
## Faculty of Electrical Engineering

# DEVELOPMENT OF MASS DETECTION MODULE FOR LOW-COST SPORT COURT SYSTEM APPLICATION

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**Bachelor of Electrical Engineering**
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# DEVELOPMENT OF MASS DETECTION MODULE FOR LOW-COST SPORT COURT APPLICATION

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# DECLARATION

I declare that this report entitled "Development of Mass Detection Module for Low-Cost Sport Court System Application" is the results 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 : ……

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# APPROVAL

I hereby declare that I have read through this report entitled "Development of Mass Detection Module for Low-Cost Sport Court System Application" and in my opinion this report is sufficient in terms of scope and quality as a partial fulfilment of Bachelor of Electrical Engineering (Control, Instrumentation & Automation).

Signature : ……

Supervisor Name : ……

Date : ……

# ABSTRACT

The purpose of this project is to implement a mass detection module which is a detection sensor module underneath a sports court floor. The existing sports electronic officiating system (or line-calling technology) have flaws which required human supervision and are not fully accurate due to certain influencing factors. Therefore, the concept of a sports officiating system is applied into the sensor module which aimed to detect the impact of a ball on the boundary line of a sports court floor. The sensor module is based on the conductive silicone rubber keypad, where it serves to determine whether the detected impact lands inside or outside of a boundary line. In addition, a printed circuit board (PCB) containing the design of keypad switches is made to allow the keypad to rest on top of it. A software algorithm is created, as to be integrated with the hardware, where microcontroller such as Arduino Mega 2560 is used. Once there is a presence of detection due to impact on the boundary line of the sport court, the result is shown by the system as '1' (one), whereas '0' (zero) if no impact is detected. Next, a liquid crystal display (LCD) is used to display the output position of the detected impact, as 'IN!' or 'OUT!'.

# ABSTRAK

Tujuan projek ini adalah untuk melaksanakan modul pengesanan jisim yang merupakan modul pengesanan di bawah lantai gelanggang sukan. Sistem perasmian elektronik (atau teknologi panggilan barisan) mempunyai kelemahan iaitu memerlukan pengawasan manusia ataupun ketepatan yang tidak sepenuhnya disebabkan oleh faktor-faktor tertentu. Oleh itu, konsep sistem perasmian sukan tersebut telah diaplikasikan ke dalam modul pengesanan yang bertujuan mengesan impak bola di atas garisan sempadan lantai gelanggang sukan. Modul pengesanan ini adalah berdasarkan pada pad kekunci getah silicon konduktif, di mana ia menentukan sama ada pengesanan tersebut dikesan di dalam ataupun di luar garisan sempadan pada gelanggang tenis tersebut. Di samping itu, papan litar bercetak (PCB) yang mengandungi reka bentuk suis papan kekunci telah direka untuk membolehkan papan kekunci untuk berehat di atasnya. Satu algoritma perisian juga telah diwujudkan, untuk mengintegrasikannya dengan perkakasan, di mana pengawal mikro seperti Arduino Mega 2560 digunakan. Apabila terdapat kehadiran pengesanan yang disebabkan oleh impak yang terjadi ke atas garis sempadan gelanggang sukan, hasilnya ditunjukkan oleh sistem sebagai '1' (satu), manakala '0' (sifar) jika tiada pengesanan dikesan. Seterusnya, paparan kristal cecair (LCD) juga digunakan untuk memaparkan keputusan kedudukan pengesanan yang dikesan, sebagai ‘IN!’ atau ‘OUT!’.

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# CHAPTER 1

# INTRODUCTION

This chapter is intended to provide a rationale for the research by highlighting the importance, depth, content, structure and complexity of the research. This chapter includes research background, motivation, problem statement, objectives and scope and limitations.

## 1.1 Research Background

The term "Sport" originated from desport, an ancient French word meaning relaxation, which denotes "anything humans find amusing or entertaining" with the old definition in English from around 1300 [1]. The characterization of sports accordingly to the International Sports Federations, SportAccord, is "a sport should have an element of competition, be in no way harmful to any living creature, not rely on equipment provided by a single supplier and no rely on any luck element specifically designed into the sports". The sports within SportAccord can be known as "primarily physical, primarily mind, primarily motorized, primarily co-ordination, or primarily animal-supported" [2].

Generally, a sports court is also known as a multi-sport game court, typically constructed outdoors and indoors [3]. The sports court concept was popularized by Sport Court, a listed brand of Connor Sport Court International. It is served to recognize the genuine segmental sports surfaces developed and continuously upgraded since they were founded in 1974. The courtyard game court idea was then introduced, bringing families and children to gather for healthy and safe recreational place. Sport Court's main highlight was the courtyard game court, where a diversity of outdoor sports and recreational games can be played. For example, basketball, volleyball, badminton, tennis, shuffleboard, and roller hockey [4].

Every sport has sporting event that requires a sports referee. A sports referee is a person of jurisdiction, who is accountable for presiding over competitive sporting events from a neutral point of view to help maintain the standards of play [5]. The key duty of sports referees is to make instant decisions and ensure that a match is conducted accordingly to the rules and regulations of the competition. If there were to be violations, a sports referee will signal the participants and other officials to regulate the play [6]. Besides referee, there are other titles, including umpire, touch judge, linesman, sports official or technical official depending on the sport itself [5].

In certain sports, such as tennis, basketball and football, uses ball which has masses as a part of the equipment of the sport. In physics, mass is a property of a physical body and the quantity of matter an object has. Accordingly, to Newton's Second Law of Motion, it is the measure of resistance to a change in its state of motion when a force is applied [7]. Meanwhile, detection meant the act of detecting [8], where the word detects means discover or investigate the presence or existence of something [9]. In addition, each of a set of standardized portions or independent component that can be used to construct a more composite structure are known as a module. In terms of software, a module is a fragment of a program that contains one or several procedures while a module is a self-contained component based on hardware terms [10]. Besides, a device that detect and measure any physical property and then records or respond to it is called a sensor. The quantity to be measured is then converted from analogue signal into a digital signal, where the data can be read, displayed or stored in a way that a computer could understand [11].

In this project, a mass detection module would be developed which act as a detection sensor underneath the boundary line of a sport court floor. The module will be made up of custom designed sensory module.

## 1.2 Motivation

The world of sport is constantly evolving over the years, and the use of technology has caused an influence on many sports. One of the downsides of the use of technology is that it can hold up the flow of the game, while in contrast, making it a more pleasurable view for the spectators to see the precise decisions being made. Most sports have previously utilized immediate replay and other high technology assistances to aid referees make the correct decision.

Since the early 1970s, technology of officiating and judging of calls in sports was introduced. The first electronic line judge device for tennis was invented in 1974 while in the 2000s, the use of video camera-based technology called Hawk-Eye has revolutionized the world of sports [12]. The Hawk-Eye system uses cameras to trace the trajectory of a ball and the images collected is then sent to a virtual-reality machine. In tennis, the Hawk-Eye allows players to challenge the umpire's decisions and provides video replays to the audience and commentators [13]. Up until very recently, soccer has always resisted the use of high technology assistance. The video replays applied in soccer could resolve decisions concerning off-sides, whether a ball passes over the goal line, and clarify penalty decisions. This technology has been a great help in assisting the referees.

Most of the sports, mainly cricket, tennis, football, and lately, badminton have embraced the technology of officiating into their games and matches. It became a decision-aid to the officials when sometimes it may be too difficult for the officials to analyze the game due to the limits of human perception.

Even though recent technology was well-accepted by players, fans or officials, the system is imperfect. Thus, this paper is proposed to enhance the officiating system by using sensory modules. This project could be used by all the sport courts throughout the world, mainly indoors.

## 1.3 Problem Statement

Despite the advantages of the system, rulings by Hawk-Eye has shown that they are only correct about 46% of the time, of the challenges made by the players. The location of the tennis ball has a margin of error of "3.6 mm" as measured by the Hawk-Eye system, which was criticized as too large [13]. Therefore, any technology can be fallible. In the tennis final at Wimbledon 2008, a ball that seemed out was called "in" by "1 mm", a distance which is smaller than the publicized margin of error [14]. Besides, the installation cost of the high-speed cameras of Hawk-Eye around the court can be very costly and because of that, it is only approved for use at tournament level [15]. Even though several high-speed cameras were used around the court, the detection might not be fully accurate as occlusion might occur in front of the cameras.

Therefore, there is a need for high performance system where the errors can be greatly reduced while increasing the detection accuracy of the system. Furthermore, this economical proposed system is practical to be implemented at any tournament level and beneficial for sport users. In this project, the proposed detection sensor module will be able to solve the arise problem, where only sensors are involved and no cameras will be used. This meant that any occlusions occurred would not affect the accuracy of the system. Moreover, the sensor module is designed at an affordable price for the market, thus can be used in almost any sport courts.

## 1.4 Objectives

There are a few objectives required to be fulfilled to achieve the relevancy of the project. The objectives of this project are to:

1. Identify the parameters required for the designation of sensor module
2. Design a sensor module with the integration of software algorithm
3. Develop a smart and cost-effective sports court system

## 1.5 Scope and Limitations

This project addresses the development of sensory modules in the cost-effective sports court system. The scope of this research is discussed.

The sensory modules to be developed will only be laid beneath the boundary line of a sports court floor. The sensor will only detect whether the detected impact is landed inside or outside of the boundary line. Only data such as position of the detected impact which is the impacted ball will be collected into the system.

The proposed system would be introduced only to practical sports court level. The current proposed system will be targeted only for tennis court. The Proteus ISIS Professional software is used to construct circuit design for simulation prior to testing of the project hardware, whereas Autodesk EAGLE is used to construct schematic diagram for the design of PCB layout. A microcontroller known as Arduino Mega 2560 with its programming software, Arduino IDE is used to develop a software algorithm and integrate it with the project hardware. The decision of the ball position will be displayed on the LCD as ‘IN!’ or ‘OUT!’.

# CHAPTER 2

# LITERATURE REVIEW

This chapter serves to establish theoretical framework to identify the research area based on previous related works to support this research. Previous works are studied in terms of the tennis court, existing sports officiating system, type of detection, type of parameters, type of sensors, and the flow to design sensors.

## 2.1 Tennis Court

The sports of tennis are played on the surface of a tennis courts, a rectangular flat surface with a low net stretched across the center. Both singles and doubles matches are competed on the same surface. A tennis court can be created with different types of materials of court surfaces, mainly clay courts, grass courts, hard courts, and carpet courts. The playing style of the game is influenced by the surfaces, with each having its own characteristics. A governing body, the International Tennis Federation (ITF) has regulated the dimensions of a tennis court, and is written in the document of 'Rules of Tennis' [16].

The length of the tennis court is 23.77 meters. For double matches, the width of the court is 10.97 meters whereas for the single matches is 8.23 meters. The service line is 6.40 meters from the net. For players to reach overrun balls, extra clear area around the court is needed, which is a total of 18 meters wide and 37 meters long. A net is stretched across the full width of the tennis court, parallel with the baselines, dividing it into two equal ends. The net posts are located 0.91 meters outside of the doubles court and also outside of the singles court on each side, respectively. The height of the net at the posts is 1.07 meters while, in the center is 0.91 meters [17]. Figure 2.1 shows the dimensions of a tennis court.

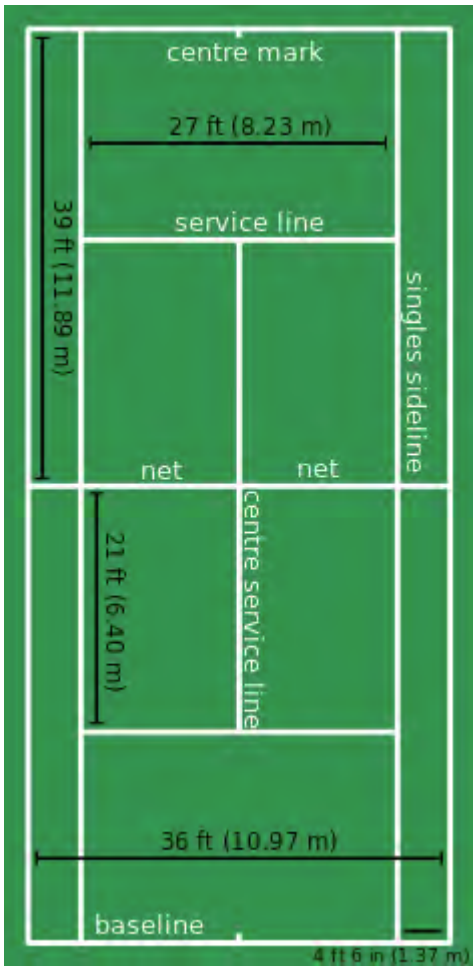


Figure 2.1: Dimensions of a Tennis Court

## 2.2 Sports Officiating System

Sports officiating system is a system of managing a sport, specifically on implementing the game rules and keeping order in the duration of the game. Primarily, the task of presiding over a sporting events was the role of a sports referee or officials. The existence of sports officiating system or line-calling technology nowadays, had become a decision-aid to the officials.

### 2.2.1 Electroline (Grant-Nicks System)

In 1974, the first computerized, electronic line judge device called as the Electroline was co-invented by Geoffrey Grant and Robert Nicks. Grant is a researcher and an enthusiastic tennis player, while Nicks is an engineer majoring in electronics. The Grant-Nicks device, Electroline made its public appearance in the tennis championship finals of both the 1974 Men's World Championship Tennis in Dallas and the 1975 Ladies' Virginia Slims tour in Los Angeles. The Electroline system, shown in Figure 2.2 was successfully demonstrated to provide automated "in" and "out" line calls, as to decide whether the ball landed within the boundaries of the playing zone [18].

The pressure-based system was comprised of thin Mylar conductive plastic pressure sensors, underneath a court surface [18], as can be seen in Figure 2.3. Besides, the system was wired to distinguish foot faults using directional microphones together with a timing circuit and automated service net-cord legal serve decisions by using piezoelectric sensor on the net. It is sensitive enough to be able to differentiate between a tennis ball and a player's foot [12]. The system was issued with a United States Patent and Trademark Office (USPTO) patent. However, the invention did not emerge as a commercial product.

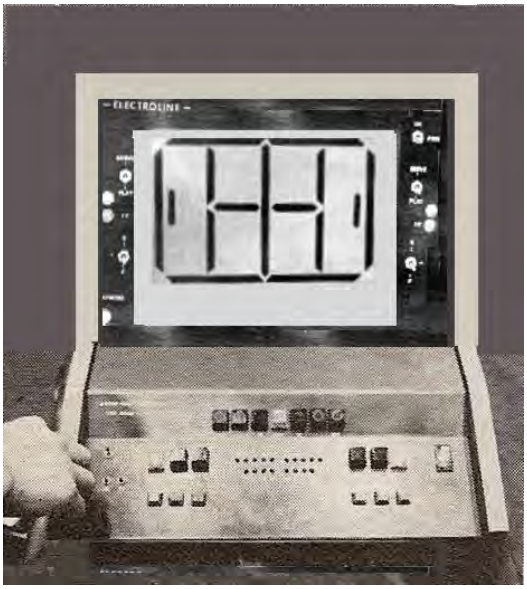


Figure 2.2: The Electroline

Figure 2.3: Grant (left) and Nicks (right) with the Mylar sensors

### 2.2.2 David Lyle System

An electronic officiating system that was initiated in Edinburgh, Scotland, United Kingdom was autonomously developed by David Lyle, at a sponsored tennis match in 1977. The Lyle system was based on a combination of an electrically conductive tennis ball [19], a micro-computer network systems equipment for making and using automatic line-call decisions in tennis [20], along with an impact-detection apparatus for determining the location of a tennis ball, whether it landed in or out of the court surface [21]. Similarly, with Grant-Nicks system, the Lyle system was also never commercialized.

### 2.2.3 Cyclops

Cyclops is a computer system invented by Bill Carlton, the inventor of plastic shuttlecock used in badminton and an aeronautics engineer. It serves as an electronic line judge on the Association of Tennis Professionals and Women's Tennis Association professional tennis tours. The Cyclops system involves the usage of two boxes bolted into the side-lines of the tennis court surface. The pair of boxes are the transmitter and receiver boxes situated on either side of the net. Moreover, a horizontal array of five or six infrared beams is projected by the transmitter across the court to its counterpart receiver box [22] [23], as shown in Figure 2.4. A control box containing the receiver which is held by the service line umpire, must be triggered before a serve and disabled after each serve. The boxes are configured so that, the good side of the service box line is covered by one infrared beam, while the fault side is covered by the other four infrared beams. Whenever a served ball breaks the first beam positioned beyond the service line, the other four beams are switched off. If the served ball breaks one of the four other beams, a loud audible beep will be heard, indicating the serve was long [22] [23] [24].

The Cyclops computer system was the first electronic officiating system ever commercialized. It was introduced to the Wimbledon Championships in 1980 and has been used ever since. Other major championships such as the U.S Open and Australian Open also adopted the use of Cyclops in their tennis matches. The system has been constantly being enhanced and is more resilient to being activated by bugs flying in front of the beams [23]. Still, Cyclops was detached from Wimbledon's Courts in 2007 [24], to permit the installation of the Hawk-Eye system which was initially presented at the U.S Open in 2006 [25].

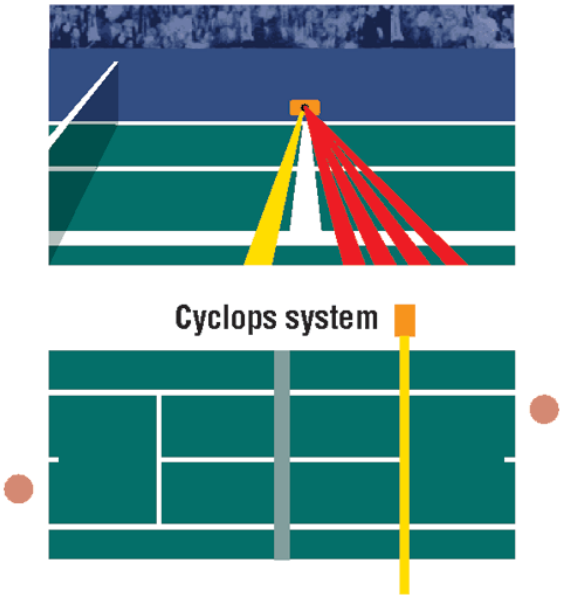


Figure 2.4: The Cyclops system

### 2.2.4 Hawk-Eye Technology

Hawk-Eye Technology invented by Dr. Paul Hawkins was firstly introduced in cricket, to intensify the TV before being adopted into tennis since 2002. Since then, it has advanced into a device that is now being utilized for officiating in a range of sports, including tennis, soccer, cricket, hurling, baseball, snooker and Australian rules football. A tennis officiating system of Hawk-Eye has received authorization by the International Tennis Federation (ITF) to be the first and only ball tracking technology which passed testing measures [13].

Hawk-Eye is a complex video processing system uniting several cameras and a host computer to accumulate and process the information. It is now widely used in numerous sports to visually track the trajectory of ball and predicting the most likely path of the ball by analyzing the pixels in each frame of each camera feed. Hawk-Eye relies on six to seven computer-linked high-performance video cameras situated around the field-of-play [13]. The video produced by all the separated six cameras are combined to synthesize a 3D representation of the path of the ball using triangulation method [14], which is accurate up to within 5mm. The example of video replay by Hawk-Eye can be seen from Figure 2.5. The video data recorded are sent in real-time to the computer for processing and data analysis, and to track the path of the tennis ball on each camera [13].


Figure 2.5: The Hawk-Eye Video Replay

## 2.3 Type of Detection

Many projects research had been carried out to detect and identify the presence of objects on top of a floor surface by using designated sensors beneath the floor.

### 2.3.1 Magic Carpet

J. Paradiso et al. proposed the Magic Carpet, an interactive environment system comprising of a pair of Doppler radars and a grid of piezoelectric wires hidden under a carpet. The Doppler radars measures upper-body kinematics whereas the piezoelectric wires are used to monitor dynamic foot position and sense foot pressure. The insulation of the piezoelectric wires is made from a type of usually obtainable piezoelectric material, Polyvinyl Dene Fluoride (PVDF) polymer. A voltage will be produced when the carpet is pressured or bent anywhere along the length of the wire. The Magic Carpet is a very responsive system, since the PVDF wire displays a much higher dynamic range in response of pressure and is much more sturdy [26].