McMaster University

SmartServe

Software & Mechatronics Capstone

Requirements Document

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Last compiled on March 5, 2018

Contents

List of Figures

Date	Revision	Comments	Author(s)
10/06/2017	0	Made Template, added sections and comments	Christopher McDonald
10/13/2017	1	Added Overview and reviewed	Christopher McDonald & Sharon Platkin
10/13/2017	2	Reviewed and Corrected Project Drivers section	Nisarg Patel
10/20/2017	3	Functional Requirements	Christopher McDonald & Sharon Platkin
11/05/2017	4	Final Revision and Review	Nisarg Patel & Christopher McDonald

Figure 1: Revision History

1 Introduction

1.1 Project Overview

SmartServe is an autonomous table tennis training system for table tennis players with various skill levels. SmartServe aids in diagnosing and improving a player's performance over time. The system trains table tennis players by shooting table tennis balls towards the player and detects successful returns from the player. The system can further adapt to the player's weaknesses and help them overcome it through further training. Importantly, SmartServe alleviates the problems of finding and working with a coach for players, as well as coaches trying to train multiple players simultaneously. The system will be deemed a success if the table tennis players and coaches can enjoy and see value in using SmartServe.

The project started at the beginning of the Fall 2017 academic term and will conclude at the end of the Winter 2018 term. In addition, the core project team consists of final year Software and Mechatronics Engineering students who are enrolled in the MECHTRON 4TB6/SFWRENG 4G06 capstone project course.

1.2 Naming Conventions and Terminology

The following terms and definitions will be used throughout this document:

- **System**: encompasses both the hardware and software parts of SmartServe
- **Shooting Mechanism**: refers to the part of the system that shoots the table tennis balls towards the user side (player)
- **Team**: all team members of the core capstone project, as noted in the list of Authors
- **User Side**: the side of the table where the user (player) is standing
- **System Side**: the side of the table where the electromechanical system is placed; it is the opposite side of the User Side
- **ACID**: a database transaction which is atomic, consistent, isolated and durable
- **FPS**: frames per second
- **GUI**: graphical user interface
- **Pitch**: rotation along the y-axis; this rotation angle primarily dictates the range of the ball from the net to the edge of the table on the user side
- **Yaw**: rotation along the z-axis; this rotation angle primarily dictates the panning functionality of the shooting mechanism from the right side to the left side of the table

- **Roll**: rotation along the x-axis

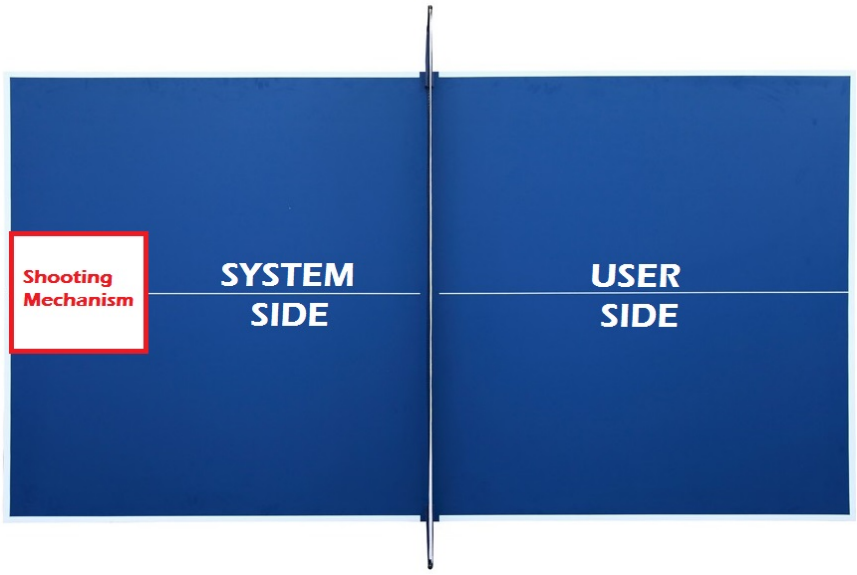

Figure 2: Top View of the Tennis Table

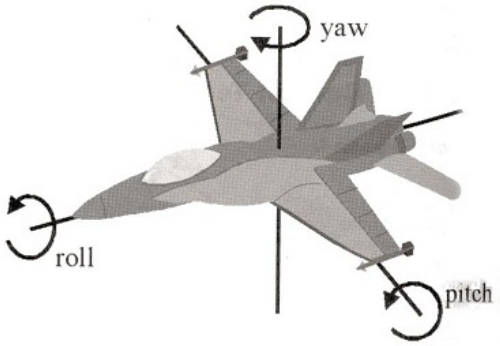

Figure 3: Pitch, Yaw and Roll Illustration

1.3 Relevant Facts & Assumptions

According to the International Table Tennis Federation (ITTF), the regulation table size is as follows: 2.74m long, 1.525m wide and 0.76m high off the ground. The table must be a uniformly dark colour with a 2cm-thick white line along the edge of the table, as well one running parallel to the 2.74m side in the middle of the table. The net in the middle

of the table must be 15.25cm vertically high from the table [1]. A 3D representation of the table setup is illustrate in Figure 4. The size of a regulated table tennis ball is 40mm in diameter [1]. For this project, the team will be using 40mm balls due to the ITTF regulation.

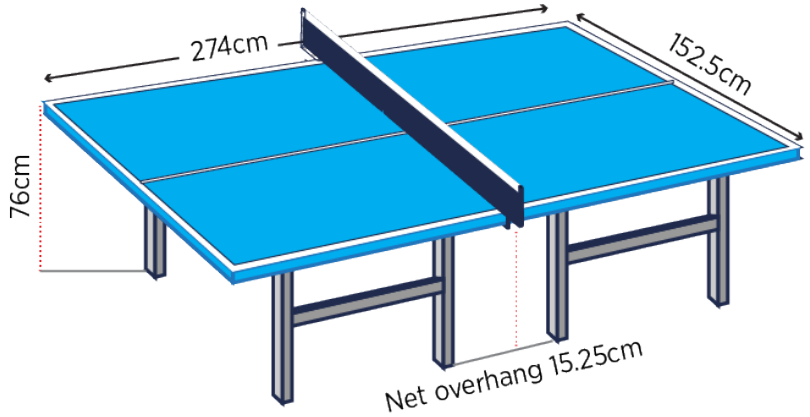

Figure 4: 3D Tennis Table with Dimensions

During gameplay, a valid serve must hit the server side first, and then bounce once on the other player's side before being returned. After that is done, a valid return would be when the ball is hit by a player, after bouncing exactly once on their side, and bounces at least one time on the opposing player's side. If a serve touches the net and lands on the opposing player's side, it is a *let*. No points are allocated and the turn must be re-served. These rules change during *Double's Gameplay* but will not be considered for this project as only one user will be supported during operation.

2 Project Drivers

2.1 Purpose

When a player wants to improve their table tennis game, a typical solution is to hire a coach. However, this does not come without its challenges. Some of these challenges include scheduling, focusing on particular shots and receiving in-depth statistical feedback. Our proposed solution will consist of a shooting mechanism, a way to identify successful returns and a system to recommend different shots. Throughout the training session, the system will provide the user with crucial feedback on the quality of their game. The system will consist of a electromechanical system to shoot the ball and a computer vision system to track the ball's location during flight. A server will also be added to store data, provide diagnostics and recommend shots given the user's past performance.

2.2 Key Stakeholders

2.2.1 Client

The client for this project comprises of the core development team as both the idea and the project execution will be undertaken by the team. It is also important to note that the project adviser, Dr. Alan Wassyng, as well as his teaching assistants will be involved in the project execution in order to provide guidance and critical feedback to the project team.

2.2.2 Users

The primary users of this project are table tennis players. Our proposed system will adapt to various playing styles and levels, and hence segmenting those players down further is not required at this stage. These users are more likely to play competitively, but could also play recreationally with friends or within a club focused around the sport.

The secondary users of this project are table tennis coaches. Although this system could replace a coach, a coach could find value in using this system to aid in training and assisting multiple players at one time. The system will provide analytics on players performance that can be very useful when training someone over a long period of time.

2.2.3 Faculty

The Department of Computing and Software at McMaster University is also a key stakeholder for this project. The development team are students of this department and would thus represent it through the work they perform. This project is also the amalgamation of the knowledge attained by the team over their undergraduate degrees. If the project is unsuccessful, the department loses the opportunity to showcase it for future students and donors.

3 Project Scope

3.1 The Scope of the Work and the Product

In order to make the project feasible within the time constraint imposed on the team, it will need to be scoped accordingly. One way we are scoping the project is by limiting the types of shots the system can take. A return by the system would first contact the table on the *User side* where a serve would first contact the table on the *System side*. We are limiting the system to only preform returns. The system will make no attempt at returning any shots from the user.

After the user has returned a shot from the system, the system will not make any attempts to return a shot that is likely to be returned given the user's returns. This is to give the system the ability to focus on a particular type of shot the user is the least proficient at returning. The characteristics of the shot following any return will be determined by the system's mode and the proficiency of the player if available.

3.1.1 Individual Product Use Cases

The actors which will be interacting with the system are the **trainee**, the **coach** and the **system administrator**. It is not necessary for a coach to be present, but they will have the ability to use the system alongside the trainee. See Figure 5 for the use case diagram. The following list contains all primary use cases:

- A trainee enters their login information
- If the login information is correct, a trainee opens their training session on the system
- A trainee begins the training session
- A trainee selects a training mode
- A trainee pauses the training session
- When the system is paused, a trainee ends the training session
- A trainee inspects their performance

The following are secondary use cases:

- A coach inspects trainee's performance
- A coach adjusts training parameters during training session
- A system administrator calibrates the system for new tables of a non-regulation size

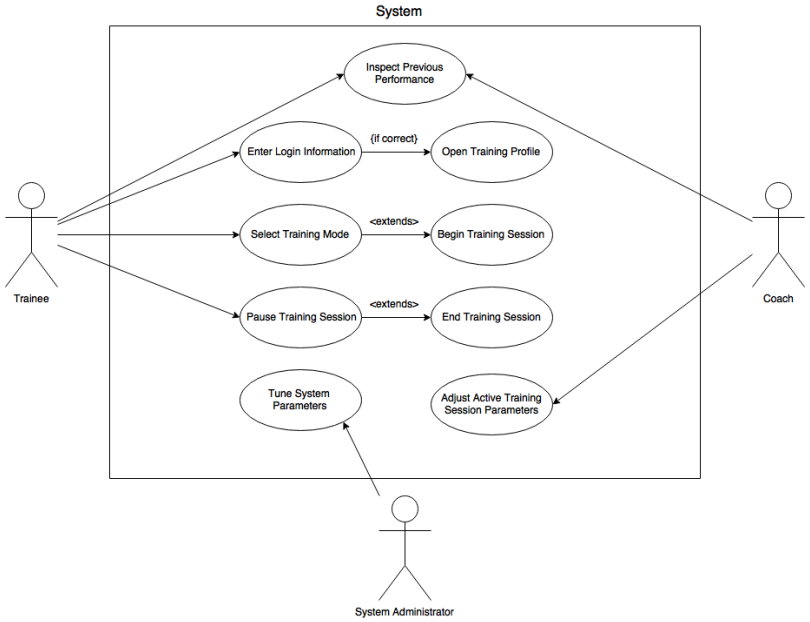

Figure 5: Use Case Diagram

3.2 Mandated Constraints

The first constraint placed on the project is time. The deliverable and presentation dates have been set, concluding with the presentations booked for April 27, 2018. Therefore, the team must successfully submit all of the deliverables and complete the project by April 27th, 2018. Additionally, a budget constraint of $750 on the Bill of Materials (BOM) for the final product is also enforced.

3.3 Undesired Behaviour

The shooting mechanism should not start, pause or end a session without the user triggering the event. The system must also refrain from shooting the ball outside the speed and angle ranges specified. Furthermore, the system should not attempt to shoot balls when it runs out of balls.

3.4 Variables

Variable Name	Type	Value	Description
Table Length	Final	274cm	The longest edge of the table tennis table
Table Width	Final	152.5cm	Perpendicular to the *Table Length*
Ball Diameter	Final	40mm	Diameter of the ball used by the system
Ball Location	Monitored	X, Y and Z cm	Relative to the center of the table on its surface
Shooting Mechanism Position	Monitored	α_p and α_y degrees	Pitch and Yaw of the shooting mechanism
User Performance	Monitored	λ_1, λ_2, ... λ_n	Return rates for n different shots from the user

Figure 6: List of Variables

3.5 Context Diagram

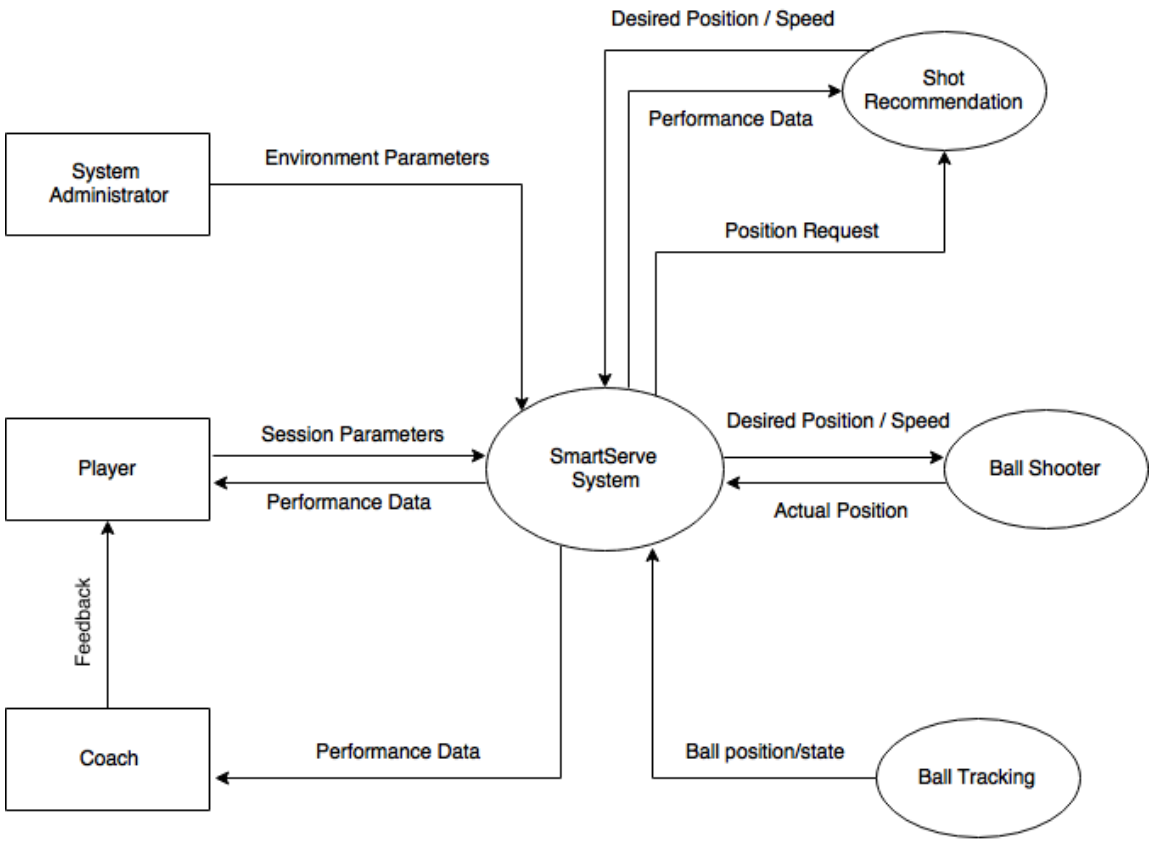

Figure 7: Context Diagram

4 Functional Decomposition Diagram

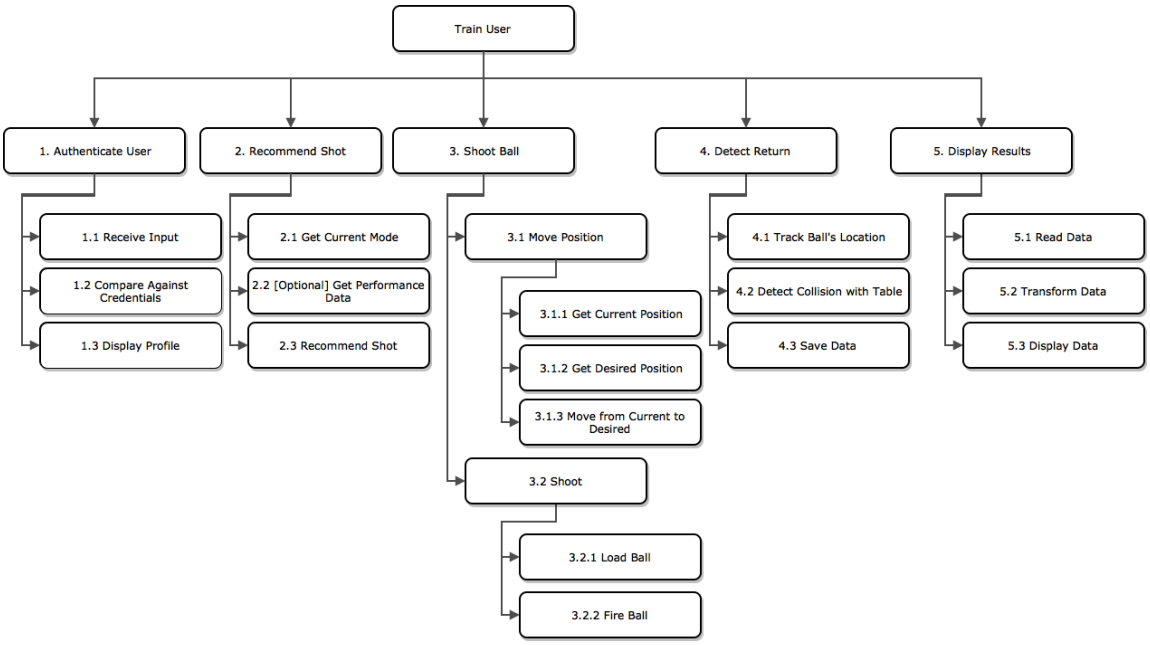

Figure 8: Functional Decomposition Diagram

5 Functional Requirements

Requirement ID: F1 **Requirement Type**: F

Description: The shooting mechanism shoots the table tennis ball towards the user side at various locations
Rationale: Provides variability in the shots made towards the user
Fit Criterion: The shooting mechanism can hit a specified section of a 4x4 grid with an accuracy of 75%, an example of this grid can be found in Figure 10

Originator: Sharon Platkin

Priority: High
History: Created Oct. 20, 2017

Requirement ID: F2 **Requirement Type**: F

Description: The shooting mechanism shoots the table tennis ball towards the user side at various speeds
Rationale: Provides variability in the shots made towards the user
Fit Criterion: Since the fastest recorded speed of a table tennis ball is 31.25 m/s, the system should be able to match at least half this speed [2]. Specifically, the shooting mechanism must shoot at speeds ranging from 10 to 15 m/s at discrete increments of 0.5 within 0.1 m/s of error

Originator: Sharon Platkin

Priority: High
History: Created Oct. 20, 2017

Requirement ID: F3 **Requirement Type**: F

Description: The shooting mechanism shoots the table tennis ball towards the user side at various degrees of Yaw
Rationale: Provides variability in the shots made towards the user
Fit Criterion: The shooting mechanism can shoot the ball at -30 to 30 degrees relative to the longest bisection of the table at discrete increments of 1 degree to have complete coverage of the User Side, see Figure 9 for calculations

Originator: Sharon Platkin

Priority: High
History: Created Oct. 20, 2017

Requirement ID: F4 **Requirement Type**: F

Description: The shooting mechanism shoots the table tennis ball towards the user side of the table with various degrees of roll
Rationale: Provides variability in the shots made towards the user
Fit Criterion: The shooting mechanism can spin the ball at 0 to 360 degrees in discrete increments of 45 degrees on the longitudinal axis with 5 degrees of error

Originator: Sharon Platkin

Priority: High
History: Created Oct. 20, 2017

Requirement ID: F5 **Requirement Type**: F

Description: The system can detect a successful return by the user
Rationale: Allows quantitative information to be collected on the user's performance
Fit Criterion: The system must detect 90% of all successful returns made by the user

Originator: Sharon Platkin

Priority: High
History: Created Oct. 20, 2017

Requirement ID: F6 **Requirement Type**: F

Description: The system saves the details for each shot taken by the shooting mechanism
Rationale: Serves the purpose of saving the state and resuming sessions over time
Fit Criterion: After each shot is returned, an ACID save transaction is performed

Originator: Christopher McDonald

Priority: Medium
History: Created Oct. 20, 2017

Requirement ID: F7 **Requirement Type**: F

Description: The system can load a previously saved state
Rationale: This will allow the user to continue a training session at different times, even if the system is powered down
Fit Criterion:

Originator: Christopher McDonald

Priority: Medium
History: Created Oct. 20, 2017

Requirement ID: F8 **Requirement Type**: F

Description: The system allows the creation of a new user
Rationale: This allows many users to use one system
Fit Criterion: A user must be able to be created only if the user does not already exist in the system

Originator: Christopher McDonald

Priority: Medium
History: Created Oct. 20, 2017

Requirement ID: F9 **Requirement Type**: F

Description: The system must authenticate users
Rationale: This will ensure a user can access their profile and restrict other users from accessing their profile
Fit Criterion: No user can access another user's profile and will have access to their own 99% of the time

Originator: Christopher McDonald

Priority: High
History: Created Oct. 20, 2017

Requirement ID: F10 **Requirement Type**: F

Description: The system can pause the shooting mechanism
Rationale: A user may need to attend other matters during training or get real-time feedback from the system
Fit Criterion: After instantiating the pause process, the system shoots at most 1

more ball(s)

Originator: Christopher McDonald

Priority: High
History: Created Oct. 20, 2017

Requirement ID: F11 **Requirement Type**: F

Description: The system can end the training session
Rationale: This will be used when a user is done training
Fit Criterion: N/A

Originator: Christopher McDonald

Priority: High
History: Created Oct. 20, 2017

Requirement ID: F12 **Requirement Type**: F

Description: The system can resume a training session from a paused state
Rationale: N/A
Fit Criterion: N/A

Originator: Christopher McDonald

Priority: High
History: Created Oct. 20, 2017

Requirement ID: F13 **Requirement Type**: F

Description: The system can display the user's performance over a custom time range
Rationale: This will aid the user in diagnosing their ability to play table tennis
Fit Criterion: N/A

Originator: Christopher McDonald

Priority: High
History: Created Oct. 20, 2017

Requirement ID: F14 **Requirement Type**: F

Description: The system has a **training** mode
Rationale: This mode will focus on playing to the user's weaknesses more so than others
Fit Criterion: After 100 pseudo-randomly distributed shots, the system will begin to distribute the shots differently. By ordering each class of shot from the least to most returned, the first 15%, the next 35% and the last half will all receive an equal share of shots.

Originator: Christopher McDonald

Priority: High
History: Created Oct. 20, 2017

Requirement ID: F15 **Requirement Type**: F

Description: The system has a **one-shot** mode
Rationale: This mode will focus on playing to one particular class of shot, as described by the user
Fit Criterion: For all shots performed in this mode, 90% must be classified as the same as the one entered

Originator: Christopher McDonald

Priority: Medium
History: Created Oct. 20, 2017

Requirement ID: F16 **Requirement Type**: F

Description: The system allows a user to adjust training parameters during a

session which is active or paused
Rationale: A coach may want to push a player to train in a particular area
Fit Criterion:

Originator: Christopher McDonald

Priority: Low
History: Created Oct. 20, 2017

Requirement ID: F17 **Requirement Type**: F

Description: The system can be calibrated for the size of the table
Rationale: As performed by a system administrator, it should be usable for all non-regulation table sizes
Fit Criterion: The system follows all documented requirements

Originator: Christopher McDonald

Priority: High
History: Created Oct. 20, 2017

Requirement ID: F18 **Requirement Type**: F

Description: The shooting mechanism will shoot a ball once the previous has been returned to the system side or 1.5 seconds after the previous shot, whichever happens first
Rationale: This will ensure the system is reasonably fast and keeps the user engaged, as well as compensates for more experienced players.
Fit Criterion: N/A

Originator: Christopher McDonald

Priority: High
History: Created Oct. 20, 2017

6 Non-Functional Requirements

6.1 Look and Feel Requirements

Requirement ID: LF1

Description: The system will have a minimalist design that is easy to navigate through
Rationale: A minimalistic design will help with user discover all the options and settings of the system
Fit Criterion: The user must be able to navigate to any feature from the profile page in at most two steps.

Originator: Sam Hamel

Priority: Medium
History: Created Oct. 27, 2017

6.2 Usability and Humanity Requirements

Requirement ID: UH1

Description: The system must be intuitive to use
Rationale: As the system is adding onto an existing process, it should not cause strain for the user to operate
Fit Criterion: The user must be able to create a user in less than 30 seconds. The user must be able to initiate *one-shot* mode in less than 2 minutes from opening their profile.

Originator: Christopher McDonald

Priority: High
History: Created Oct. 20, 2017

Requirement ID: UH2

Description: The system will operate using the English language
Rationale: Some of the Development team only speaks English
Fit Criterion: All outputs generated by the system will be in English

Originator: Sharon Platkin

Priority: High
History: Created Oct. 27, 2017

6.3 Performance Requirements

Requirement ID: P1

Description: The response time of feedback for user input must be less than or equal to 100ms
Rationale: 100ms is the approximate maximum amount of time for the user to perceive the system as reacting instantaneously [3]. Users should feel that all inputs have been registered by the system
Fit Criterion: Any click inputs that generate feedback must do so in at most 100ms.

Originator: Sam Hamel

Priority: High
History: Created Oct. 27, 2017

Requirement ID: P2

Description: The system must include all but the previous 3 shots made toward the user
Rationale: This will keep the performance measures relatively up to date for relevant and up-to-date feedback
Fit Criterion: Any results by any return from the player must be displayed on the GUI (graphical user interface) before the player returns 3 more shots

Originator: Sam Hamel

Priority: High
History: Created Oct. 27, 2017

Requirement ID: P4

Description: The system must be able to support a total of 1000 users, consisting of players and coaches
Rationale: If the system is used by a company, they will have a large amount of users using the system
Fit Criterion: The system can store up to a thousand user profiles and their accompanying performance history data

Originator: Sam Hamel

Priority: Medium
History: Created Oct. 27, 2017

Requirement ID: P5

Description: The system will be able to support only one user playing at any given time
Rationale: The system will not be able to differentiate between player returns if they were more than one user playing at the same time
Fit Criterion: The system will work as expected for one player playing 99% of the time

Originator: Sam Hamel

Priority: High
History: Created Oct. 27, 2017

6.4 Operational and Environmental Requirements

Requirement ID: OE2

Description: The system will be functional in indoor settings with bright florescent lighting in the room
Originator: Sam Hamel

Priority: High
History: Created Oct. 27, 2017

6.5 Maintainability and Support Requirements

Requirement ID: MS2

Description: The system should be able to add new metrics to analyze performance
Rationale: More efficient and appropriate methods may be found in order to analyze player performance
Fit Criterion: The system will be able to add new performance metrics and analysis methods so long as no changes need to be made to the hardware

Originator: Sam Hamel

Priority: High
History: Created Oct. 27, 2017

6.6 Security Requirements

Requirement ID: S1

Description: The system must hash all passwords for user profiles
Rationale: If the system is compromised, no person should be able to read user's passwords in plain text.
Fit Criterion: The system uses a hashing algorithm currently supported by NIST, the National Institute of Standards and Technology.

Originator: Christopher McDonald

Priority: High
History: Created Oct. 20, 2017

Requirement ID: S2

Description: The system must encrypt all performance data for each user
Rationale: If the system is compromised, no person should be able to exploit an opponent's weaker aspects
Fit Criterion: The system uses an encrypting algorithm currently supported by NIST, the National Institute of Standards and Technology.

Originator: Christopher McDonald

Priority: Low
History: Created Oct. 20, 2017

6.7 Political Requirements

Requirement ID: P1

Description: The system must allow full read access for coaches
Rationale: If a coach purchases this system, they should be able to analyze all players information for training purposes
Fit Criterion:

Originator: Christopher McDonald

Priority: Medium
History: Created Oct. 20, 2017

6.8 Legal & Compliance Requirements

Requirement ID: LC1

Description: The system must comply and operate for all ITTF rules and regulations
Rationale: ITTF mandates the acceptance of all table tennis equipment and the system should work with these to be used by professional players
Fit Criterion: The system must work for any 2 tables and nets which the ITTF has accepted

Originator: Christopher McDonald

Priority: High
History: Created Oct. 20, 2017

6.9 Health and Safety Requirements

Requirement ID: HS1

Description: The shooting mechanism will always hit the table at least once
Rationale: This will give the user more time and context to react to the shot
Fit Criterion: The system imposes limits for speed and pitch of the shot

Originator: Christopher McDonald

Priority: High
History: Created Oct. 20, 2017

Requirement ID: HS2

Description: The shooting mechanism will not shoot the ball faster than 22 m/s
Rationale: This is 70% of one of the world's fastest shots taken in table tennis and is unlikely to be of any practical use
Fit Criterion: The system will constrain the speed of its shooting mechanism

Originator: Christopher McDonald

Priority: High
History: Created Oct. 20, 2017

Requirement ID: HS3

Description: The system should have no exposed electronic wiring or components
Rationale: This will protect the user from electric shocks and the system from damage
Fit Criterion: Only by disassembling the system should wiring and components be exposed

Originator: Christopher McDonald

Priority: High
History: Created Oct. 28, 2017

Requirement ID: HS4

Description: The system will carry warnings around moving parts
Rationale: Moving parts can expose users to risk of pinching extremities
Fit Criterion: Warning signs are displayed at every point of risk

Originator: Christopher McDonald

Priority: High
History: Created Oct. 28, 2017

Requirement ID: HS5

Description: The system will have a button to cease all power to the system
Rationale: In the case of dangerous operation, the system must be able to be powered off manually
Fit Criterion: One button will shut down system and is labeled as such

Originator: Christopher McDonald

Priority: High
History: Created Oct. 28, 2017

7 Project Issues

7.1 Open Issues

Due to the nature of the project, all aspects of it must operate proficiently in order for it to be successful. For example, one potential issue would arise if no spin must be applied to the ball. Without detailing how the system works, the team considers this to be difficult without hardware that has no error in operation.

Some players may be able to hit the ball much faster than the solution we build to capture successful returns. For example, if some optical sensor is used it must be fast enough to

capture the ball at the point of contact, or very close to it, in order to accurately determine if it did hit the table.

Between shots of the system, it must determine where the next shot will be, get into the necessary position and shoot the ball. For some cases, the shot determination could take longer than usual or the distance between initial and final state could be far. This could jeopardize the system's ability to meet requirement F18.

7.2 Off-the-Shelf Solutions

For the second issue noted in the above section, a high speed camera could be used but would exceed the budget constraint placed on this project. For example, a GoPro HERO5 camera can film at 120fps but costs $490 [4]. Additionally, a camera which can film up to 500fps costs as much as $999.99 [5]. These would far constrain our budget, but would solve the issue should it arise. An alternative could be mat embedded with sensors, omitting all optical sensor requirements. A mat which is roughly one-quarter the size of what we would need to cover one side of table costs $119.99, which includes a wireless pager and any markup costs done by the manufacturer. A total estimate for our materials can be estimated to be $150.00.

For the third issue, faster motors could be used to make the shooting mechanism move faster. However, these also must fit in the budget and will be adjusted accordingly to do so.

7.3 New Problems

As of March 5, 2018, no new problems exist.

7.4 Risks

The largest and only risk to note is potentially going over budget. This is mainly with respect to the proficiency of the sensors and motors used as it is typically positively correlated with price.

7.5 User Documentation & Training

The user should be informed on the following items in order to use the system effectively:

- Available training modes and their purpose
- How to read performance charts and data
- Load table tennis balls into the correct location

- Ensure system is positioned correctly

8 Likely Changes

As noted in the Project Goals document, many of the anticipated changes include enhanced accuracy of some requirements. These include the following:

- F1 will be changed to a 8x8 grid and then a 16x16 grid
- Adding a **random** shooting mode
- Adding variable heights for the shooting mechanism
- Adding the ability to track the ball throughout its travel across the table

9 Appendix

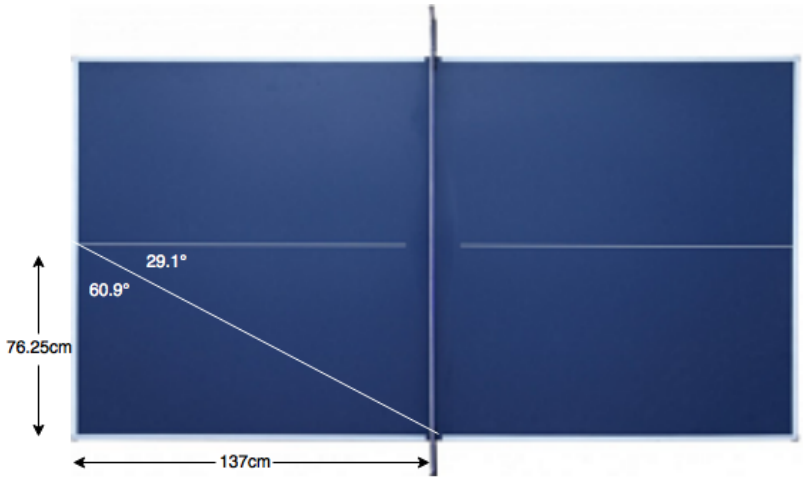

Figure 9: Valid Range of Shot Calculation

10 Appendix

10.1 Figures

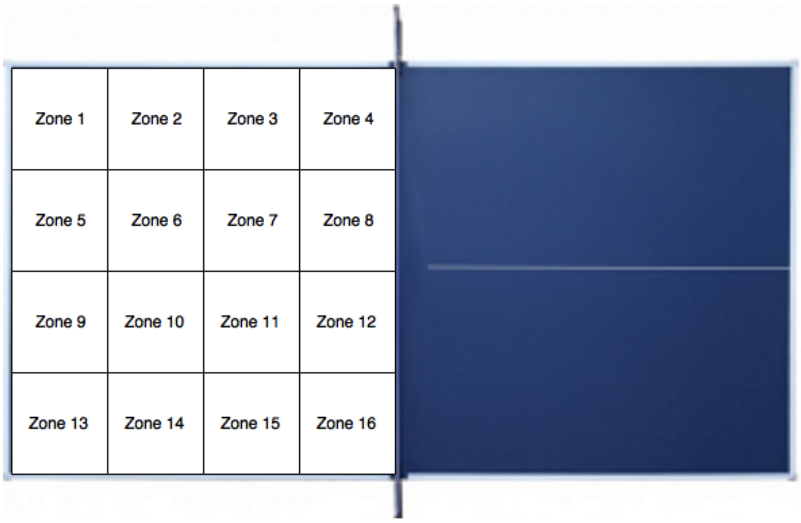

Figure 10: Table Tennis Table with 4x4 Grid Zones

11 References

[1] The International Table Tennis Federation. *ITTF Handbook*. 2017. URL: https://d3mjm6zw6cr45s.cloudfront.net/2016/12/2017_ITTF_Handbook.pdf (visited on 11/02/2017).

[2] Greg Letts. *Maximum Speed of a Ping Pong Ball*. 2016. URL: https://www.thoughtco.com/ping-pong-ball-maximum-speed-3974874 (visited on 11/02/2017).

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