FAKULTI KEJURUTERAAN ELEKTRIK
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LAPORAN PROJEK SARJANA MUDA

DESIGN AND DEVELOPMENT OF HIGH ACCURACY SHUTTLECOCK LAUNCHING SYSTEM

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Bachelor of Mechatronics Engineering with Honours

June 2014

“ I hereby declare that I have read through this report entitle “Design and Development of High Accuracy Shuttlecock Launching System” and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Mechatronics Engineering with Honours.”

Signature : ....

Supervisor’s Name : ....

Date : ....

DESIGN AND DEVELOPMENT OF HIGH ACCURACY SHUTTLECOCK LAUNCHING SYSTEM

SHITIAN LING

A report submitted in partial fulfillment of the requirements for the degree of Bachelor of Mechatronics Engineering with Honours

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2014

I declare that this report entitle “Design and Development of High Accuracy Shuttlecock Launching System” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : ....

Date : ....

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ABSTRACT

In many sports such as tennis and table tennis, there are training machines available for exercises or training purpose. The benefits in using these machines with high functionality and comparatively low cost have contributed to their extreme skills improvement. The machines setting duplicated accurately for every shots. Thus training on particular areas of the player's game is relatively simple and more focused. Badminton players can acquire same advantages as mentioned with a shuttlecock feeder machine. There are machines rarely available in the market. One of the options for consumers is the Knight Trainer, which consists of two rotating wheels to transmit the shuttlecock. However, the cost is extremely expensive to invest in with a minimum of RM15, 000. The overall look of Knight Trainer has all the desired qualities but it does possess numerous deficiencies. From the reviews by several badminton players, the machine is unpractical, less accurate and retains high initial and operating costs. This research aims to improve the accuracy of Shuttlecock Launching System (SLS) by studying the shuttlecock trajectory. Besides, the aim to design and develop a low cost solution in manufacturing so that the SLS is allowed for a retail price comparable to machines in other sports. Research had been conducted on the trajectory of shuttlecock to predict the angles and velocities needed to launch different types of shot. From the study, a desired motor specification can be obtained by computing the torque and speed required. The results obtained with two approaches are compared by analyzing the trajectory models occurred from the simulations. The accuracy of feeder mechanism are founded (12 ± 15.8) mm and (15.4 ± 13) mm with standard deviation of 5.716 mm and 5.824 mm respectively. For the launching mechanism, results showed an error percentage as low as 4.70% at an angle setting of 22.5° for the shuttlecock trajectory. For overall system of SLS, the accuracy for angle settings of 22.5°, 45° and 67.5° achieved 20%, 0% and 60% respectively.

ABSTRAK

Dalam banyak sukan seperti tenis dan *ping pong*, terdapat mesin latihan yang disediakan untuk tujuan latihan. Manfaat dalam menggunakan mesin ini dengan fungsi yang tinggi dan kos yang agak rendah telah menyumbang kepada peningkatan kemahiran yang melampau mereka. Penubuhan mesin diulang tepat untuk setiap pukulan. Oleh itu, latihan dalam bidang-bidang tertentu permainan pemain adalah agak mudah dan lebih fokus. Pemain badminton boleh memperoleh kelebihan yang sama seperti yang dinyatakan dengan mesin feeder *shuttlecock*. Salah satu pilihan untuk pengguna adalah *Knight Trainer*, yang terdiri daripada dua roda berputar untuk menghantar bola itu. Walau bagaimanapun, kos sangat mahal untuk melabur dalam sekurang-kurangnya RM15,000. Kelihatan keseluruhan *Knight Trainer* mempunyai semua ciri yang dikehendaki tetapi ia mempunyai banyak kekurangan. Dari ulasan mengikut beberapa pemain badminton, mesin tersebut kurang praktikal, kurang tepat dan mengekalkan kos permulaan dan operasi yang tinggi. Penyelidikan ini bertujuan untuk meningkatkan ketepatan *Shuttlecock Launching System (SLS)* dengan mengkaji trajektori *shuttlecock* itu. Selain itu, matlamat untuk mereka bentuk dan membangunkan satu penyelesaian kos rendah dalam pembuatan supaya *SLS* dibenarkan untuk harga runcit setanding dengan mesin dalam sukan lain. Penyelidikan telah dijalankan pada trajektori *shuttlecock* untuk meramalkan sudut dan halaju yang diperlukan untuk melancarkan pelbagai jenis pukulan. Dari kajian ini, spesifikasi motor yang dikehendaki boleh diperolehi dengan mengira *torque* dan kelajuan yang diperlukan. Keputusan yang diperolehi dengan dua pendekatan berbanding dengan menganalisis model trajektori berlaku dari simulasi. Ketepatan mekanisme feeder adalah diasaskan (12 ± 15.8) mm dan (15.4 ± 13) mm dengan sisihan piawai masing-masing 5.716 mm dan 5.824 mm. Untuk mekanisme pelancaran tersebut, keputusan menunjukkan peratusan kesilapan serendah 4.70% pada tetapan sudut sebanyak 22.5° untuk trajektori *shuttlecock* itu. Untuk sistem keseluruhan *SLS*, ketepatan untuk tetapan sudut sebanyak 22.5°, 45°, dan 67.5° mencapai 20%, 0%, dan 60% masing-masing.

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x	-	Horizontal displacement
y	-	Vertical displacement
t	-	Time taken
v	-	Velocity
a_c	-	Constant acceleration
g	-	Gravity acceleration
F	-	Force
F_i	-	Resistive force
F_a	-	Buoyant force
α, k	-	Constant
m	-	Mass
θ	-	Angle
d	-	Distance travel
V	-	Volume
ρ	-	Density
η	-	Dynamic viscosity
R	-	Radius

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CHAPTER 1

INTRODUCTION

1.1 Motivation

These days, badminton is one of the famous racquet sports in the world and has been comprised in Olympic Games organizations, which are the leading international sporting event with more than 200 nations participating. Footwork is about movement skills. While it's obvious that racket skills are important, good movement skills are often underestimated by players. Good footwork supports players to reach the shuttlecock early and it is desirable in all state of affairs.

There are various types of training for the experts in the badminton circles. One of the popular ways of training is the “Multi-shuttle” training session. This training works with a lot of shuttlecocks which the coach will throw towards the player to achieve the strokes. The training phase can be distributed into two types:

a) Technical
   - Carry out different shot techniques such as smash, clear, drop and defensive shots, net play, backhands and drive shot.
   - Practice various movements on court which includes running to net, to side, backwards and jumping.

b) Physical
   - For the stamina, aerobic and anaerobic endurance
   - For the durability, explosive strength and concentration strength
   - For the speed consistency, stability and speed of reaction and action

Multi shuttlecock drills suit the technical training very well because it allows coach to allocate the direction, speed and angle of the flight of shuttlecocks. For drop, clear, smash and backhand strokes, shuttlecock travels at a high trajectory to the back line of the court. Player has to reach the shuttlecock and perform an overhead stroke as shown in Figure 1.1.

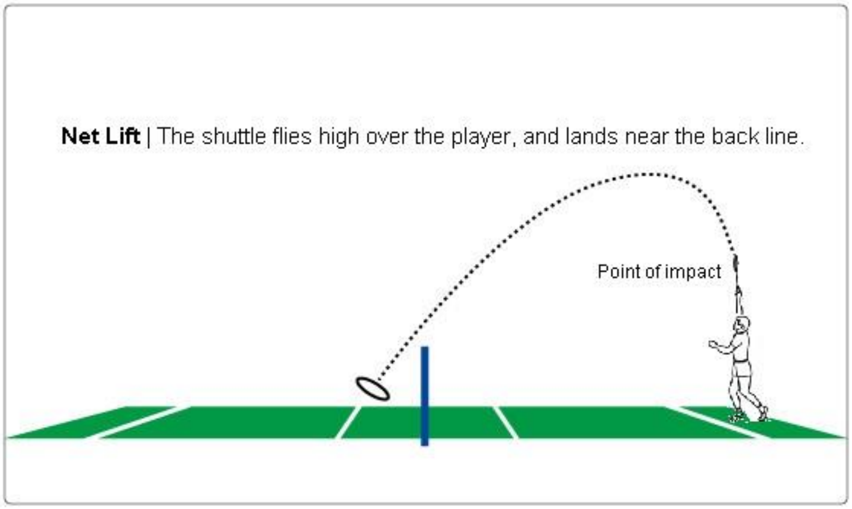

Figure 1.1 Net lift

For net play and drive shot, these shots are done in the fore court which is nearest to the net area. Net play is targeted shot that propel the shuttlecock across the net at an angle perpendicular to the floor. This will make the player runs toward the net to perform net play as well as drive shot. The trajectory of the shuttlecock is the lowest as shown in Figure 1.2.

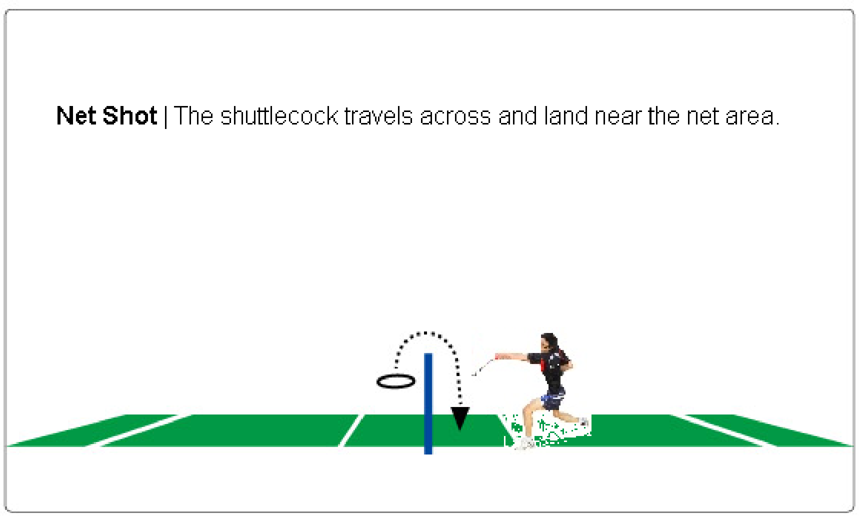

Figure 1.2 Net shot

Regarding defensive shot, it is performed after a smash shot. During smash shot, shuttlecock travels with a high speed and power downward to the player which is usually done from the back line of the court. The angle of shuttlecock's trajectory is relatively low with high steepness as shown in Figure 1.3. Therefore, it is difficult for player to carry out a defensive shot.

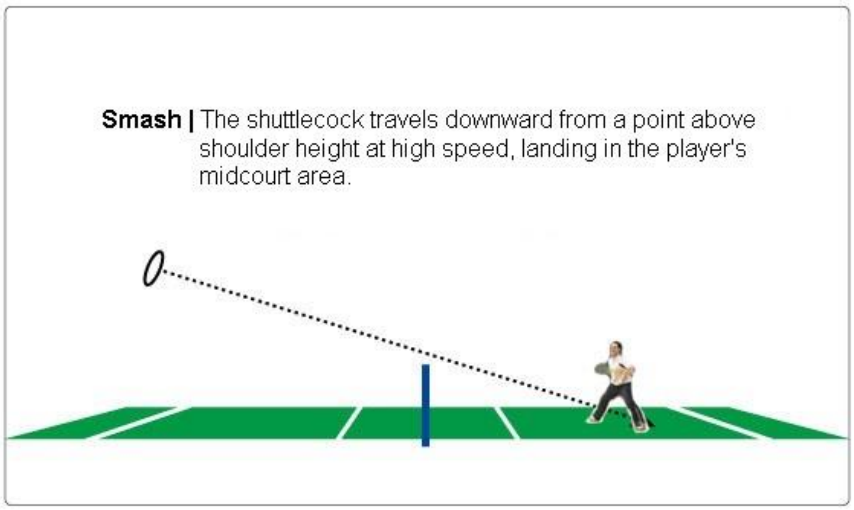

Figure 1.3 Smash shot

As a badminton coach to conduct a technical training, he/she has to perform shuttlecock serve to the player with different speeds, directions, as well as angles. A set of this training usually requires 100 shuttlecocks serve at a time. During training period, coach has to repeat the serve and collect the shuttles. This will consume lots of energy for a coach to deal with several players at a time. With this Shuttlecock Launching System (SLS), coaches can simply concentrate on coaching whilst improve badminton skills of the players. Furthermore, players can improve their performance which focuses on their agility in the competition.

1.2 Problem Statement

The research is initiated by evaluating the problem statement so that the objective can be achieved among the scope and limitation of the research.

The problem faced in badminton field there is no machine which is comprehensive to replace coaches or practice partner during training. The ability to practice independently has been limited. However, the available products on the market are expensive which cost at least RM9000 and make the product has not be in great demand to the public. This is because the machines contain two high speed motors which are costly. Besides, the other problem is the existing products mostly consist of two rotating wheels as the shuttlecock launcher. From the research it was examined that this type of actuation system can destroy the cork when it is dragged into the launching mechanism[2]. Also, the accuracy of launching the shuttlecock to a target is affected by the rotating wheels. This is led by different speeds of the rotating wheels which are difficult to be synchronized[3]. For the feeder mechanism, the problem faced during the operation is the irregular position of shuttlecocks in the storage as shown in Figure 1.4. This may lead to the inaccurate shot when the shuttlecock is supplied to the launching mechanism. Other than that, another challenge is the time-optimal control between the feeder and launching mechanism which is shown in Figure 1.5. The racket has to move to an exact position where the intersection between racket and shuttlecock occurs.

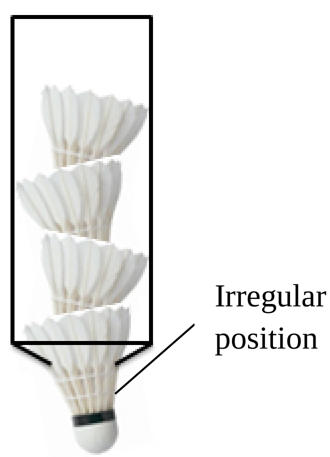

Figure 1.4 Illustration of feeder storage with irregular shuttlecocks' position

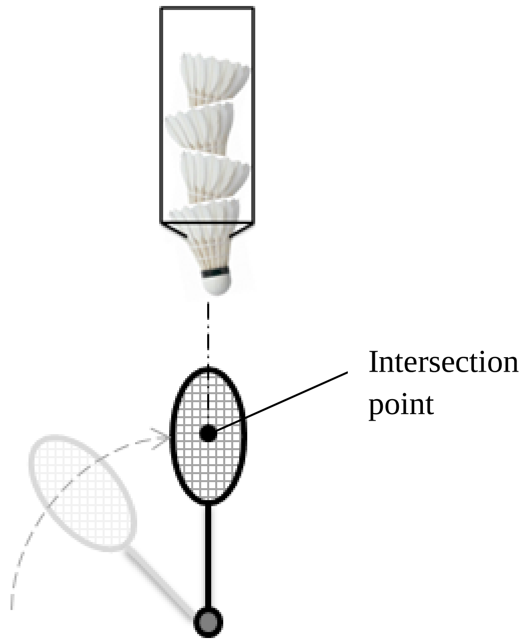

Figure 1.5 Overview of hit operation

1.3 Project Objectives

- To design and develop a Shuttlecock Launching System (SLS) with lateral swing.
- To analyze the accuracy and improve performance of the machine by simulating the existed trajectory of shuttlecock.

1.4 Scope of the project

This research focuses on:

- The design of electric and electronic parts of SLS.
- The development of shuttlecock launching prototype in which the desired position of shot is adjustable.
- Analysis on the accuracy of the shots and verify with the existed trajectory equation.

1.5 Outline of the Dissertation

The remainder of the report is organized as follows. First, the theory of SLS is introduced in Chapter 2, which also involves SLS problem, performance indices, comparison among available solutions and summary of literature review. Next, research methodology is developed in Chapter 3. The experimentally obtained results and analysis are then presented in Chapter 4 and discussed in details. Finally, conclusion and future works are drawn in Chapter 5 and the references are stated after that.

CHAPTER 2

LITERATURE REVIEW

2.1 Theory of Shuttlecock Launching System (SLS)

2.1.1 Motion of a Projectile

The current study is to understand the aerodynamics of shuttlecock. Shuttlecock travels in curvilinear motion which moves along a curved path. Thus, vector analysis is used to formulate the position, velocity and acceleration of the shuttlecock. Consider a shuttlecock launched at a point (x_0, y_0), with an initial velocity of v_0, having components $(v_0)_x$ and $(v_0)_y$ as shown in Figure 2.1. The weight causes the projectile to have a constant downward acceleration, $a_c = g = 9.81\ m/s^2$.

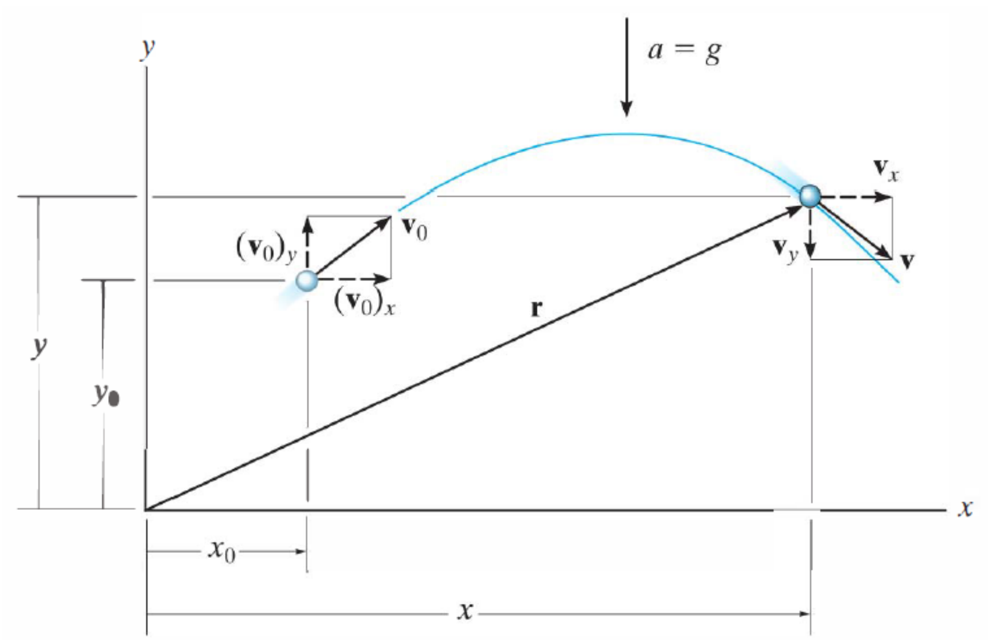

Figure 2.1 Trajectory of shuttlecock[4]

Horizontal Motion

The velocity in the horizontal direction always remain constant, and $a_x = 0$. Hence,

$$x = x_0 + (v_0)_x t \tag{2.1}$$

Vertical Motion

Since the acceleration is directed upward, then $a_y = -g$. Then,

$$v_y = (v_0)_y - gt \tag{2.2}$$

$$y = y_0 + (v_0)_y t - \frac{1}{2} g t^2 \tag{2.3}$$

$$v_y^2 = (v_0)_y^2 - 2g(y - y_0) \tag{2.4}$$

To analyze the motion of shuttlecock in the air, the air resistive force is taken into account. There are two models of equation: a linear model (air resistive force is assumed linear in the velocity of shuttlecock) and a quadratic model (air resistive force is assumed quadratic in the velocity of shuttlecock). Since the air resistive force is assumed linear in this research, linear model of air resistance is chosen to describe the motion of shuttlecock. It does not require complicated calculation in collecting data. Theoretically, the resistive force is written as $F_i = -(\alpha_i + k v_i)$, Assume that $\alpha_x = \alpha_y = \alpha$[5].

For horizontal direction,

$$m \frac{dv_x}{dt} = -\alpha - k v_x \tag{2.5}$$

For vertical direction,

$$m \frac{dv_y}{dt} = -mg + F_a - \alpha - k v_y \tag{2.6}$$

where F_a is the buoyant force. By integrating both equations 2.5 and 2.6, the velocities for the vertical and horizontal direction will be,