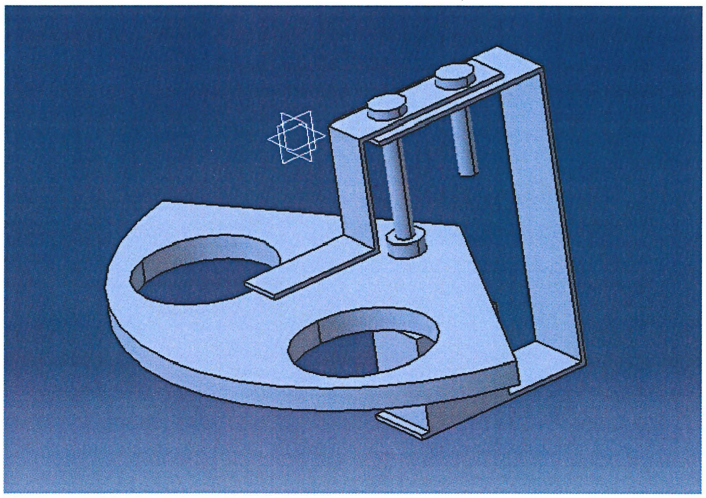

Figure 3.13 Ball feeder mechanism

3.6.4 Base

The base is made for allowing the whole system installed on it as one. Firstly, polystyrene was used to structure the base but polystyrene is weak and easy to break. Therefore, the polystyrene structure was coated and laminated a layer of fibreglass by using the mixture of epoxy resin and hardener. Using the epoxy as the coat layer because epoxies have a tendency to be stronger than different resin, surely a great deal less brittle all alone than polyester. In other words, they have great flexural quality. They come as two sections which are normally blended in ratio ranging 2:1-4:1 resin to hardener by weight. Likewise contrasted with others, epoxy resin has a long pot-life which means working time. For example, even a "quick" epoxy resin will in any case give 15mins working time before it begins gelling while a standard or moderate can take at least 100mins which the normal would appear to be 40mins. A "quick" epoxy might be demouldable in 8hrs and sandable after 12-18 hrs while a "moderate" may require 30hrs preceding it can be expelled from the form. Full cure for the most part takes 5-7 days. This allow the user to mould and structure their work properly before it is harden. The density of polyester resin SG 1.1 is on average which the weight in grams of 1 cubic centimeter of blended resin. Viscosity is higher than different resins which it is normally

a thicker fluid with an mPas of 1000-1400 being viewed as "medium" for epoxy. Thus, fibreglass with epoxy resin as the coat layer making the base strong and light weight compare to just use aluminium as a whole.

3.6.5 Sensor Holder

Laser emitter and light dependent resistor (LDR) will be used in pair in testing. First of all, the holder was made by the same material as the base which were epoxy resin and fibreglass. Same procedure for making the holder was just same as making the base. After the polystyrene which coated with fibreglass is harden, the laser emitter will installed at the upward of the rollers aligned with the mirror which placed below the rollers. The light dependent resistor will be placed next to the laser emitter across the rollers so that the LDR can detect the laser light with the reflection of the mirror. The mirrors were glued on each side of the L-shape aluminium profile to make them in 90 degree. The 90 degree angle allowed the laser emitter light to reflect to the light dependent resistor (LDR). To complete the system, the holder was also made in the angle of 20 degree to align with the launcher system. The system was shown in the Figure 3.14.

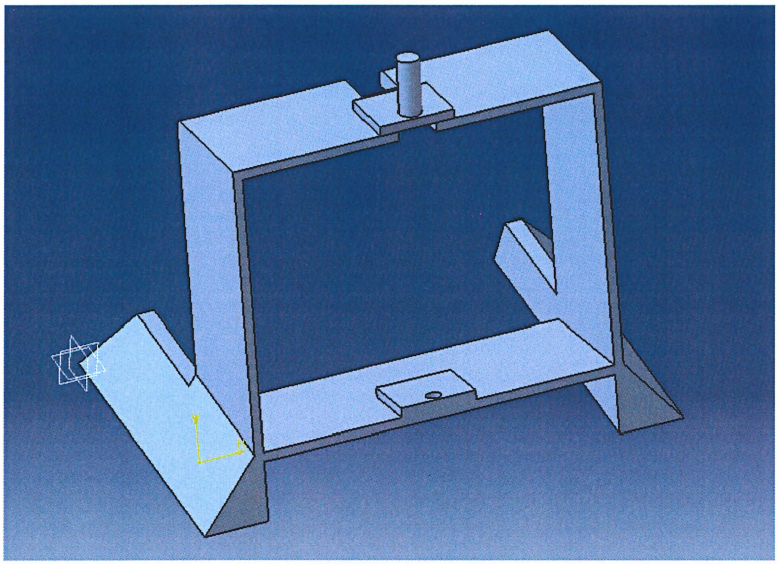

Figure 3.14 Sensor holder

3.7 Circuit Design

Arduino Mega 2560 was used as the core processing unit which was connected to the system via USB connection. At the same time, brushless DC (BLDC) motors and rotation servo motor were chosen as actuator of table tennis launcher. A servo tester was selected to control the two Electronic Speed Controller (ESC) which are used to drive the BLDC motors. The BLDC motors are powered up by an 11.1V Lithium Polymer battery. A laser emitter and a light dependent resistor (LDR) are mounted in between the BLDC motors and connected to Arduino Mega for ball speed testing purpose. A Bluetooth Module was also selected to voice control the Arduino Mega via hand phone. The electronics components are listed and discussed in detail in this section. While Figure 3.15 showed the control circuit schematic of table tennis launcher.

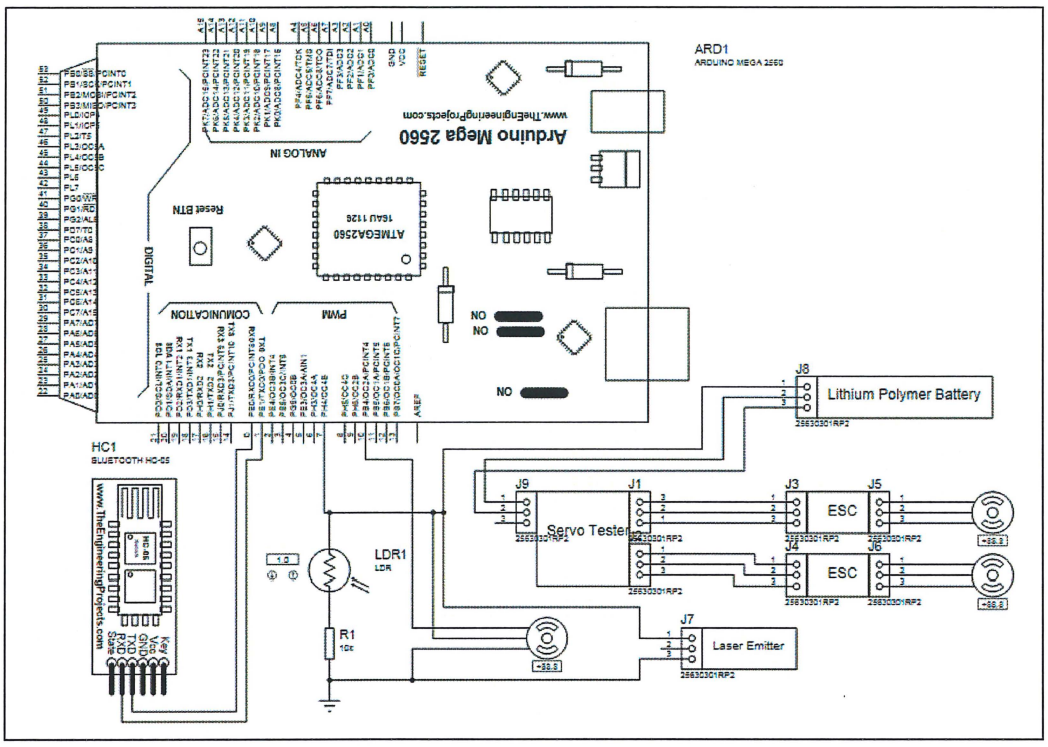

Figure 3.15 Control circuit schematic of table tennis launcher

3.7.1 Arduino Mega 2560

The Mega 2560 is a microcontroller board and it is based on the ATmega2560. It has 54 digital input or output pins. 15 of them can be utilized as PWM outputs. Whereas, it has 16 analog inputs, 4 universal asynchronous receiver/transmitter (UARTs) for device serial ports, a USB connection, a power jack, a 16 MHz crystal oscillator, an In-Circuit Serial Programming (ICSP) header, and a reset button. It contains everything expected to bolster the microcontroller; essentially associate it to a PC with a USB cable or power it with an AC-to-DC connector or battery to begin. This board is used as the controller board of the table tennis ball feeder. This board will be interfaced with voice control application and drive the servo motor of the ball feeder.

3.7.2 Electronic Speed Controller

An electronic speed control (ESC) is an electronic circuit used to change the speed of an electric motor, its path and furthermore to act as a dynamic brake. These are frequently utilized on radio controlled models which are electrically powered, with the change most as often as possible utilized for brushless motors fundamentally giving an

electronically produced 3-phase electric power low voltage source of energy for the motor. An ESC can be a different unit which knots into the throttle collector control channel or joined into the recipient itself, similar to the circumstance in most toy-grade R/C vehicles. Some R/C makers that interface elite specialist hardware in their entrance level vehicles, compartments or flying machine utilize included gadgets that consolidate the two on a sole circuit board.

An ESC controls the speed of the motors spin. It helps the comparative reason as the throttle servo of a controlled plane. It is an edge between the radio receiver of a plane and the power plant. An electronic speed control will have 3-sets of wires. One wire will connect to the primary battery of a plane. The second wire will have an average servo wire that attaches into the input's throttle channel. Also, third wire is utilized for powering the motor. The principle components of an electronic speed control incorporate battery eliminator circuit, low voltage cutoff, and brake.

The components used in ESC mainly include the following:

- 3 phase BLDC motor solder pads
- Negative (-) LIPO pin
- Positive (+) LIPO pin
- Servo signal or PWM signal input
- GND reference of PWM Signal
- Solder jumper for altering the direction of Rotation (CW/CCW)
- Solder jumper for varying the type of the PWM input signal

3.7.3 Brushless DC (BLDC) Motor

The Brushless DC (BLDC) motor is the perfect selection for applications that require high reliable quality, high efficiency, and high power to-volume proportion. As a rule, a BLDC motor is thought to be a superior motor that is equipped for giving a lot of torque over an inconceivable speed go. BLDC motor are a subordinate of the most usually utilized DC motor, the brushed DC motor, and they have a similar torque and speed execution bend attributes. The significant distinction between the two is the utilization of

brushes. BLDC motor do not have brushes henceforth the name "brushless DC" and must be electronically commutated.

Commutation is the demonstration of changing the motor phase currents at the suitable circumstances to deliver rotational torque. In a brush DC motor, the engine gathering contains a physical commutator which is moved by methods for real brushes in the end to move the rotor. With a BLDC motor, electrical current powers a changeless magnet that makes the motor moves, so no physical commutator is vital.

A BLDC motor has high reliability since it does not have any brushes to destroy and supplant. At the point when worked in rated conditions, the life expectancy is more than 10,000 hours. For long haul applications, this can be a gigantic advantage. At whatever point a motor breaks down or should be supplanted, the project, or part of it, must be shut down. This costs you time and cash, maybe an extraordinary arrangement relying upon to what extent it takes to supplant the ragged part or parts and kick the application off once more. In spite of the fact that a BLDC motor may cost more than a brushless motor, it will regularly more than pay for itself in the measure of work time spared.

There are two basic BLDC motor designs which are inner rotor and outer rotor design. In an outer rotor design, the windings are situated in the centre of the engine. The rotor magnets encompass the stator windings. The rotor magnets go about as an insulator, along these lines decreasing the rate of heat dissipation from the motor. Because of the position of the stator windings, outer rotor designs ordinarily work at lower duty cycles or at a lower rated current. The essential preferred standpoint of an outer rotor BLDC motor is generally low cogging torque. Therefore, two out rotor BLDC motors are used to control the movement of the launching system. The model of the BLDC motors used in this project is Emax BL2810/12 1100KV Outrunner Brushless Motor. The basic details of the motors are as follows:

- Weight: 86g
- Diameter: 39mm
- Length: 31.5mm
- Stator Dimensions: 28mm x 10mm
- Winds: 12
- Shaft: 5mm x 50mm

- Exposed Shaft: 17.78mm
- Bearing Size: 5mm x 10mm x 4mm
- Mounting Holes: 25mm x 25mm, tapped for 3mm screws
- Connectors: 4.0mm Male Bullet Connectors
- Voltage: 9.0v - 13.0v (3 cell Lipo battery)
- KV Rating: 1100kv
- Maximum Current: 30 amps/30 seconds
- Maximum Power: 350 watts

3.7.4 Servo Tester

A servo tester is a little independent electronic gadget that enables a servo to be moved over its whole scope of movement. It does this by imitating how the receiver conveys a scope of various length pulses to set the position the servo ought to move to, as characterized by the servo protocol. The knob or buttons on the servo tester enable the pulse length to be controlled straightforwardly. The essential use for a servo tester is to check servo precision and range. But, the servo tester was used to control the brushless DC motor in this project by using duty circle.

3.7.5 Servo Motor

TowerPro SG91R Micro Servo motor was selected as the core motor in the feeding system because it is smaller in size and lightweight with high output control. It can turn around 180 degrees which is 90 toward every rotation and works simply like the standard sorts but smaller. Servo motors (or servos) are independent electric gadgets that rotate or push parts of a machine with great precision. It controlled by sending an electrical pulse of variable width, or pulse width modulation (PWM), via the control wire. Servo motor already has built in motor driver which do not require an external motor driver to drive it. The basic details of the servo motor are as follows:

- Modulation: Analog
- Torque: 4.8V (1.80 kgcm)
- Speed: 4.8V (0.10 sec/60°)
- Weight: 9.0 g

- Dimensions:
    - Length: 23.1 mm
    - Width: 12.2 mm
    - Height: 29.0 mm

3.7.6 Lithium Polymer Battery

Lithium polymer battery (lithium-ion polymer battery) is otherwise called LiPo battery. LiPo battery is a kind of battery that is rechargeable and is generally utilized as a part of radio control field. In this project, a LiPo cell is utilized to control the two blushless DC motor. LiPo battery utilized in this project. Typically a LiPo cell has an ostensible voltage of 3.7V. For the 11.1V battery appeared in the figure, there consist of three cells. These three cells are attached in series so that the voltage can sum up. For this situation, this LiPo battery is called 3S (Three cells) pack, implying that three cells in a pack. There are likewise 2S (Two cells) and 4S (Four cells) pack.

The following thing that should be thought about LiPo battery is the capacity. The capacity of a battery is essentially a measure of how much power the battery can supply or to what extent it can hold. The unit of measuring the capacity of the battery is communicated in mAh. This is stating how much power the battery can supply persistently in 60 minutes. The limit of the LiPo battery utilized is 2200mAh. It implies that this battery can ceaselessly supply current of 3200mA in 60 minutes. In other words, it supply current of 2.2A in 60 minutes.

Another critical data about this LiPo battery is the discharge rating of the battery. The discharge rating is a measure of how quick the battery can be discharged securely and without damaging the battery. The discharge rating is so essential to be known in light of the fact that it is important to ensure that the application that uses the battery will not draw the current higher than the discharging rating to keep the LiPo battery from being ruined. The discharge rating of the battery is 40C. To take in the greatest current can be drawn securely, the follow condition is embraced:

$$40C = 40 \times \text{Capacity (in Amps)}$$

The capacity of the above battery is 2.2A. Thereby, the maximum current draw can be calculated as follows:

Maximum discharge rate = 40 × 2.2A

= 88A

The calculation demonstrated that only the utilization of under 88A current draw is reasonable of utilizing this battery. Since this battery is utilized to control up for two brushless DC motors, so a calculation of computing the greatest current draw for the motors is important to be done. Referring to the datasheet of the motor, the rated current is 13A. Since there are two motors, so the total current draw is around 26A, far lower than 88A. In this manner, this battery is reasonable for the proposed system.

3.7.7 Light Dependent Resistor

A light dependent resistor is a component that is delicate to light. At the point when light falls upon it then the resistance changes. Estimations of the resistance of the LDR may change over many requests of size the value of the resistance falling as the level of light increments. It is normal for the values of resistance of a LDR or photoresistor to be a few megohms in dimness and afterward to tumble to a couple of hundred ohms in splendid light. With such a wide variety in resistance, LDRs are easy to utilize and there are numerous LDR circuits accessible.

Light dependent resistors, LDRs are regularly utilized as a part of circuits where it is important to recognize the nearness or the level of light. They can be depicted by an assortment of names from light dependent resistors, LDR, photoresistor, or even photograph cell, photocell or photoconductor. Albeit different gadgets, for example, photodiodes or photograph transistor can likewise be utilized, LDRs or photoresistors are an especially advantageous hardware part to utilize. They give substantial change in imperviousness to changes in light level.

In perspective of their low cost, simplicity of make, and usability LDRs have been utilized as a part of an assortment of various applications. At one time LDRs were utilized

as a part of photographic light meters, and now they are utilized as a part of launching speed testing mechanism in this project.

3.7.8 Laser Light Emitter

Lasers concentrate all their power in a small point, which makes them perfect for laser needle therapy. Also, laser light is coherent, which additionally makes it perfect for this application. Lasers are utilized as a part of fiber optic correspondence frameworks because light can be transmitted over significantly more prominent distances than incoherent light. The coherent light can be transmitted hundreds, even a large number of miles through fiber optic links without much loss. Similarly, laser light has a tendency to infiltrate effectively to the meridians and travel along them, for vitality moving impacts in the meridians, even at a separation from the point being dealt with. Thus, HLM1230 5mW Red Laser Module was paired with a light dependent resistor (LDR) in the ball launching speed testing mechanism. The basic details of the laser light emitter are as follows:

- Input Voltage: 3.5-4.5V
- Operating Current: < 25mA
- Wavelength: 645-655nm
- Optical Power: < 5mW
- Beam Diameter: 0.75mm
- Divergence: > 0.5mRad
- Warm up Time: < 1.0s
- Operating Temperature: -10degC

3.7.9 Bluetooth Module

HC-05 Bluetooth modules was chosen as the serial communication device in the feeding system for sending data between Arduino Mega 2560 equipped with an Android smartphone. This is because the Bluetooth module is easy to use and inexpensive. The purpose of using the module is to send text commands from the smartphone to Arduino Mage 2560 for controlling a digital output pin. Also, the module allows the Arduino Mega 2560 sending back the text to the smartphone. The LED will blink rapidly once the

Bluetooth module has been associated and power connected. This implies it has not been "paired" with another Bluetooth gadget. The LED remains on persistently when paired.

3.7.10 Android Based Phone

Android is a versatile working machine (OS) principally based at the Linux bit and as of now developed by utilizing Google. With a user interface construct absolutely in light of direct control, the OS reaches inputs that freely relate to genuine worldwide moves, such as swiping, tapping, pinching, and opposite pinching to administer in plain view things, and a virtual keyboard. The Android stage was used due to its monstrous market all around and it's perfect to utilize customer interface programs on the Android phones extend the usefulness of gadgets and are composed for the most part in the Java programming dialect the utilization of the Android software program improvement package (BT Voice App). The voice recognizer that is a constructed characteristic for Android phones is utilized to construct an application which the individual can perform to automate the living appliances. The receiver voice order is given to switch the gadget on or off. The voice recognizer tunes in and converts what is said to the nearest matching phrases or text. The Bluetooth connector blessing inside the cell phone is designed to send these words to the Bluetooth module on the Arduino board that may in flip deal with the electric machines.

3.8 Voice Control Table Tennis Ball Feeder Programming

This stage will be carried out after the hardware of table tennis ball feeder has successfully been fabricated. This is because the table tennis ball feeder will act and perform according to the serial command from the voice controlling part. The command will be sent through Bluetooth module communication.

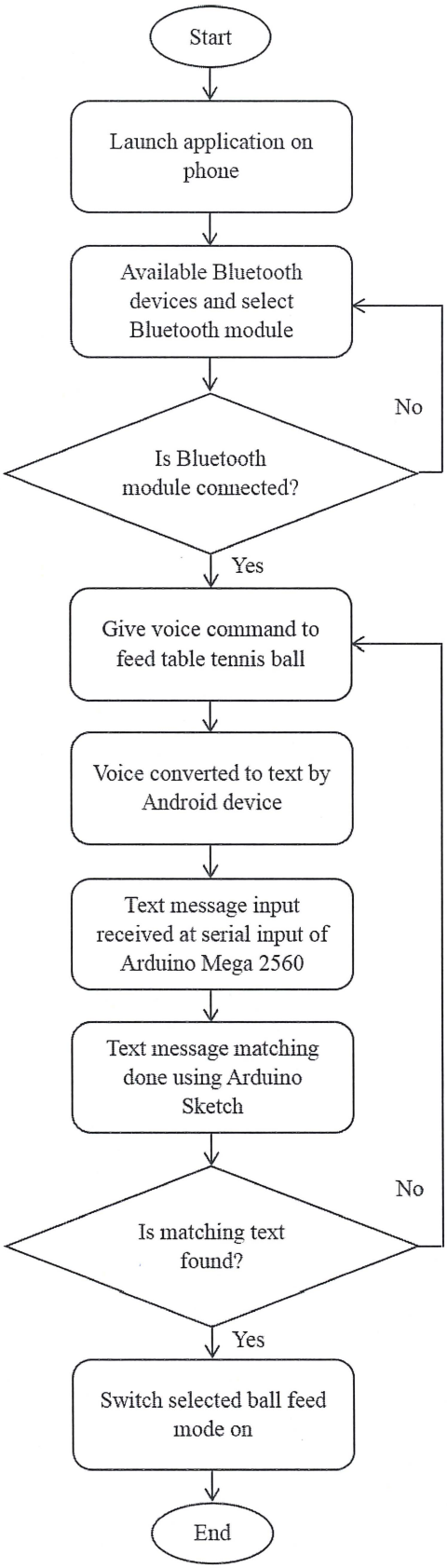

Figure 3.16 Voice control table tennis ball feeder programming flow chart

The application initially scans for the Bluetooth gadget. If it is available then it on the voice recognizer. It peruses the voice and changes over the sound flag into a string. It creates an incentive for every machine which will be given to the microcontroller gadget. The microcontroller utilizes the port in serial mode. Subsequent to perusing the information it interprets the input value and sends a flag to the parallel port through which the transfer circuit will be initiated. Bluetooth module was used in this work.

3.9 Ball Launches Speed Testing Programming

The mechanism of the LDR Laser sensor pair is that when the ball launched on the path of laser light to the LDR, the laser light will be cut off and thus the LDR will recorded the time taken between the start of the ball and the end of the ball for the absence of laser light. So exact length of the ball is entered if not it would not show real speed. This speed meter is slightly not reliable and if the ball too fast, the serial monitor will show infinity through whole process. To solve the problem, adjusting the ADC resolution by coding the ADC and set the time from millisecond to microsecond.

3.10 Prototype Testing Mechanism

After fabricated the prototype, a prototype testing will be carried out to study the systems current performance and after that attempt to make sufficient alterations in the specific areas needed. The areas of testing which were imperative to the accomplishment of the launcher comprised of maximum launching distance, accuracy, repeatability and ease of use. After finishing the testing, the vital changes were executed to the framework.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In brief, the development progress of the table tennis launcher framework was viewed as smooth however a minor deviate from schedule. The control circuit and the structure of the launcher were successfully built. In the meantime, the programming of framework was accomplish a palatable level however require facilitate improvement to accomplish completely useful stage. So as to guarantee the table tennis launcher system runs smoothly, four primary elements are considered. The variables are maximum launching distance, accuracy, repeatability and ease of use. The results and data recorded for each sections are discussed in detailed.

4.2 Image Acquisition Algorithm

In this section, the outcome of the imaging acquisition system will be shown and discussed in details. The ball's flight trajectory is appeared on the images as shown in Figure 4.1 and Figure 4.2.

Figure 4.1 Result of GIMP images multilayer compositing

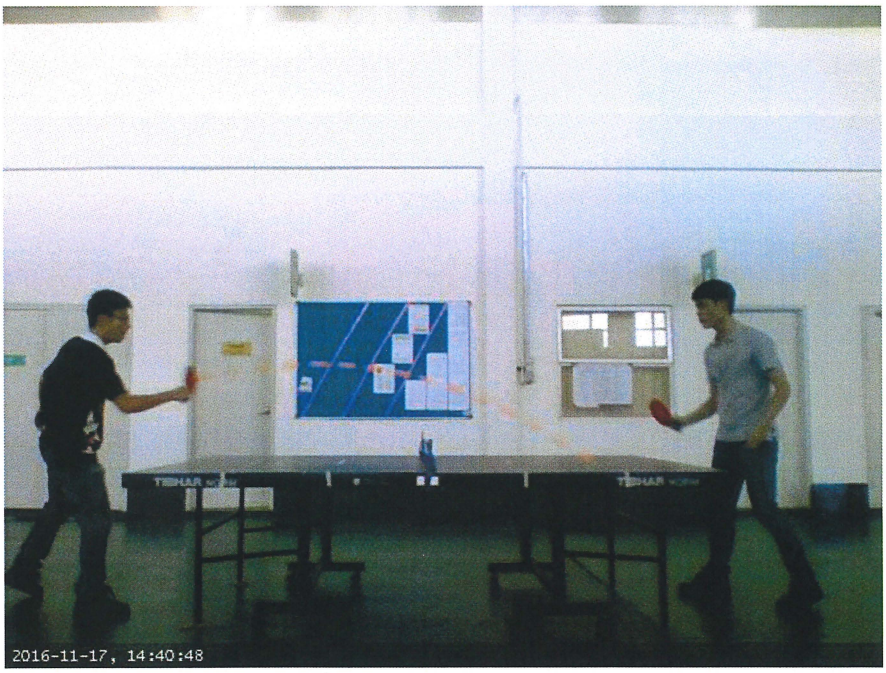

Figure 4.2 Result of GIMP images multilayer compositing

The composite image was imported to AutoCAD 2016 to extract the coordinates. Ball trajectory of the composited image are plotted via excel as shown in Figure 4.3.

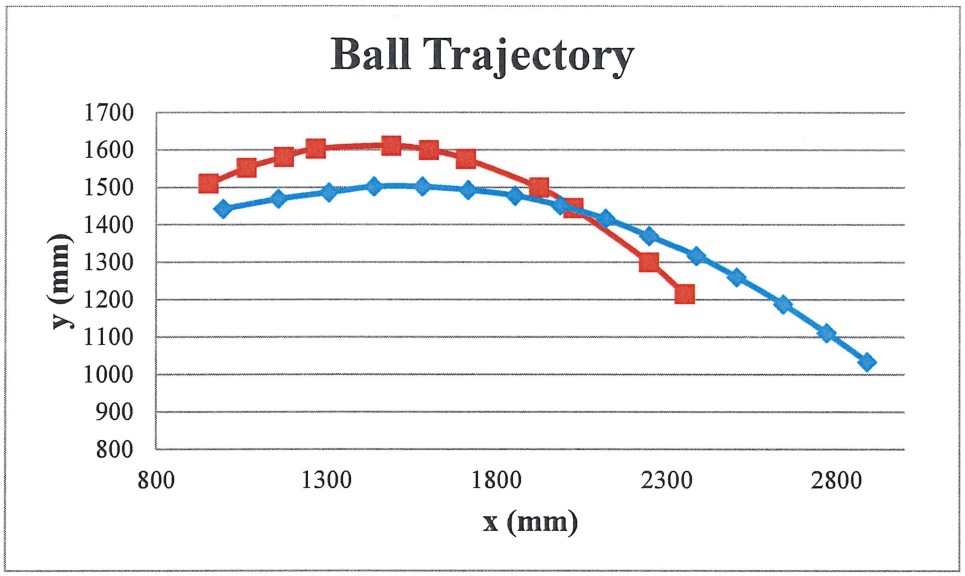

Figure 4.3 Ball trajectories of the balls in the images

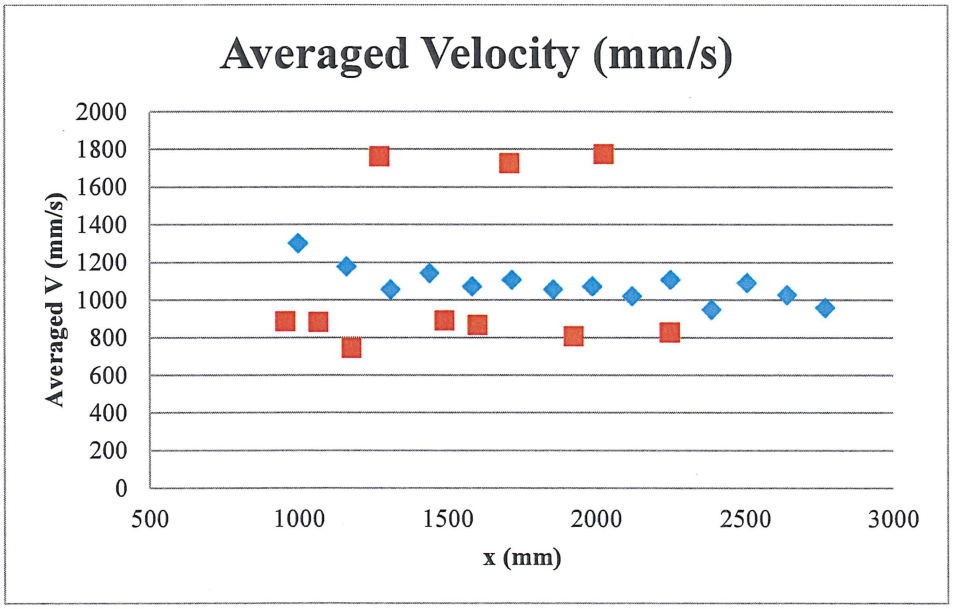

Figure 4.4 Result of ball's velocity in the images

Referring to Figure 4.3, the ball trajectory showed an upward curve pattern while its velocity graph showed a downward curve pattern. The phenomenon is due to the law

of conservation of energy. According to the law of conservation of energy, energy cannot be created or destroyed. It can only be changing from one form to another. At the beginning, the table tennis ball is at the highest point. It stored the maximum potential energy and minimum kinetic energy. Then the ball was stroked and flied upward due to the lift force. At this moment, the stored potential energy will be converted to kinetic energy as time passed. The equation below showed the relationship between potential energy and kinetic energy, and how does its ratio converted. The total potential energy will be fully converted to kinetic energy when the ball reached the minimum point.

$$\text{Total Energy} = \text{Potential energy} + \text{Kinetic energy} \tag{4.1}$$

$$Total\ Energy = mgh + \frac{1}{2}mv^2 \tag{4.2}$$

The equation above showed as the height of the ball, h decreases, the velocity of ball, v increases. This can prove the reason why the position graph of the ball showed an inverse pattern with the velocity of the bob as shown in Figure 4.4. However, due to this experiment is carried out by human stroking the table tennis ball, the ball will not exactly travel in a straight line when in top view and it might have a slight angle. Thus, Figure 4.4 showed some errors on it. This will be improved in the next experiment later on.

4.3 Table Tennis Launcher Structure

The designing of the table tennis launcher was completed successfully. There were couple of areas of the system that changed from the first draft design to second draft design and lastly to the final structure design which more advanced ideas could be actualized into the system. The main modification of the system was the adjustment in the launching wheels and the feeding structure. In first, the design of the wheels for launching system was situated in-accordance with each other vertically. This allowed the balls were launched a predictable area on the table tennis table for each ball launched. The disservice to this is in real game versus an opponent shots return to all areas of the table so that the challenger would need to work over the entire table to score points. Consequently, the orientation of the wheels was moved to the balanced position which is placed beside each other horizontally. The balls which are currently launch in various areas on the table tennis table. Thus honing techniques would be like a real game volleying in various areas on the table as though an actual game being played. One of the

areas overlooked was the horizontally ball launched projectile problem. Therefore, 20 degree angle inclined for the launching wheels was implemented to produce the ball projectile as the real game. The final structure of the table tennis launcher as displayed in Figure 4.5.

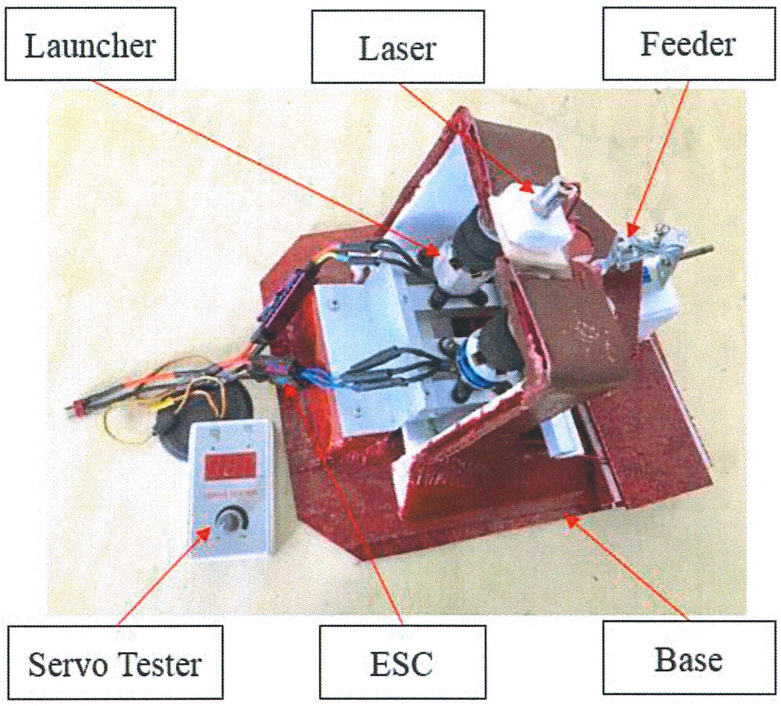

Figure 4.5 The final structure of the table tennis launcher

4.4 Table Tennis Launcher Performances

The launcher was designed to launch table tennis ball with multivariable speed and frequency. The feeding frequency of table tennis ball was regulated by a servo motor which function to rotate the feeder plate. Figure 4.6 shows the different direction of rotation of servo motor will feed the balls.

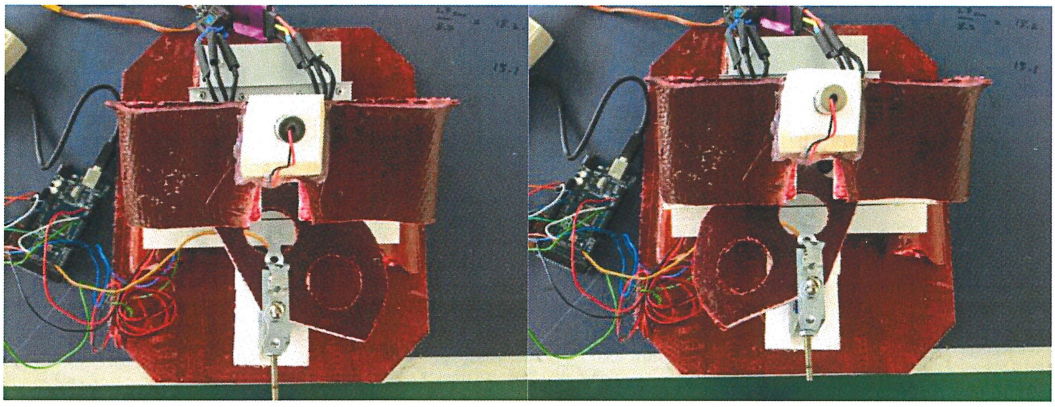

Figure 4.6 Ball feeding mechanism

Besides that, players are able to choose different frequency of ball shoot by control the servo motor via phone Apps. By choosing the option of the feeding frequency, servo motor will rotate the plate together with balls in the selected time.

4.4.1 Consistency

Testing for consistency comprised of 5 balls series being put into the feeder and launcher to investigate the launching speed of each ball. The fundamental objective of this test was to guarantee the balls were launched over the 5 inch net and hit any area on the opposing side. At first, adjust the orientation of the launching wheel. This permitted the table tennis balls to be launched that particular range each time however this was not the main objective. In the table tennis ball game, the goal is to consistent the ball speed in order to cover as many areas of the table tennis table as possible to force the opponent to extend all through the entire table. By modifying the direction of the launcher wheel, balls were then launched at various areas of the table tennis table with various speed but the speed is consistent for every particular area. The table tennis launcher launching motors was set at range of duty cycle and the ball launching speed at every duty cycle as well as the maximum launching distance was recorded in Table 4.1. Imaging acquisition mechanism was used to determine the launching distance which displayed in Figure 4.7.

Figure 4.7 3D Trajectory of Table tennis ball

Table 4.1 Maximum Ball Launching Speed Measured by Sensor and Distance for Each Duty Cycle

Duty Cycle (ms)	Ball Launching Speed (m/s)						Total Distance (m)					
	1st	2nd	3rd	4th	5th	Avg	1st	2nd	3rd	4th	5th	Avg
1.10	6.82	6.81	6.92	6.64	6.63	6.76	1.40	1.45	1.43	1.43	1.42	1.43
1.11	7.28	7.00	7.56	7.53	7.67	7.41	1.59	1.57	1.59	1.58	1.55	1.58
1.12	8.36	8.95	8.52	8.77	8.90	8.70	1.69	1.70	1.68	1.73	1.71	1.70
1.13	8.53	9.27	9.29	8.13	9.97	9.04	1.93	1.91	1.96	1.95	1.94	1.94
1.14	9.63	10.49	9.69	10.87	10.94	10.32	2.14	2.18	2.19	2.16	2.15	2.16

Table 4.1 illustrated the speed of each launch from minimum speed till maximum speed under the condition without ball feeding frequency adjustment function. It is obvious that five times launching speed varied during the launching. The differences between the rotational speeds during the launching can be easily noticed. The launching speed of ball gets more unstable when it is approaching the maximum speed of launching. This is because the different brand of ESCs caused the two brushless DC motor rotate in slightly different speed.

4.4.2 Maximum Launching Speed and Distance

With the design of the table tennis launcher, one of the most imperative features is the maximum launching range of the framework. The table tennis launcher launching

motors was set at range of duty cycle and the launching distance at every duty cycle was recorded in Table 4.1. As recorded in Table 4.1, the ball launching motor was set at 5 different duty cycle levels and total distance of the launching ball was recorded. The launcher was placed 360mm start from the edge of the actual table tennis table as shown in Figure 4.8.

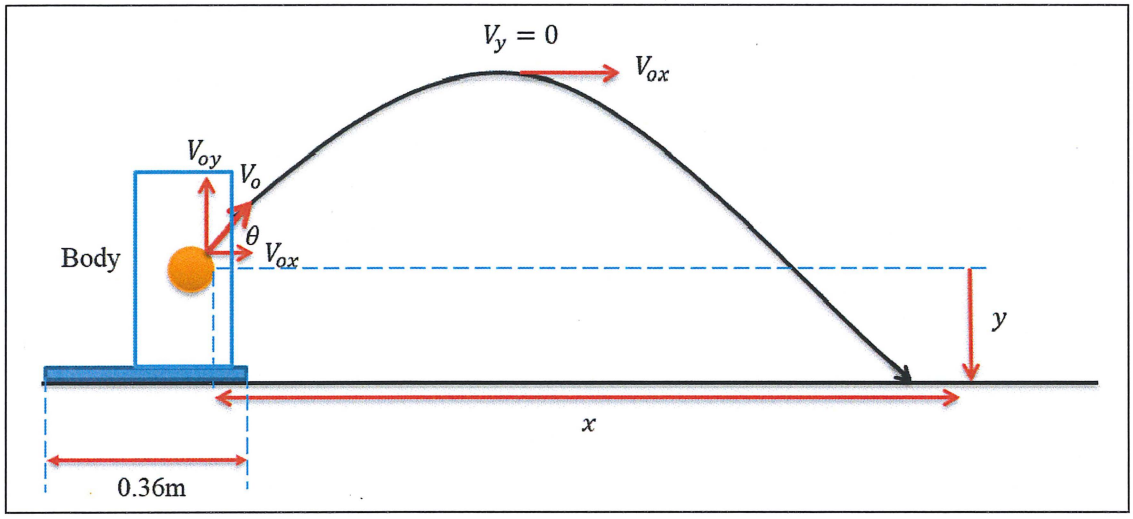

Figure 4.8 The launcher was placed 360mm start from the edge of the actual table tennis table

The total horizontal length of a standard table tennis table is 2.74m (9 feet); in this manner the net is situated at 1.37m (4.5 feet). With the 0.36m displacement nearer, at 1.10ms the launched ball demonstrated to able to cover half of the table tennis table and reach over the net. As the duty cycle increase gradually, the launching speed and distance of the ball increase as well. At 1.09 ms the table tennis ball was launched at a speed of 5.42m/s and a distance of 1.33m which lesser than haft of the table length and unable to surpass the net. This enables the displacement to be closer to the net if necessary and the launched balls demonstrate to even now cover the required least launching distance of 1.37m to clear the net.

4.4.3 Repeatability

Testing for repeatability was finished to guarantee there was no jamming of the balls in the feeder along the table tennis game. This test comprised of a pair balls arrangement in the feeder and the objective was to guarantee that each ball was

legitimately dispersed from the feeder, effectively move onto the launcher by the ball feeding system and after that be launched.

Table 4.2 Ball Successfully Dispersed From the Feeder

Duty Cycle (ms)	**Ball successfully dispersed from the feeder**	
	1st Trial	2nd Trail
1.10	Yes	Yes
1.11	Yes	Yes
1.12	Yes	Yes
1.13	Yes	Yes
1.14	Yes	Yes

There were almost no issues with this testing because of the way that the ball holder for the feeder could fit two standard table tennis balls at once. The ball pusher stopped each ball and the variable frequency controlled the servo motor which pushed the balls onto the launcher.

4.4.4 Ease of Use

Testing for usability was finished to guarantee that every user would comprehend the essential guidelines of the framework to ensure that all users could appropriately utilize the table tennis launcher system. The user was given a set of instructions and guidelines to take after and test the simplicity of the ability to utilize the framework. Instructions are listed beneath:

1. Carefully place and adjust the position of the table tennis launcher.
2. Power on ball launcher motor and ball feeder motor by plugging in the Lipo battery and power bank respectively.
3. Connect ball feeder and BT Voice Control Application via Bluetooth.
4. Set ball launching motor speed about 1.10 to 1.14ms.
5. Place table tennis balls in the feeder.
6. Give command to the feeder via phone so that table tennis balls can be launched.

7. Adjust ball launching motor speed if the ball launching distance is too short or too long.
8. Choose ball feeding option if the frequency of ball feeding is too slow or too fast.

An aggregate of 5 users were tried then made a request to finish a rating on how well every client could adapt to the system utilizing the essential instructions.

Table 4.3 Product Satisfaction Survey

	Rating from Photographic Guidelines					
	1	2	3	4	5	Average
Ease of Use	-	-	1	2	2	4.2
Ease of Instructions	-	-	-	3	2	4.4
Adaptability	-	-	1	3	1	4.0
Overall Experience	-	-	-	3	2	4.4

1 Strongly Disagree 2 Somewhat Disagree 3 Neither Agree nor Disagree
4 Somewhat Agree 5 Strongly Agree

Table 4.3 demonstrates the outcomes from the rating of the guidelines given to the user. On the left of the table are the ranges which were appraising and to the far right are the normal rating for the coveted zone. In view of these outcomes the users rarely confronted any obstacles following in guidelines and correctly allowing the table tennis ball to work appropriately.

CHAPTER 5

CONCLUSION

5.1 Introduction

This chapter describes mainly about the conclusion that has been made for the overall project and some recommendations of the project in the future.

5.2 Conclusion

Table tennis launcher project has successfully met the objectives and project scopes stated in Chapter 1. In this project, a table tennis launcher that showed the combination of mechatronic engineering and sport as a sport technology demonstrator. Also, the microcontroller module utilized as a part of this project was Arduino Mega 2560 with Android Voice Control Application via Bluetooth as a stage. This voice control application can ease player in manipulating the product from certain distance. Moreover, the results show that the maximum launching distance is 2.19m through the application of image acquisition technique. Survey also showed that the system can be used as an alternative tool for training.

5.3 Recommendations on Future Work

There is a limitation of the table tennis launcher in this project. The launcher control framework itself was open loop and no feedback system. It implies that table tennis launcher cannot decide if the ball launch was met the user desire. To settle this issue, each time the launcher was introduced on table tennis table, it have to adjust to guarantee the reference value been set in centre and guarantee there is no external disturbance, for instance, an external force or vibration. In future advancement for this issue, recommended to introduce an appropriate sensor that able to identify the position of ball and input to the launcher. Suggested sensor was Kinect by Microsoft, which

incorporated the depth sensor and RGB camera. Kinect can detect the landing point of table tennis ball feedback to the system based on error change and calibrate the actuator.

REFERENCES

Ahmad, M.H. Bin, 2013. Design and Fabrication Of Ball Feeder Mechanism And Body For Tennis Ball Machine. *Thesis of Universiti Teknikal Malaysia Melaka.*

Dohare, D., 2016. A Review Study Speed Control Of Dc Motor With Classical Controller and Softcomputing Technique. , pp.253–259.

Flores, M.A., Bercades, P.D. & Florendo, F., 2010. Effectiveness of Shadow Practice in Learning the Standard Table Tennis Backhand Drive. , 6(6), pp.105–110. Available at: http://www.ittf.com/ittf_science/sscenter/int_journal6/docs/_105.pdf.

Haque, M.E. & Rahman, M.F., 2001. Influence of Stator Resistance Variation on Direct Torque Controlled Interior Permanent Magnet Synchronous Motor Drive Performance and Its Compensation. *Conference Record of the IEEE Industry Applications Conference, 2001*, 4(C), pp.2563–2569.

Harvey, S. et al., 2013. A season long investigation into coaching behaviours as a function of practice state: the case of three collegiate coaches. *Sports Coaching Review*, 2(1), pp.13–32. Available at: http://www.tandfonline.com/doi/abs/10.1080/21640629.2013.837238.

Hojatighomi, T., 2013. The Dynamics of Flight of a Table Tennis Ball.

Jayabalakrishnan, D. & Achanta, R.K., 2013. A study on quantizing high level table tennis for robot training in India. Available at: http://www.ittf.com/ittf_science/SSCenter/TTSSJ_No8.html.

Kassim, K.A.B.M., 2013. Design and Fabrication of. *Thesis of Universiti Teknikal Malaysia Melaka.*

Minnich, A., Advisor, F. & Dong, J., 2011. Automatic Dog Ball Launcher. *Thesis of the*

University of Cincinnati.

Nakashima, A. et al., 2011. Robotic table tennis based on physical models of aerodynamics and rebounds. *2011 IEEE International Conference on Robotics and Biomimetics, ROBIO 2011*, pp.2348–2354.

Norris, M. et al., 2012. A Study to Investigate the Reliability and Consistency of the Sports Tutor Tennis Cube Velocity, Trajectory and Landing Points. , (5), pp.381–384.

Oguntoyinbo, O.J., 2009. PID Control of Brushless DC Motor and Robot Trajectory Planning Simulation with MATLAB/Simulink. *Thesis Bachelor*, p.90. Available at: http://publications.theseus.fi/bitstream/handle/10024/7467/Oludayo Oguntoyinbo.pdf.

Ponnusamy, B., Yong, W.F. & Ahmad, Z., 2015. A low cost automated table tennis launcher. *ARPN Journal of Engineering and Applied Sciences*, 10(1), pp.291–296.

Ramesh, S., 2013. Modelling of Geared DC Motor and Position Control using Sliding Mode Controller and Fuzzy Sliding Mode Controller. *IJCA Proceedings on International Conference on Innovations In Intelligent Instrumentation, Optimization and Electrical Sciences (ICIIIOES)*, 13, pp.16–23. Available at: http://www.ijcaonline.org/proceedings/iciiioes/number13/14373-1611.

Singh, K. & Pandey, P.K., 2013. Modeling and Simulation of Brushless DC Motor Using PWM Control Technique. *International Journal of Engineering Research and Applications*, 3(3), pp.612–620.

Sun, Y. et al., 2011. Balance motion generation for a humanoid robot playing table tennis. *IEEE-RAS International Conference on Humanoid Robots*, pp.19–25.

Tripathi, N., Singh, R. & Yadav, R., 2015. Analysis of Speed Control of DC Motor – A

review study. *International Journal of Engineering Sciences & Research Technology*, 4(2), pp.298–305. Available at: http://www.ijesrt.com/issues pdf file/Archives-2015/August-2015/44_SPEED CONTROL OF DC MOTOR A REVIEW.pdf.

Williams, H., 2011. Ping pong ball launcher. *Ping Pong Ball Launcher*, pp.8–9.

Wójcicki, K., Puciłowski, K. & Kulesza, Z.S., 2011. Mathematical Analysis for a New Tennis Ball Launcher. *Acta Mechanica et Automatica*, Vol. 5(No. 4), pp.110–119. Available at: http://yadda.icm.edu.pl/yadda/element/bwmeta1.element.baztech-article-BPB2-0062-0016.

Yong, L.P., 2014. Table Tennis Trainer (3T). *Thesis of Universiti Teknologi Malaysia.*

Yousif, B.F. & Yeh, K.S., 2011. Badminton training machine with impact mechanism. *Journal of Engineering Science and Technology*, 6(1), pp.61–68.

Zheng, W. & Jin, K., 2016. Multi Ball Training Method : A New Attempt of Table Tennis Training in Colleges and Universities. , (SSEHR), pp.261–264.

APPENDIX A
BILL OF MATERIAL

Component	Unit Price (RM)	Unit	Subtotal (RM)
Table Tennis Ball	1.00	2	2.00
DC Brushless Motor	61.90	2	123.80
Motor Wheel	14.00	2	28.00
Lithium Polymer Battery	69.00	1	69.00
ESC (Electronic Speed Control)	65.00	2	130.00
Arduino Mege 2560	178.00	1	178.00
LDR	10.60	3	31.80
Laser Emitter	9.30	3	27.90
Servo Motor	21.20	1	21.20
		Total	611.70

APPENDIX B
FINAL YEAR PROJECT 1 PLANNING

Task	Week													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Project Briefing														
Search for Related Articles, Books and Past Research Papers														
Literature Review														
Determine Problem Statement, Objectives & Scopes														
Study and review for software to be used														
Software installation and testing														
List bill of components and budget plan														
Draft proposal preparation														
Proposal and presentation slide review by supervisor														
Finalize proposal and slide														
Milestone 1: Proposal Presentation													▲	
Finalize report														
Submit report														

APPENDIX C
FINAL YEAR PROJECT 2 PLANNING

Task	Week													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Circuit Schematic Design														
Launcher Structure Construction														
Controller Programming														
Final Prototype Assembling														
Design Verification on Prototype														
Test and Troubleshoot														
Results Analysis and Discussion														
Project Conclusion														
Write Report														
Milestone 2: Report and Poster Review By Supervisor													▲	
Revise Report and Poster														

APPENDIX D
ARDUINO PROGRAM CODE

```
#include <Servo.h>
#define Laser 13
Servo servoMain;
float period;
float object_length = 40; //object length in mm
unsigned long durationLow;
unsigned long durationHigh;
int ServoOption = 0;
long delay_time=0;
long delay_set=0;
int StepCount=0;

void setup()
{
 pinMode(Laser, OUTPUT);
 Serial.begin(9600);  //start serial monitor
 servoMain.attach(10);
}
void loop()
{
 String voice;
 //String Command;
 Calculate_Velocity();

 if (Serial.available()>0){
  voice= Serial.readStringUntil('#');

 if(voice == "*a")
  {
    servoMain.write(150);
    Calculate_Velocity();
    delay(1000);
    servoMain.write(30);
    Calculate_Velocity();
    delay(1000);
    servoMain.write(90);
   }

   else if(voice == "*b")
   {
    servoMain.write(150);
    Calculate_Velocity();
    delay(1250);
    servoMain.write(30);
    Calculate_Velocity();
    delay(1250);
```

```
    servoMain.write(90);
   }

   else if(voice == "*c")
   {
    servoMain.write(150);
    Calculate_Velocity();
    delay(1500);
    servoMain.write(30);
    Calculate_Velocity();
    delay(1500);
    servoMain.write(90);
   }

   else if(voice == "*d")
   {
    servoMain.write(30);
    Calculate_Velocity();
    delay(1000);
    servoMain.write(90);
   }

   else if(voice == "*e")
   {
    servoMain.write(150);
    Calculate_Velocity();
    delay(1000);
    servoMain.write(90);
   }
}
}

float Calculate_Velocity()
{
float ballspeed = 0;
 digitalWrite(Laser, HIGH);
   durationLow = pulseIn(7,LOW);

if ( durationLow != 0)
{
        period = durationLow;
        ballspeed = ((object_length) / (period/1000));
        //return ballspeed;
        Serial.println("Ball Speed " + (String)ballspeed);
        durationHigh=0;
        durationLow=0;
}
}
```

APPENDIX E
CONFERENCE PAPER

Development of Table Tennis Launcher

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Abstract **– This article presents the development of low cost electronic controlled table tennis launcher. The objective of the study is to determine the kinematics of table tennis ball by using images acquisition system. The launcher comprise a launching and feeding system that can be operated by a voice control algorithms with microcontroller. Details of methodology used and performance analysis results will be discussed.**

I. INTRODUCTION

Table tennis is a sport that played by two or four players struck a small lightweight ball over the net with plastic rackets on a hard table [6]. Until now, ITTF has more than 220 member associations and up to 300 million table tennis players from all around the world. In other words, table tennis is gaining more popularity nowadays. Therefore, table tennis launcher is a high demand device now for training [20].

Table tennis launcher is a device that can shoo t the table tennis ball in the specific position that player desired over and over again until player masters the skills. In addition, if player miss the ball or hit the ball to the wrong direction, the table tennis launcher will still shoot the ball to the same position player had set earlier. This is something that a human partner or human coach unable to do.

A plenty number of table tennis launcher being commercialized in all around the world. These launchers consist of two types such as recreational type and high-end type [20]. Recreational type launcher use for recreation purpose at home or leisure sport centre while high-end type use at professional sport training centre

Hence, in this project, a table tennis launcher with launching system and feeding system will be designed and fabricated for the need and demand. However, the fabricated table tennis launcher may not accurate and consistence as coaches and players expect while doing the repeating ball shot [11]. This is hard for player to focus on his or her tactic and technique while performing on a practice or training exercise. With this intention, the control system has to be designed with voice controller for obtaining better manipulation. The system will be capably using by player from all ages.

II. METHODOLOGY

This section explained the technique adopted to build up a table tennis launcher with launching system and feeding system. Details of imaging system for identifying the kinematics of table tennis ball will be clarified in the upcoming section. Moreover, the following section likewise covers the explanation of the mechanical construction, electrical circuit design and the programming.

A. Mechanical Construction

CATIA V5R20 software was used as Computer Aided Design (CAD) tool in this project. The final concept structure of table tennis launcher is shown in Figure 1. Polystyrene was used as the main material for table tennis launcher due to its light weight. Table tennis launcher was controlled by two Brushless DC Motors (BLDC) and one servo motor. These motors controlled each of their mechanical part of the system which are launcher and feeder.

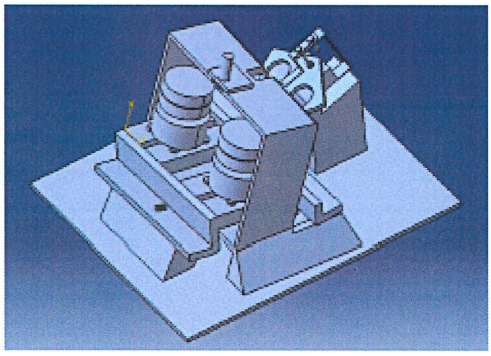

Figure 1 Final concept structure of table tennis launcher

The base is made for allowing the whole system installed on it as one. Firstly, polystyrene was used to structure the base but polystyrene is weak and easy to break. Therefore, the polystyrene structure was coated and laminated a layer of fibreglass by using the mixture of epoxy resin and hardener. Using the epoxy as the coat layer because epoxies have a tendency to be stronger than different resin, surely a great deal less brittle all alone than polyester. In other words, they have great flexural quality.

The motors will be installed parallel to each other horizontally on a motors holder to launch the ball with counter rotating rubber wheels. The motors

holder was made by aluminium due to its light weight and robust characteristic. There is a 35mm gap between the motors to allow the table tennis ball to launch through them. To generate a trajectory launch, the system was installed in an angle of 20 degree.

Ball feeder was designed to control the frequency of table tennis ball launch from the launcher. One servo motor was used in this mechanism with one 60 degree of rotation, one table tennis ball will be pushed to the launcher. Frequency of ball shoot will increase as servo motor rotate faster. One semi-circle plate was attached on the servo horn to function as the table tennis ball holder. Two holes were made in diameter of 35mm which is smaller than 40mm actual table tennis ball size on the semi-circle plate to prevent the ball falling through the plate and it was functioning as the ball holder.

B. Circuit Design

Arduino Mega 2560 was used as the core processing unit which was connected to the system via USB connection. At the same time, brushless DC (BLDC) motors and rotation servo motor were chosen as actuator of table tennis launcher. A servo tester was selected to control the two Electronic Speed Controller (ESC) which are used to drive the BLDC motors. The BLDC motors are powered up by an 11.1V Lithium Polymer battery. A laser emitter and a light dependent resistor (LDR) are mounted in between the BLDC motors and connected to Arduino Mega for ball speed testing purpose. A Bluetooth Module was also selected to voice control the Arduino Mega via hand phone. The electronics components are listed and discussed in detail in this section. While Figure 2 showed the control circuit schematic of table tennis launcher.

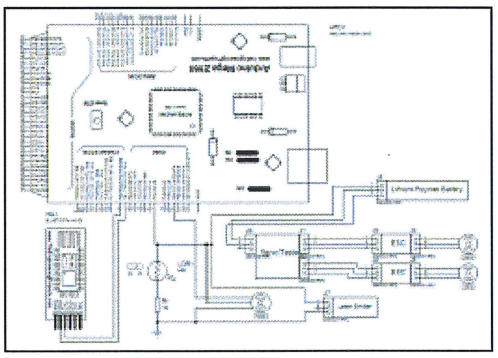

Figure 2 Control circuit schematic of table tennis launcher

C. Voice Control Table Tennis Ball Feeder Programming

This stage will be carried out after the hardware of table tennis ball feeder has successfully been fabricated. This is because the table tennis ball feeder will act and perform according to the serial command from the voice controlling part. The command will be sent through Bluetooth module communication.

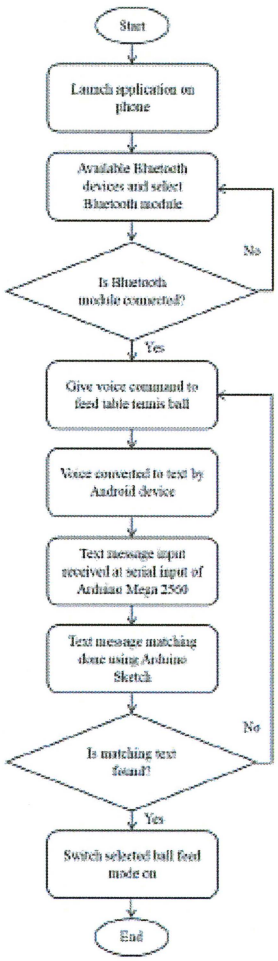

Figure 3 Voice control table tennis ball feeder programming flow chart

The application initially scans for the Bluetooth gadget. If it is available then it on the voice recognizer. It peruses the voice and changes over the sound flag into a string. It creates an incentive for every machine which will be given to the microcontroller gadget. The microcontroller utilizes the port in serial mode. Subsequent to perusing the information it interprets the input value and sends a flag to the parallel port through which the transfer circuit will be initiated. Bluetooth module was used in this work.

III. RESULTS AND DISCUSSION

In brief, the development progress of the table tennis launcher framework was viewed as smooth however a minor deviate from schedule. The control circuit and the structure of the launcher were successfully built. In the meantime, the programming of framework was accomplish a palatable level however require facilitate improvement to accomplish completely useful stage. So as to guarantee the table tennis launcher system runs smoothly, four primary elements are considered. The variables are maximum launching distance, accuracy, repeatability and ease of use. The results and data recorded for each sections are discussed in detailed.

A. Table Tennis Feeder Structure

The launcher was designed to launch table tennis ball with multivariable speed and frequency. The feeding frequency of table tennis ball was regulated by a servo motor which function to rotate the feeder plate. Figure 4 and Figure 5 show the different direction of rotation of servo motor will feed the balls.

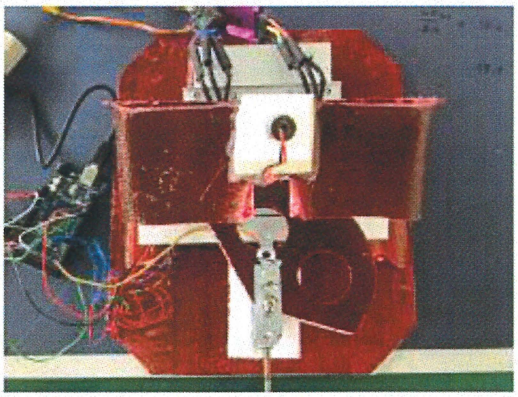

Figure 4 Direction of rotation of servo motor: 150 degree rotation

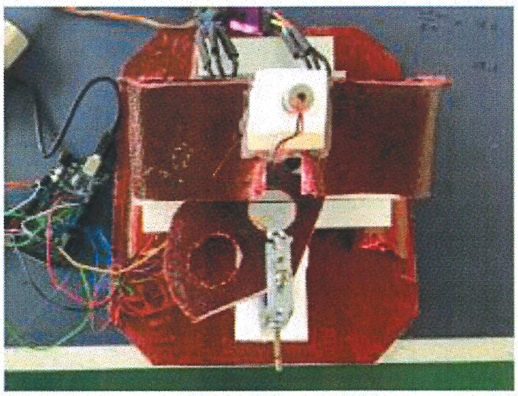

Figure 5 Direction of rotation of servo motor: 60 degree of rotation

Besides that, players are able to choose different frequency of ball shoot by control the servo motor via phone Apps. By choosing the option of the feeding frequency, servo motor will rotate the plate together with balls in the selected time.

B. Maximum Launching Speed and Distance

With the design of the table tennis launcher, one of the most imperative features is the maximum launching range of the framework. The table tennis launcher launching motors was set at range of duty cycle and the launching distance at every duty cycle was recorded in Table 1. As recorded in Table 1, the ball launching motor was set at 5 different duty cycle levels and total distance of the launching ball was recorded. The launcher was placed 360mm start from the edge of the actual table tennis table.

Table 1 Maximum Ball Launching Speed Measured by Sensor and Distance for Each Duty Cycle

Duty Cycle (ms)	Ball Launching Speed (m/s)						Total Distance (m)					
	1st	2nd	3rd	4th	5th	Avg	1st	2nd	3rd	4th	5th	Avg
1.10	6.82	6.81	6.92	6.64	6.83	6.76	1.40	1.43	1.43	1.43	1.42	1.43
1.11	7.28	7.08	7.56	7.53	7.67	7.41	1.59	1.57	1.59	1.56	1.55	1.58
1.12	8.38	8.93	8.52	8.77	8.90	8.70	1.69	1.70	1.68	1.75	1.71	1.70
1.13	8.53	9.27	9.29	8.13	8.97	9.04	1.93	1.91	1.96	1.95	1.94	1.94
1.14	9.63	10.49	9.69	10.87	10.04	10.32	2.14	2.18	2.19	2.16	2.15	2.16

The total horizontal length of a standard table tennis table is 2.74m (9 feet); in this manner the net is situated at 1.37m (4.5 feet). With the 0.36m displacement nearer, at 1.10ms the launched ball demonstrated to able to cover half of the table tennis table and reach over the net. As the duty cycle increase gradually, the launching speed and distance of the ball increase as well. At 1.09 ms the table tennis ball was launched at a speed of 5.42m/s and a distance of 1.33m which lesser than haft of the table length and unable to surpass the net. This enables the displacement to be closer to the net if necessary and the launched balls demonstrate to even now cover the required least launching distance of 1.37m to clear the net.

C. Repeatability

Testing for repeatability was finished to guarantee there was no jamming of the balls in the feeder along the table tennis game. This test comprised of a pair balls arrangement in the feeder and the objective was to guarantee that each ball was legitimately dispersed from the feeder, effectively move onto the launcher by the ball feeding system and after that be launched.

Table 2 Ball Successfully Dispersed From the Feeder

Duty Cycle (ms)	Ball successfully dispersed from the feeder	
	1st Trial	2nd Trail
1.10	Yes	Yes
1.11	Yes	Yes
1.12	Yes	Yes
1.13	Yes	Yes
1.14	Yes	Yes

There were almost no issues with this testing because of the way that the ball holder for the feeder could fit two standard table tennis balls at once. The ball pusher stopped each ball and the variable frequency controlled the servo motor which pushed the balls onto the launcher.

D. Ease of Use

Testing for usability was finished to guarantee that every user would comprehend the essential guidelines of the framework to ensure that all users could appropriately utilize the table tennis launcher system. The user was given a set of photographic guidelines to take after and test the simplicity of the ability to utilize the framework. Photographic guidelines are listed beneath:

1. Carefully place and adjust the position of the table tennis launcher.
2. Power on ball launcher motor and ball feeder motor by plugging in the Lipo battery and power bank respectively.
3. Connect ball feeder and BT Voice Control Application via Bluetooth.
4. Set ball launching motor speed about 1.10 to 1.14ms.
5. Place table tennis balls in the feeder.
6. Give command to the feeder via phone so that table tennis balls can be launched.
7. Adjust ball launching motor speed if the ball launching distance is too short or too long.
8. Choose ball feeding option if the frequency of ball feeding is too slow or too fast.

An aggregate of 5 users were tried then made a request to finish a rating on how well every client could adapt to the system utilizing the essential photographic directions.

Table 3 Product Satisfaction Survey

	Rating from Photographic Guidelines					
	1	2	3	4	5	Average
Ease of Use	-	-	1	2	2	4.2
Ease of Instructions	-	-	-	3	2	4.4
Adaptability	-	-	1	3	1	4.0
Overall Experience	-	-	-	3	2	4.4

Table 3 demonstrates the outcomes from the rating of the photographic guidelines given to the user. On the left of the table are the ranges which were appraising and to the far right are the normal rating for the coveted zone. In view of these outcomes the users rarely confronted any obstacles following in guidelines and correctly allowing the table tennis ball to work appropriately.

IV. CONCLUSION

Table tennis launcher project has successfully met the objectives and project scopes stated in Chapter 1. In this project, a table tennis launcher that showed the combination of mechatronic engineering and sport as a sport technology demonstrator. Also, the microcontroller module utilized as a part of this project was Arduino Mega 2560 with Android Voice Control Application via Bluetooth as a stage. This voice control application can ease player in manipulating the product from certain distance. Moreover, the results show that the maximum launching distance is 2.19m through the application of image acquisition technique. Survey also showed that the system can be used as an alternative tool for training.

V. REFERENCES

[1] Ahmad, M.H. Bin, 2013. Design and Fabrication Of Ball Feeder Mechanism And Body For Tennis Ball Machine. *Thesis of Universiti Teknikal Malaysia Melaka*.

[2] Dohare, D., 2016. A Review Study Speed Control Of Dc Motor With Classical Controller and Softcomputing Technique. , pp.253–259.

[3] Flores, M.A., Bercades, P.D. & Florendo, F., 2010. Effectiveness of Shadow Practice in Learning the Standard Table Tennis Backhand Drive. , 6(6), pp.105–110. Available at: http://www.ittf.com/ittf_science/sscenter/int_journal6/docs/_105.pdf.

[4] Haque, M.E. & Rahman, M.F., 2001. Influence of Stator Resistance Variation on Direct Torque Controlled Interior Permanent Magnet Synchronous Motor Drive Performance and Its Compensation. *Conference Record of the IEEE Industry Applications Conference, 2001*, 4(C), pp.2563–2569.

[5] Harvey, S. et al., 2013. A season long investigation into coaching behaviours as a function of practice state: the case of three collegiate coaches. *Sports Coaching Review*, 2(1), pp.13–32. Available at: http://www.tandfonline.com/doi/abs/10.1080/21640629.2013.837238.

[6] Hojatighomi, T., 2013. The Dynamics of Flight of a Table Tennis Ball.

[7] Jayabalakrishnan, D. & Achanta, R.K., 2013. A

study on quantizing high level table tennis for robot training in India. Available at: http://www.ittf.com/ittf_science/SSCenter/TTSSJ_No8.html.
[8] Kassim, K.A.B.M., 2013. Design and Fabrication of. *Thesis of Universiti Teknikal Malaysia Melaka*.
[9] Minnich, A., Advisor, F. & Dong, J., 2011. Automatic Dog Ball Launcher. *Thesis of the University of Cincinnati*.
[10] Nakashima, A. et al., 2011. Robotic table tennis based on physical models of aerodynamics and rebounds. *2011 IEEE International Conference on Robotics and Biomimetics, ROBIO 2011*, pp.2348–2354.
[11] Norris, M. et al., 2012. A Study to Investigate the Reliability and Consistency of the Sports Tutor Tennis Cube Velocity, Trajectory and Landing Points. , (5), pp.381–384.
[12] Oguntoyinbo, O.J., 2009. PID Control of Brushless DC Motor and Robot Trajectory Planning Simulation with MATLAB/Simulink. *Thesis Bachelor*, p.90. Available at: http://publications.theseus.fi/bitstream/handle/10024/7467/Oludayo Oguntoyinbo.pdf.
[13] Ponnusamy, B., Yong, W.F. & Ahmad, Z., 2015. A low cost automated table tennis launcher. *ARPN Journal of Engineering and Applied Sciences*, 10(1), pp.291–296.
[14] Ramesh, S., 2013. Modelling of Geared DC Motor and Position Control using Sliding Mode Controller and Fuzzy Sliding Mode Controller. *IJCA Proceedings on International Conference on Innovations In Intelligent Instrumentation, Optimization and Electrical Sciences (ICIIIOES)*, 13, pp.16–23. Available at: http://www.ijcaonline.org/proceedings/iciiioes/number13/14373-1611.
[15] Singh, K. & Pandey, P.K., 2013. Modeling and Simulation of Brushless DC Motor Using PWM Control Technique. *International Journal of Engineering Research and Applications*, 3(3), pp.612–620.
[16] Sun, Y. et al., 2011. Balance motion generation for a humanoid robot playing table tennis. *IEEE-RAS International Conference on Humanoid Robots*, pp.19–25.
[17] Tripathi, N., Singh, R. & Yadav, R., 2015. Analysis of Speed Control of DC Motor – A review study. *International Journal of Engineering Sciences & Research Technology*, 4(2), pp.298–305. Available at: http://www.ijesrt.com/issues pdf file/Archives-2015/August-2015/44_SPEED CONTROL OF DC MOTOR A REVIEW.pdf.
[18] Williams, H., 2011. Ping pong ball launcher. *Ping Pong Ball Launcher*, pp.8–9.
[19] Wójcicki, K., Pucilowski, K. & Kulesza, Z.S., 2011. Mathematical Analysis for a New Tennis Ball Launcher. *Acta Mechanica et Automatica*, Vol. 5(No. 4), pp.110–119. Available at: http://yadda.icm.edu.pl/yadda/element/bwmeta1.element.baztech-article-BPB2-0062-0016.
[20] Yong, L.P., 2014. Table Tennis Trainer (3T). *Thesis of Universiti Teknologi Malaysia*.
[21] Yousif, B.F. & Yeh, K.S., 2011. Badminton training machine with impact mechanism. *Journal of Engineering Science and Technology*, 6(1), pp.61–68.
[22] Zheng, W. & Jin, K., 2016. Multi Ball Training Method : A New Attempt of Table Tennis Training in Colleges and Universities. , (SSEHR), pp.261–264.

VI. APPENDIX

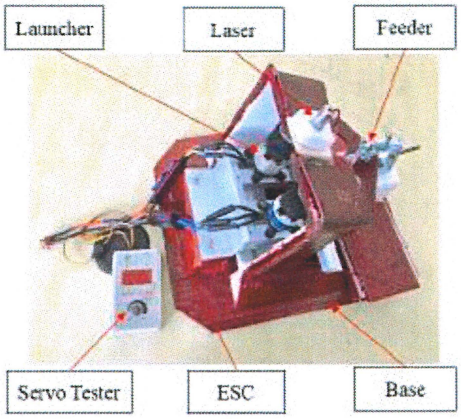

Figure 6 The final structure of the table tennis launcher