POOL SHARK TECHNOLOGIES
Simon Fraser University
8888 University Drive
Burnaby BC Canada
V5A 1S6

November 6, 2000

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Re: ENSC 340 Project - Ace Training System Functional Specifications

Dear Dr. Rawicz:

The attached document, ENSC 340 Project – Ace Training System Function Specifications, discusses in detail the operational aspects of our project for ENSC 340. This project is to design and develop a user-friendly pool table that teaches the players how to hit the balls into the pocket.

These functional specifications outline the operation of the overall system. The system is divided into few components including sensors, image processing unit, and user interface, and each of them is briefly explained. The document also lists the operation requirements, safety requirements, training requirements, and testing requirements.

Pool Shark Technologies consists of five talented and ambitious fourth-year engineering students' expertise in both hardware and software: Desmond Cheung, Humphrey Ng, Patrick Pun, Janice Wong, and Lawrence Wong. If you have any questions or concerns, please feel free to contact Humphrey Ng by phone at 431-6333 or by email at hngc@sfu.ca.

Sincerely,

Janice Wong
Team Leader
Pool Shark Technologies

Enclosure: ENSC 340 Functional Specifications for an Ace Training System

Functional Specification for

Ace Training System

Team: **Desmond Cheung**
Humphrey Ng
Patrick Pun
Janice Wong
Lawrence Wong

Contact: **Humphrey Ng**
hngc@sfu.ca

Submitted to: **Dr. Andrew Rawicz – ENSC 340**
Steve Whitmore – ENSC 305
Jason Rothe – ENSC 340 TA
James Balfour – ENSC 340 TA
School of Engineering Science
Simon Fraser University

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Executive Summary

Snooker and billiards are two of the most popular recreational games in the world. Here in Canada and in the United States, the popularity of pool is on the rise. In Europe, snooker is as commonly played as hockey and basketball here in North America.

Pool Shark Technologies is taking advantage of this vast and growing market by creating the Ace Training System (ATS), a virtual coach that teaches the player to play the game like a professional. The ATS is designed for every kind of player, whether he or she is a beginner learning the game for the first time, or a professional trying to perfect his or her skills.

The first version of the ATS will be in the form of a prototype, which will have all the essential features of the ATS. However, the setup will consist of three balls, as opposed to the entire set of snooker balls.

This document intends to outline the functionality of the ATS. Among the information given is a summary of the various components of the ATS.

1 Introduction

The game of snooker is being played throughout the world. Its origin can be traced back to the 17th century, where throughout Europe especially England, large cities and small towns all have pool halls for the public.[1] Snooker was one of the most popular sports at all time, even now.

In the General Household Survey of 1990 conducted in Britain, snooker proved to be one of the most popular played sports, ranked second most popular for men and fifth for women. In 1997, an independent survey showed that for the British national television network BBC's coverage of the 1996 World Snooker Championship, 40 million of Britain's current 54 million population watched, with viewing figures peaking at 8.9 million and 9.8 million at the latter stages of the tournament.[2]
In North America, the popularity of snooker is not as titanic as compared to Europe. However, North Americans are more familiar with a game that derived from snooker – billiard, also known as pool. The two games, snooker and pool, differ by the size of the table and the rules of the game. The objective of these games, nevertheless, remains the same: to hit the ball into the pocket.

To capture the enormous global market, Pool Shark Technologies is developing the *Ace Training System* that teaches how to play the games of snooker. The product is being created by five enthusiastic engineering students from Simon Fraser University, who have very keen interest in the games of snooker and pool.

Our first product will be a prototype of the full-scale ATS. To ensure that the different components and abilities of the ATS are demonstrable, we have placed a few limitations on our prototype. The most important limitation is that there will be a total of three balls on the table, instead of the full set. Other restrictions are outlined at a later section.

This document is the functional specifications of the ATS. We are providing a functional overview, as well as usability and operating conditions of our system, which assist in the system design and the implementation stages for future references. Details about the prototype ATS that we will be developing will be explained throughout the document.

[1] Taken from The Global Snooker Center. http://website.lineone.net/~janiew/history_001c.htm 2000
[2] Taken from The Snooker Sponsorship Company. http://www.snookersponsorship.com/corporate.htm 2000.

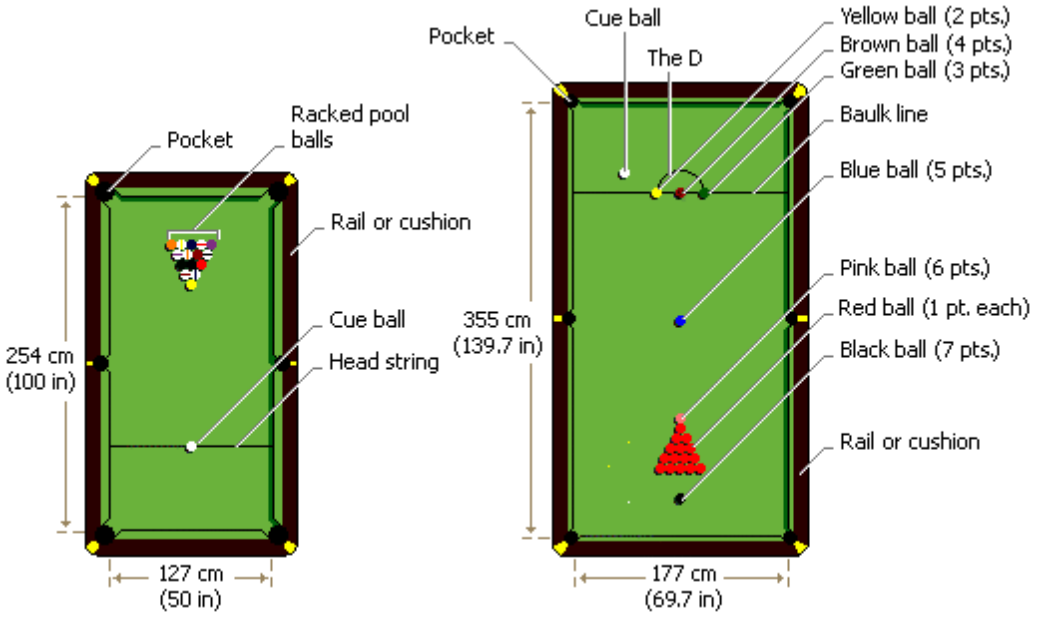
2 Background on Pool and Snooker

The games of snooker and pool have the same origin. In this section, the similarities and differences between the two games are discussed.

Pool, sometimes called pocket billiards, is the most popular style of play in North America. A pool table is smaller than a snooker table (50 by 100 inch) and has six pockets. The most widely played versions are 8-ball and 9-ball. In 8-ball, the two players must hit all the balls with the distinct pattern, either solid or strip, before hitting the black ball (the "8-ball") to win the game. In the game of 9-ball, nine numbered balls are used. The cue ball must contact the lowest-numbered ball first; if it does and any ball is pocketed, the shooter gets another turn. Whoever pockets all nine balls wins. Figure 1 shows the different dimensions and the different styles of play between pool and snooker.[3]

The typical snooker table is 2 by 4 m (6 by 12 ft) and has six narrow pockets with rounded openings. Twenty-two balls are used: 15 red balls, 6 balls numbered from 2 to 7, and 1 cue ball. Players score points by pocketing reds and numbered balls alternately. When pocketed, reds remain out of play, while pocketed numbered balls are returned to the table to assigned spots. When the reds are gone, the numbered balls are pocketed in numerical order (refer to Figure 1). Points are also scored when the opponent fails to hit balls in the proper sequence.

Aside from the dimensions of the table and the goals of the different games, pool and snooker are games that test one universal skill. That is, to use the cue ball to hit the target into the pocket. This skill can be perfected using the ATS, which is described in the following section.



Pool **Snooker**

Figure 1: General Information on Pool and Snooker

[3] Taken from Microsoft Encarta. http://www.encarta.com 2000.

3 System Overview

The Ace Training System (ATS) focuses on assisting the snooker player to hit the most appropriate target ball into the best pocket depending on their location and color. The high-level flow chart is shown in Figure 2.

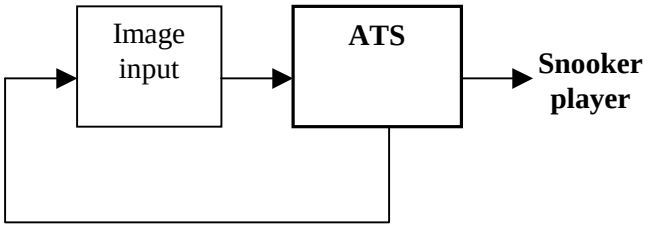


Figure 2: System Context Diagram

First, the system uses sensors to detect the location of the balls and to identify their colors. This information, along with the type of game being selected, is then processed in the ATS to determine the best target ball to hit. To guide the users to make the best possible shot, the system lights up the indicators located around the pool table, which forms an imaginary straight line between the cue ball and the intended location to hit. A more detailed system block diagram is shown in Figure 3.

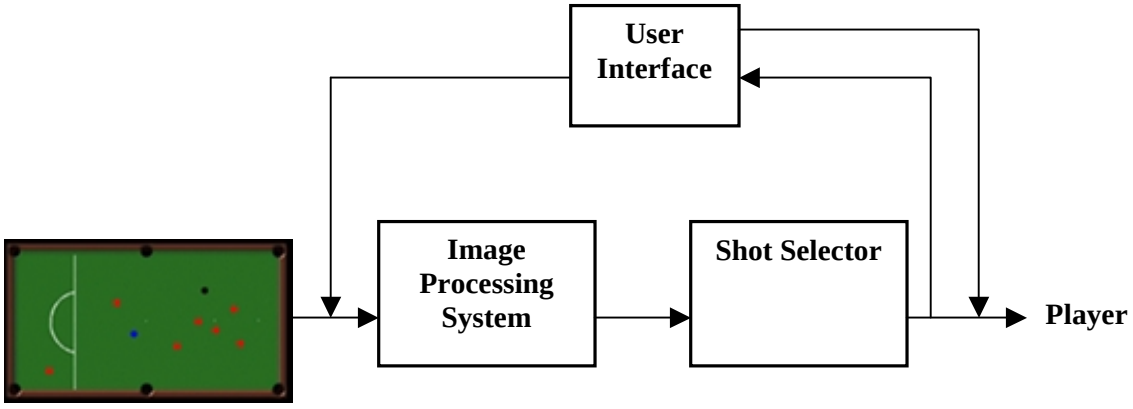


Figure 3: System Block Diagram

The subsystems will be discussed in the following sections.

4 Image Processing System

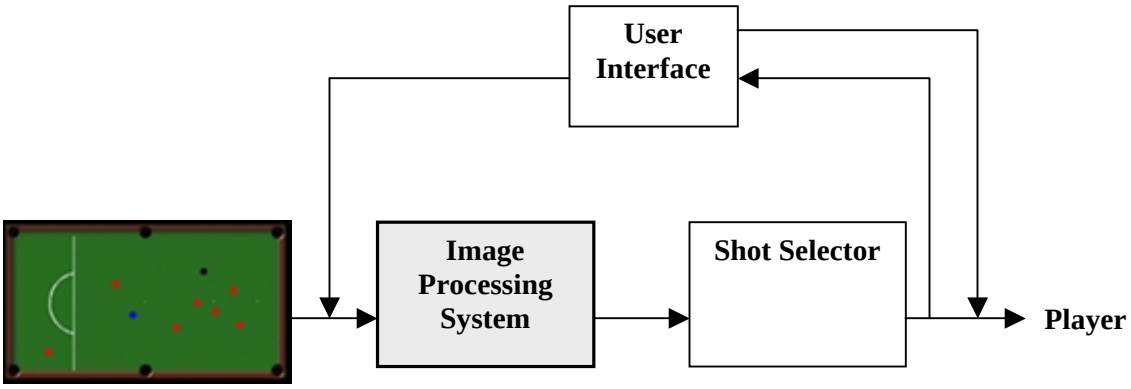


Figure 4: Image Processing System Context Diagram

The Image Processing System (IPS) shall take an image of the snooker table, and output the location and the color of the balls to the Shot Selector. It also handles the input from the user. Figure 4 shows the relationship between the IPS and the remainder of the system.

The IPS can further be broken down into two functions: Image Acquisition and Image Decoder. The two functions are shown in Figure 5.

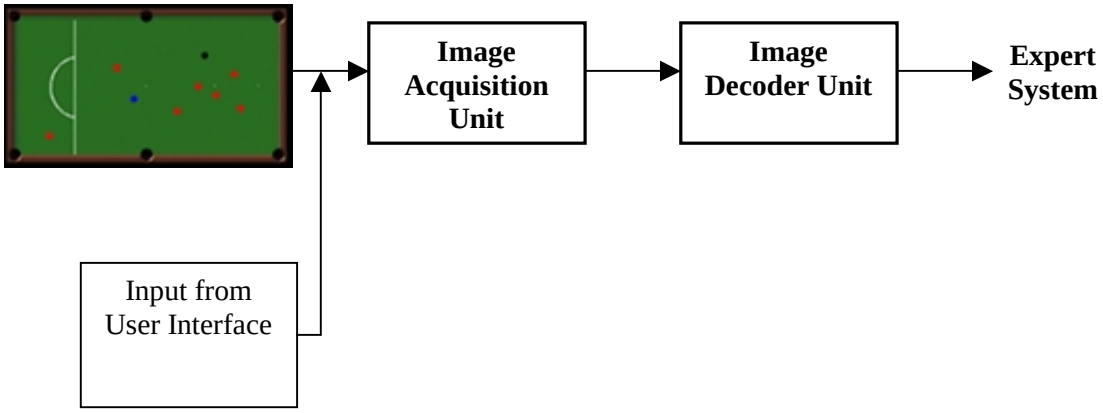


Figure 5: Image Processing System Function Block Diagram

4.1 Image Acquisition

Signals are acquired by the Image Acquisition system. Figure 6 shows the block diagram of this system below.

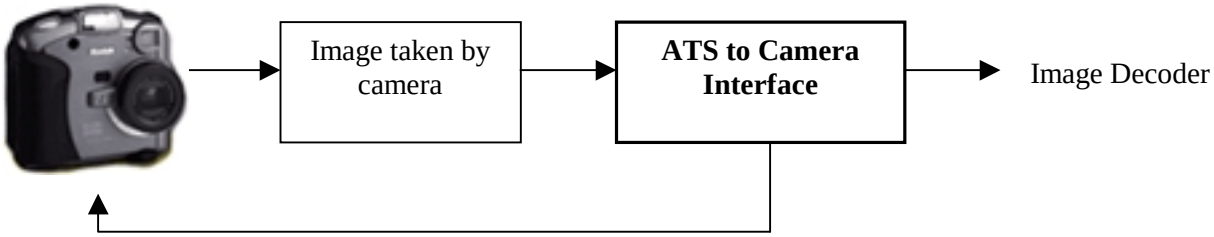


Figure 6: Image Acquisition Block Diagram

The Ace Training System (ATS) is connected to a digital camera. Through the ATS-Camera interface, the camera can be controlled to capture images of the snooker table and to send images back to the interface. These image signals are then passed on to the Image Decoder for further processing.

The image taken is in an uncompressed format, .TIFF, to ease the image processing process. This uncompressed format is larger in size than other compressed format. However, using the fastest available connection, Universal Serial Bus (USB), and a software driver controlling the operation of the camera, this is not a significant problem.

In this prototype Ace Training System, the size of the image is 720 x 480 pixels. The resolution has to be increased to 1440 x 960 pixels, 2240 x 1500 pixels, or 1792 x 1200 pixels when a full size Ace Training System is implemented.

4.2 Image Decoder Unit

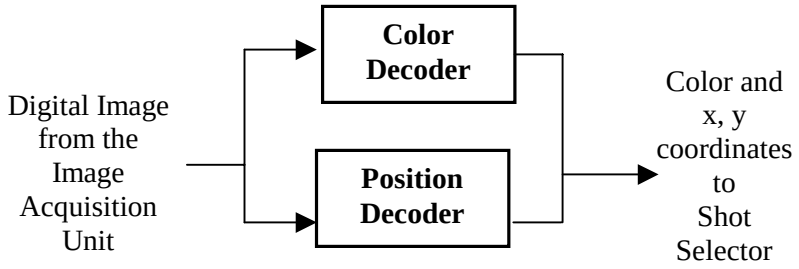


Figure 7: Image Decoder Function Block Diagram

The Image Decoder Unit shall process the output from Image Acquisition Unit, and shall output the colors and positions of the balls to the Shot Selector, as shown in Figure 7. The Decoder Unit can be further broken down to two functions, one to detect color, and the other to detect position. These two functions are implemented in software, using various image processing algorithms.

4.2.1 Position Decoder

The Position Decoder shall process the digital image, and output the corresponding positions of the balls. The decoder can do this by first scanning through 720 x 480 pixels image, then outlining the difference of the colors between the balls and the table. The positions of the balls can be found by determining the center points of the color differences, with reference to the index point located on the side of the table. The outputs of this function are x- and y-coordinates, with respect to reference point, for the specific colored ball.

4.2.2 Color Decoder

The Color Decoder shall process the digital image, and output the corresponding colors of the balls. Integrated closely with the Position Decoder, the outlines of the balls were distinguished by comparing the color differences between the balls and the table. By allowing a range of a specific color that may result from shades and reflections, the color of the balls can be determined. The outputs of this function are the colors of the specific ball.

5 Shot Selector

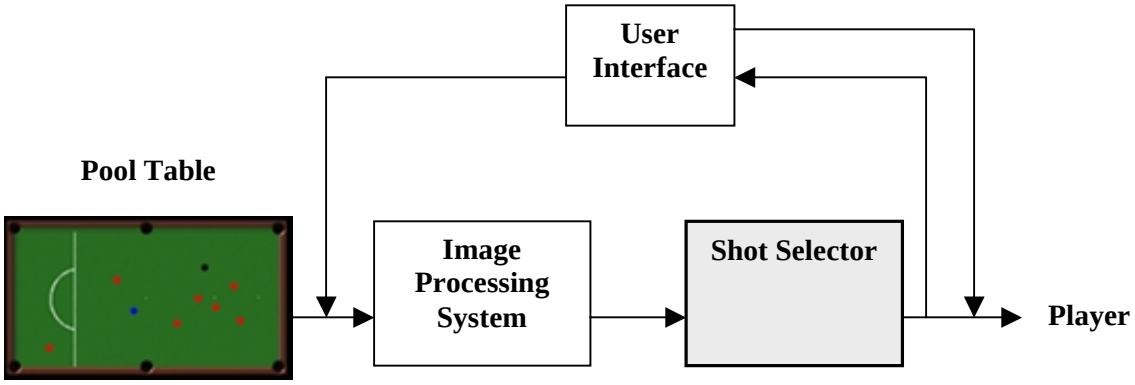


Figure 8: Shot Selector Context Diagram

After the user chooses which ball he or she wants to hit, the Shot Selector shall process the data from the Image Processing System, and output the most appropriate shot to the user interface. In other words, the Shot Selector will decide the highest percentage shot available for the chosen ball. Of course, the Selector will advise the user if the chosen ball is an invalid one, or if no possible shot is available. Figure 8 shows the relationship between the Shot Selector and the remainder of the system.

With the ATS prototype, there will be three balls on the table- white, black, and red. The following explanation will be based on this prototype setup.

Three functions constitute the Shot Selector. These functions are: Best Shot Evaluator, Shots Calculation, and Shot History. They are outlined in Figure 9 and described in the following subsections.

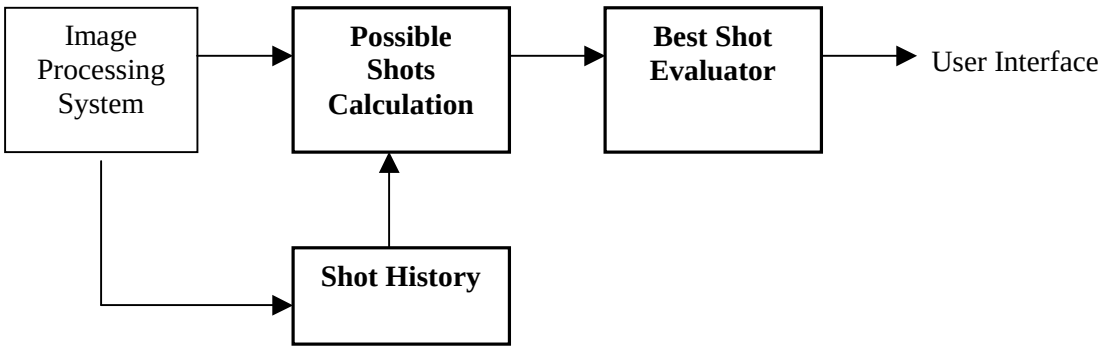


Figure 9: Shot Selector Function Block Diagram

5.1 Shot History

In snooker, the player must first attempt to hit the red ball into the pocket, followed by a different-colored ball (See Background on Pool and Snooker on page 6). In cases where no red balls have been pocketed, the player must continue to attempt for the red ball.

The Shot History Function initially set the target ball to the red ball during system start up. It processes the outputs from the IPS, which are the positions and colors of the balls, and determines if any red balls have been pocketed. The output of the function is either red ball or other colored ball.

5.2 Shots Calculation

By processing the data outputs from Shot History function and the IPS, the Shots Calculation function determines all the shot vectors that are possible. After the user inputs the ball to hit, this function will check whether the ball is a valid one to hit. If it is, then the function will calculate the best possible shot for the ball for each of the six pockets. It shall also take considerations into bank shots, which allows the player to bank off the side to make a shot. At the initial prototype stage, the ATS will concentrate mainly on straight shots and bank shots. Other types of shots can be added later on.

5.3 Best Shot Evaluator

The purpose of the Best Shot Evaluator function is to find the best path to pocket the target ball by analyzing all the possible shot vectors that had been calculated from the Shots Calculation function. Paths that have minimum number of banks off the table and minimum distance between the cue ball and the target ball are preferred, to allow the user to make high precision shots.

In cases when the target ball cannot be pocketed, the function shall also determine a safety shot.

After the analysis of the vectors, a single path of the best possible shot will output to the User Interface.

6 User Interface

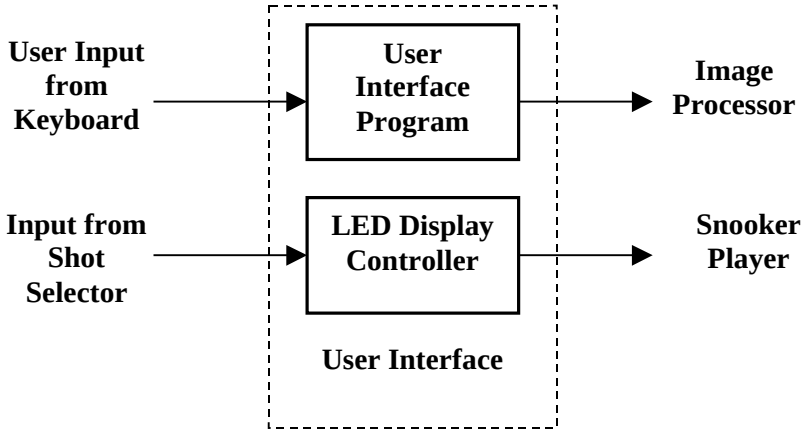


Figure 10: User Interface Block Diagram

The user interface interacts with the user in two different scenarios. If the next shot is a red ball, the Shot Selector will choose the best red ball to play. Through the user interface, the shot indicator then displays the proper direction the player should aim.

If the next shot is one of the other color balls (yellow, green, brown, blue, pink, or black), the user can input which ball he or she wants to hit. The Shot Selector will receive the input and perform the necessary calculations and analysis. Of course, the prototype ATS will only have two balls to choose from, but nevertheless the interface will be demonstrated as easy to use and simple to understand.

6.1 LED Display Controller

A string of LEDs encircling the billiard table will indicate the direction of the best shot. The player should hit the ball in the direction of the illuminated LED in order to pocket the desire target ball. The LED Display Controller will receive from the Shot Selector the details of the recommended shot. Then the controller will calculate which LED to turn on, and subsequently send a signal to turn it on. The LED Display Controller will most likely be in a form of a multiplexor being controlled by a microcontroller.

While the LED display is not as elegant as, say, using a movable laser pointer to display the best shot, it is nonetheless suitable for our prototype purposes.

6.2 User Interface Program

The UI program is a user-friendly program that provides to the user a visual interaction with the ATS. Using the UI program, the user can enter the desired target ball and then receive information related to the recommended shot, such as strength of shot. As well, warnings will be provided to the user to ensure that he or she stays within the rules of snooker.

7 Testing

A large part of the ATS consists of its various software subsystems, that is, the image processing system, the expert system, and the camera interface. Each of these modules will be tested individually using test drivers. Extra attention will be paid to ensure minimum cohesion between the modules, so that they can be tested independently. After each module has been integrated with the main module, the ATS will undergo integration testing to ensure proper data communication between the subsystems. Finally, system testing and stress testing will then be conducted to test the overall performance of the ATS.

The hardware portion of the ATS includes the shot indicator, which will most likely be controlled by a microcontroller. The method of testing followed will be the same as with the software subsystems. The subsystems will be individually tested before integrating with the main module. At that time integration testing will be conducted. Then, just like the software subsystems, the hardware module will be involved with system and stress testing. Figure 11 illustrates the different test phases of the ATS.

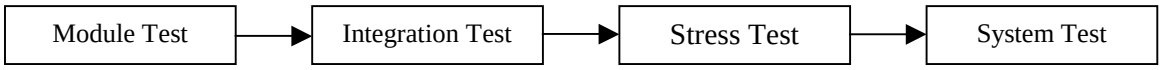


Figure 11: Test Phase of the ATS

7.1 Module Testing

7.1.1 Image Processing System Testing

The image processing system will be tested to verify the functionality of the following:

- Camera – ensure to be centered on top of the snooker table, successfully capture and send images to the image decoder, test its response, and verify the camera can restart its software.
- Position Decoder – successfully extract the ball objects from the received images by comparing the color differences, determine the object position, and verify the decoder can restart its software.
- Color Decoder – verify the colors extracted from each balls in the images, and verify the decoder can restart its software.
- Serial Communication – verify appropriate response to each dummy transmitted command generated by a test driver.

7.1.2 Shot Selector System Testing

The shot selector system will be tested to verify the functionality of the following.

- Shot History – ensure to output the proper colored ball to be hit, and verify the software can restart.

- Shot Calculation – ensure all output shot vectors are accurate to make the possible shots, test additional shot vectors of one-bank shots, test the total time response of the calculation, and verify the software can restart.
- Best Shot Evaluator – verify the output shot is the best possible shot and the easiest to make, ensure the output shot of the evaluator can be sent to the user interface, test the total time response of the evaluation, and verify the software can restart.

7.1.3 User Interface Testing

The user interface will be tested to verify the functionality of the following:

- GUI Interface – verify clarity and usability, and test if the software can restart successfully.
- Possible Shot Vectors – ensure the vectors shown correspond to the output of the Shot Selector System.

7.1.4 LED Interface Testing

The LED interface will be only tested on the serial communication such that appropriate LEDs turn on according to each dummy transmitted command from a test driver.

7.2 Integration Testing

The integration testing ensures the data communication between the modules after the modules are integrated. The functionality of each module aforementioned will be tested to guarantee successful integration of the system.

7.3 Stress Testing

The stress testing will be conducted to test the overall performance of the ATS system. Different ball setup scenarios (i.e. different color balls and ball positions) will be carried out to ensure appropriate shot calculation and best possible shot vectors are indicated onto the user interface, and the corresponding LEDs will turn on.

7.4 System Testing

The system testing will be tested in the same methods as completed in the stress testing.

8 System Requirements

Our virtual snooker coach system consists of the following major components: a computer, a pool table, a camera, an array of LEDs, a matrix of multiplexors, and possibly an HC11 evaluation board to control the multiplexors.

In order to provide high resolution, we are going to need LEDs of around 5mm in diameter. The purpose of the evaluation board is to act as a control unit to tell a specific LED to light up. In addition, for our ATS program to run at a reasonable speed, the minimum requirement for the computer is a Pentium 90. Table 1 illustrates the physical requirements of some of these components. Table 2 and Table 3 describe the environmental and electrical requirements for the computer, the camera and the LEDs. Some of these requirements may change in the future if we are going to put our ATS in an embedded system.

8.1 Physical Requirements

	Computer	Pool Table	Camera	LED
Height	70cm	1.2m	10.6cm	0.8cm
Length	50cm	4m	5.7cm	0.5cm diameter
Width	30cm	2m	11.8cm	0.5cm diameter
Weight	15lb	300lb	430g without batteries	5g

Table 1: ATS System Physical Requirements

8.2 Environmental Requirements

	Computer	Camera	LED
Operating Temperature	25°C ± 20°C	25°C ± 20°C	-80 °C to +204°C
Shipping Temperature	25°C ± 20°C	25°C ± 20°C	-80 °C to +204°C
Heat Dissipation	Minimal	Minimal	Minimal
Humidity	Full Range of ATM humidity	Full Range of ATM humidity	Full Range of ATM humidity

Table 2: ATS System Environmental Requirements

8.3 Electrical Requirements

	Computer	Camera	LED
Voltage	AC 110V 60Hz	DC 6V	5V maximum
Power	250W-300W	4AA batteries	

Table 3: ATS System Electrical Requirements

8.4 Safety Requirements

8.4.1 Enclosure

The components will not have sharp edges, corners or points that would pose a danger to the user. The camera will be mounted sturdily to prevent any injuries caused by falling off of the lamp.

8.4.2 Electrical Isolation

The computer is electrically isolated by the case so that there will be no electrical shock.

8.4.3 Emission

The components must not emit any form harmful electric discharge.

8.5 Reliability Requirements

The virtual snooker coach system will meet the following reliability requirements:

8.5.1 Accuracy

The expert system will provide high accuracy in calculation of the ball angles. Our user interface displayed on the monitor will clearly indicate the position of where the ball should be hit. However, when the target ball is near the corners of the table, the location of the indicators on the table must have much higher resolution comparing to the other area. This is because when the ball is near the corner, the indicators should line up as an arc to display the exact angle to hit. Since the table does not have round corners, thus the difference between the arc distance and the corner of the table introduce an error. The case where maximum error is illustrated in Figure 12.

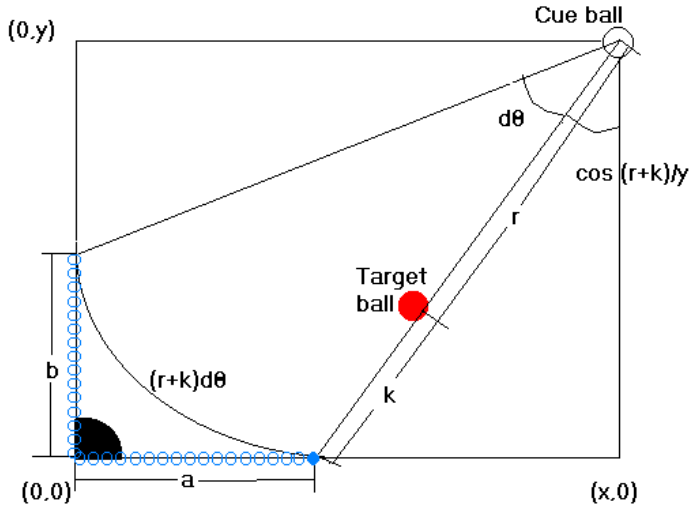


Figure 12: Accuracy of the ATS

Two equations can be derived from the figure above.

$$(r + k)^2 = y^2 + (x - a)^2 \quad (1),$$

$$(y - b) = (r+k) \tan (90\text{-}\cos((r+k)/y) - d\theta) \quad (2).$$

The error introduced due to the corner will be:

$$[(a+b) - (r+k)d\theta]/ (a+b) \quad (3).$$

The maximum error will occur when x and y are the dimensions of the pool table. Assuming the player's aiming error $d\theta$ is 5° off and solving for a and b using equations 1 and 2, the maximum error introduced due to the corner will be 5%.

8.5.2 Durability

Our system is highly durable as long as the external components: the camera, pool table and computer are functioning properly, and this depends on the components that are owned by the user.

9 Standards

The ATS system will comply with American National Standards Institute (ANSI), Canadian Standards Association (CSA), and International Organization for Standardization (ISO).

10 Training

Training is minimal because the system requires only limited inputs. The user interface is self-explanatory. A simple manual will come with the end product.

11 Potential System Limitations

This section will be dedicated to explaining the limitation of the ATS prototype that we will be building. There are a few limitations that the prototype ATS has in relation to the "final version" of the ATS.

- The best shot calculated by our expert system may not be the ball that the user would like to hit.
- When the cue ball is snookered, the ATS will teach the player to hit a safety shot rather than to pocket the ball.
- During a cut shot, the white ball might be potted as well. The player will learn to avoid this situation through practice and his or her own discretion, since the ATS cannot control the strength of the shot itself.
- Since they are illegal in snooker, jump shots will not be considered.
- Although it is a skill that is essential for a professional snooker player, angled shots will be beyond the scope of the ATS prototype.

- There is a limitation on the accuracy in the recommended shot. Due to the possible round off errors by the Shot Selector subsystem and the CPU itself, there may be small inaccuracies. As well, the resolution of the image taken by the camera will be another source of inaccuracy. But those mistakes should be quite minor.

- In addition, the accuracy of the recommended shot will be affected by the width of the LEDs, and the distance between LEDs.

12 Conclusion

Pool Shark Technologies is dedicated to implementing the latest technology to enhance the age-old game of snooker and pool. Our current project, the Ace Training System, is expected to generate enormous interest to millions of pool enthusiasts around the globe. By guiding the users to make the best appropriate shot, learning to play pool is very easy.

The system overview of our design describes how the Ace Training System works. We further broke down into each component of the subsystem. The operating requirement is also identified in this functional specification. These features and requirements will be carried through into our design and implementation stage of the product.

Appendix A: Snooker glossary

angled shot: When the corner of a pocket prevents a player shooting the cue ball directly at an object ball.

bed of table: The flat, cloth-covered surface of the table within the cushions; the playing area exclusive of the cushions.

cut shot: A shot that requires the cue ball to drive the object ball other than straight ahead.

cushion: The cloth-covered rubber which borders the inside of the rails on carom and pocket billiard tables; together the cushions form the outer perimeter of the basic playing surface.

jump shot: A shot in which the cue ball or object ball is caused to rise off the bed of the table.

safety: Defensive positioning of the balls so as to minimize the opponent's chances to score. Player's turn ends after a safety play.

snookered: The condition of incoming player's cue ball position when he cannot shoot in a straight line and contact all portions of an on ball directly facing the cue ball (because of balls not "on" that block the path.