Project Title

Software Requirements Specification

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Date	Revision #	Comments	Authors
DD/MM/YYYY	0	- Initial document creation	Eric Le Fort Max Moore

Table 1: Revision History

1 Introduction

1.1 Project Overview

The purpose of this project is to provide the client with an autonomous solution for a pool playing partner. The robot will utilize Visual Recognition (VR) to make its own decisions regarding its shot selection and will play the game similar to how a regular opponent will.

1.2 Product Perspective

This section will outline various interfacing requirements as well as memory constraints of the system.

1.2.1 System Interfaces

1.2.2 Hardware Interfaces

The user will have the ability to interface with the system using hardware either through buttons, sensors or any other hardware solutions. This functionality will allow the user to give the robot trivial commands relating to the status of the game.

1.2.3 Software Interfaces

1.2.4 Communications Interfaces

This system will have two inter-system communication interfaces:

1. VR to PC

   The communication between the VR and the PC will require the system to output the image takes by the VR to the PC for further computation.

2. PC to μC This method of communications defines the method of transferring information from the PC to the μC that will control the hardware.

3. μC to PC

1.2.5 Memory Constraints

The PC will not be very limited in terms of memory since it will have large memory storage. The limitations of the PC will arise from its RAM memory which may cause the computations to take time.

The μC is more heavily constrained by its memory since most uC use chip memory that is general in the order of Kilobytes.

1.3 Naming Conventions & Definitions

This section outlines the various definitions, acronyms and abbreviations that will be used throughout this document in order to familiarize the reader prior to reading.

1.3.1 Definitions

Table 2 lists the definitions used in this document. The definitions given below are specific to this document and may not be identical to definitions of these terms in common use. The purpose of this section is to assist the user in understanding the requirements for the system.

1.3.2 Acronyms & Abbreviations

Table 3 lists the acronyms and abbreviations used in this document.

Table 2: Definitions

Term	Meaning
X-axis	Distance along length of pool table
Y-axis	Distance across width of pool table
Z-axis	Height above pool table
θ	Rotational angle of robot arm end-effector
Cue	Robot arm end-effector
Direct shot	No obstacles between cue ball and target ball
Straight shot	A direct shot in which the cue ball, target ball, and target hole form a straight line
Break	This refers to the first shot at the beginning of a game of pool when the cue ball is used to strike and separate the rest of the arranged balls
Jump	In reference to a pool ball, this means that the ball loses contact with the table surface
Personal Computer (PC)	A laptop that will be used to run the more involved computational tasks such as visual recognition and the shot selection algorithm.
Camera	Some form of image capture device (e.g. a digital camera, smartphone with a camera, etc.)
Repeatability Area	Area that covers the final location of the end effector after repeating same command multiple times
End-effector	The end of the arm that will strike the cue ball.
Table State	The current positions of all the balls on the table.
Standard Shot	A shot that does not involve backspin, jumps, curving, etc. (I.e. trick shots)

Table 3: Acronyms and Abbreviations

Acronym/Abbreviation	Meaning
VR	Visual Recognition
PC	Personal Computer
μC	Micro-Controller

2 Project Drivers

2.1 The Purpose of the Project

2.2 The Clients, the Customers, and Other Stakeholders

2.2.1 The Clients

- Dr. Wassyng

2.2.2 The Customers

- Professional pool players
- Amateur pool players
- Pool hall owners

2.2.3 Other Stakeholders

- Team Members
- Pool Table Manufacturers

2.3 Users of the Product

- Control test group
- Professional pool players
- Amateur pool players
- Demonstrators

3 Project Constraints

3.1 Mandated Constraints

These are the constraints that are outside of the control of the development team:

- 750 dollars investment limit
- Must create a functional prototype
- The group will be required to complete the entirety of this project by April 2017

3.2 Other Constraints

- System will be customized for specific table
- The robot should not be required to break the balls
- The robot shall only perform standard shots
- No motion further than 2ft away from table (in the plane of the table surface)
- No motion/components further than 4ft above the table surface
- Cannot move at a dangerous speed
- The system shall adhere to the rules of pool (e.g. only moving balls by taking shots with a cue, only striking the cue ball, etc.)
- Application of chalk to the cue will be handled manually

3.3 Scope

The scope of the project includes only the components of pool that require the player to attempt and take a shot. In other words, the system will not handle freely placing a ball on the table, breaking at the beginning of the game, or automatically knowing when it should take its shot.

3.4 Relevant Facts & Assumptions

This section will outline various facts and assumptions that will be leveraged in the design of this system.

3.4.1 Facts

- Weight, size, and colour of the balls.
- Table dimensions
- Table-ball coefficient of friction
- The spring constant of the table wall.

3.4.2 Assumptions

- Table surface and walls are uniform
- Table plane is completely perpendicular to the force of gravity
- Balls are uniform in shape and density
- No interference will occur mid-shot (e.g. user moves a ball, stops a balls motion, etc.)
- Balls never jump

4 Requirements

The following section outlines the various requirements of this system. For each requirement, a description of the requirement, the rationale behind the requirement, and a fit criterion for when the requirement is satisfied are provided. The values given for customer satisfaction and dissatisfaction are from 0-5. The values for requirement priority are either high, medium or low.

Requirement types will correspond to the following table:

Requirement Type	**Description**
1	Software Capability
2	Software Communication
3	Mechanical
4	Electrical
LF	Look & Feel
UH	Usability & Humanity
P	Performance
OE	Operation & Environmental
MS	Maintainability & Support
S	Security
CP	Cultural & Political
L	Legal

Table 4: Requirement Types

4.1 Functional Requirements

The following is a collection of the functional requirements of this system:

Requirement #: 1 **Requirement Type**: 1

Description: Obtain visual data of the table.
Rationale: The system must be able to take in data to be used in the VR algorithm.
Fit Criterion: This requirement will be considered satisfied if the data obtained is of sufficient quality to be successfully used by the VR algorithm.

Originator: Eric Le Fort

Customer Satisfaction: 0 **Customer Dissatisfaction**: 0
Priority: High **Conflicts**: None
Supporting Material: None

History: Created 01-NOV-2016

Requirement #: 2 **Requirement Type**: 2

Description: Communicate image data from camera to PC.
Rationale: The system will have a separate device for image capture. It is imperative that that device can communicate its data to the PC in order to be used in the VR algorithm.
Fit Criterion: This requirement will be considered satisfied if the data received by the PC is identical to the data transmitted by the camera.

Originator: Eric Le Fort

Customer Satisfaction: 0 **Customer Dissatisfaction**: 0
Priority: High **Conflicts**: None
Supporting Material: None

History: Created 01-NOV-2016

Requirement #: 3 **Requirement Type**: 1

Description: Create model of table state in software using VR.
Rationale: The table must be modelled such that the shot selection algorithm has information to work off of.
Fit Criterion: This requirement will be considered satisfied if the modelling of each ball on the table is accurate to within 1 centimeter of their actual position.

Originator: Eric Le Fort

Customer Satisfaction: 0 **Customer Dissatisfaction**: 0
Priority: High **Conflicts**: None
Supporting Material: None

History: Created 01-NOV-2016

Requirement #: 4 **Requirement Type**: 1

Description: Select an optimal shot based off a series of simulations using the table state.
Rationale: The system must be able to come up with a shot to make given the table state.
Fit Criterion: This requirement will have various degrees of success. It will be considered satisfied on its simplest level if the system comes up with a shot that makes rational sense (i.e. analyzing the shot shows that it appears to have good probability of sinking a ball).

Originator: Eric Le Fort

Customer Satisfaction: 2 **Customer Dissatisfaction**: 4
Priority: Medium **Conflicts**: None
Supporting Material: None

History: Created 01-NOV-2016

Requirement #: 5 **Requirement Type**: 2

Description: Communicate the model of the table state from MATLAB to the system's core programming language.
Rationale: MATLAB will only be used to compute VR calculations and a more suitable language will be utilized to handle the rest of the program's functionality. Therefore, the results that MATLAB arrives at must be passed to the other language.
Fit Criterion: This requirement will be considered satisfied if the data received by the core programming language is identical to that computed in MATLAB.

Originator: Eric Le Fort

Customer Satisfaction: 0 **Customer Dissatisfaction**: 0
Priority: High **Conflicts**: None
Supporting Material: None

History: Created 01-NOV-2016

Requirement #: 6 **Requirement Type**: 1

Description: Create an instruction set for the embedded system based on the selected shot.
Rationale: Once a shot is selected, the system must then determine the necessary steps to take in order for the machine to be able to make the shot. This will include motion of all elements to position the end-effector at a suitable location from machine's current location as well as how the end-effector should strike the cue ball.
Fit Criterion: This requirement will be considered satisfied if the instruction set provided contains all necessary information and that information does in fact instruct the embedded system on how to go about making the selected shot.

Originator: Eric Le Fort

Customer Satisfaction: 0 **Customer Dissatisfaction**: 0
Priority: High **Conflicts**: None
Supporting Material: None

History: Created 01-NOV-2016

Requirement #: 7 **Requirement Type**: 2

Description: Communicate the instruction set to the μC.
Rationale: The system must be able to communicate the instruction set generated on the more computationally powerful PC to the μC in order to operate the machine.
Fit Criterion: This requirement will be considered satisfied if the data received by the μC is identical to that computed in the PC.

Originator: Eric Le Fort

Customer Satisfaction: 0 **Customer Dissatisfaction**: 0
Priority: High **Conflicts**: None
Supporting Material: None

History: Created 01-NOV-2016

Requirement #: 8 **Requirement Type**: 2

Description: Communicate a simple response back to the PC indicating the validity of the instruction set received by the μC.
Rationale: The μC should generate a response to the PC as to whether the instruction set provided is valid considering the current state of the system. This will act as a contingency if the machine was disturbed (e.g. forced out of position by the user) by alerting the PC that its assumption of the machine's location was wrong.
Fit Criterion: This requirement will be considered satisfied if the response received is identical to the response sent and if the response is correct given the current state of the system.

Originator: Eric Le Fort

Customer Satisfaction: 0 **Customer Dissatisfaction**: 2
Priority: Low **Conflicts**: None
Supporting Material: None

History: Created 01-NOV-2016

Requirement #: 9 **Requirement Type**: 1

Description: The μC must be able to interpret the instruction set to real-world controls.
Rationale: The instruction set will be in more abstract terms. The embedded system must encode these instructions to the equivalent electrical signals.
Fit Criterion: This requirement will be considered satisfied if the control signals generated from the instruction set are correct.

Originator: Eric Le Fort

Customer Satisfaction: 0 **Customer Dissatisfaction**: 0
Priority: High **Conflicts**: None

Supporting Material: None

History: Created 01-NOV-2016

Requirement #: 10 **Requirement Type**: 4

Description: The system should be able to keep track of information pertaining to the machine's current physical state.
Rationale: If the system has a way of verifying the machine's current physical state, it will be able to detect unexpected disturbances. This will lead to higher accuracy of instructions being generated in certain cases as well as enabling the machine to self-correct as necessary.
Fit Criterion: This requirement will have various degrees of success. It will be considered satisfied on its simplest level if it can be used to calibrate the system (i.e. a default starting point to return to when in doubt). Other levels of success would include more set points that can be used as reference.

Originator: Eric Le Fort

Customer Satisfaction: 0 **Customer Dissatisfaction**: 0
Priority: Low **Conflicts**: None
Supporting Material: None

History: Created 01-NOV-2016

Requirement #: 11 **Requirement Type**: 1

Description: The system must keep track of the machine's current physical state.
Rationale: In order to determine how to move the machine to take its next shot, the system must know the starting physical state of the machine.
Fit Criterion: This requirement will be considered satisfied if the physical state of the machine is updated correctly as expected movements are made by the machine.

Originator: Eric Le Fort

Customer Satisfaction: 0 **Customer Dissatisfaction**: 0
Priority: High **Conflicts**: None
Supporting Material: None

History: Created 01-NOV-2016

Requirement #: 12 **Requirement Type**: 3

Description: The machine must be able to move the end-effector to the determined location and orientation.
Rationale: The system must be able to relocate the end-effector in order to make a shot.
Fit Criterion: This requirement will be considered satisfied if the machine successfully moves to the location specified by the system within 5 millimeters and orientation within half of a degree.

Originator: Eric Le Fort

Customer Satisfaction: 5 **Customer Dissatisfaction**: 5
Priority: High **Conflicts**: None
Supporting Material: None

History: Created 01-NOV-2016

Requirement #: 13 **Requirement Type**: 3

Description: The machine must be able to move the end-effector to strike the cue ball, taking a shot.
Rationale: The system must be able to strike the cue ball in order to actually take a shot.
Fit Criterion: This requirement will be considered satisfied if the machine actuates the end-effector within 5% of the specified speed.

Originator: Eric Le Fort

Customer Satisfaction: 5 **Customer Dissatisfaction**: 5
Priority: High **Conflicts**: None
Supporting Material: None

History: Created 01-NOV-2016

Requirement #: 14 **Requirement Type**: 3

Description: The machine must be able to take user input to indicate options such as: take a shot, move out of the way or stop operation.
Rationale: The user will need to indicate to the system what it needs it to do. Automatically knowing what the user would desire from the machine is outside of the scope of this project.
Fit Criterion: This requirement will be considered satisfied if the embedded system can receive signals from the user signifying the specified functionalities.

Originator: Eric Le Fort

Customer Satisfaction: 2 **Customer Dissatisfaction**: 5
Priority: High **Conflicts**: None
Supporting Material: None

History: Created 01-NOV-2016

Requirement #: 15 **Requirement Type**: 3

Description: The machine must be capable of moving out of the way to pre-determined locations upon user request.
Rationale: The system must be able to move the machine out of the way if the machine is in the user's way while they are attempting to make a shot.
Fit Criterion: This requirement will be considered satisfied if after the machine is instructed to move out of the user's way it moves to a pre-determined location.

Originator: Eric Le Fort

Customer Satisfaction: 4 **Customer Dissatisfaction**: 3
Priority: Low **Conflicts**: None
Supporting Material: None

History: Created 01-NOV-2016

Requirement #: 16 **Requirement Type**: 3

Description: Actuators need to provide enough force to move its corresponding part.
Rationale: Each moving part of the robot will have different masses and the actuator in charge of moving it needs to be able to provide suficient force to move it.
Fit Criterion: Requirement is satisfied if all parts are able to move.

Originator: Ernest Selman

Customer Satisfaction: 0 **Customer Dissatisfaction**: 0
Priority: Medium **Conflicts**: None
Supporting Material: None

History: Created 03-NOV-2016

Requirement #: 17 **Requirement Type**: 3

Description: End effector needs to provide enough force to shoot cue ball.
Rationale: Due to mass of cue ball and the lost of energy when the ball rolls on the table the end-effector needs to provide suficient energy to move the ball accross the table.
Fit Criterion: Requirement is satisfied if robot is able shoot the cue ball with enough energy to travel along the length of the table, bounce and return.

Originator: Ernest Selman

Customer Satisfaction: 5 **Customer Dissatisfaction**: 3
Priority: Medium **Conflicts**: None
Supporting Material: None

History: Created 03-NOV-2016

Requirement #: 18 **Requirement Type**: 3

Description: Robot needs to shoot cue ball regardless of the position of the cue ball
Rationale: If the cue ball is on the edge of the table or surounded by other balls, the robot needs to hit the cue ball without moving other ball with the end effector.
Fit Criterion: Requirement is satisfied if robot is able to hit the cue ball in any state of the table with out moving other balls.

Originator: Ernest Selman

Customer Satisfaction: 3 **Customer Dissatisfaction**: 3

Priority: High **Conflicts**: None
Supporting Material: None

History: Created 03-NOV-2016

Requirement #: 19 **Requirement Type**: 3

Description: Robot needs to have small repeatability area so that if it performs the same function multiple times, the end effector ends up in the same location every time.
def "repeatability area": area that covers the final location of end effector after repeating same comand multiple times.
Rationale: This requirement is needed to have the same results for the same state of the table.
Fit Criterion: Requirement is satisfied if robot is able to make the same shot multiple times.

Originator: Ernest Selman

Customer Satisfaction: 3 **Customer Dissatisfaction**: 3
Priority: Medium **Conflicts**: None
Supporting Material: None

History: Created 03-NOV-2016

4.2 Non-Functional Requirements

The following is a collection of the non-functional requirements of this system:

4.2.1 Look & Feel Requirements

Requirement #: 1 **Requirement Type**: LF

Description: Players must be able to see the table setup upon their turn.
Rationale: The users must be able to make decisions about future shots.
Fit Criterion: 90% of users should conclude that the position of the robot does not inhibit their ability to see the game-state when necessary.

Originator: Maxwell Moore

Customer Satisfaction: 2 **Customer Dissatisfaction**: 4
Priority: High **Conflicts**: None
Supporting Material: None

History: Created 03-NOV-2016

4.2.2 Usability & Humanity Requirements

Requirement #: 1 **Requirement Type**:UH

Description:The design of the robot shall not greatly inhibit a players ability to make a shot.
Rationale: The users must be able to play acceptably alongside the robot.

Fit Criterion: 90% of users should conclude that the position of the robot doesn't inhibit their ability to make shots as well as they would be able to on a regular pool table.

Originator: Maxwell Moore

Customer Satisfaction: 1 **Customer Dissatisfaction**: 5
Priority: High **Conflicts**: None
Supporting Material: None

History: Created 03-NOV-2016

Requirement #: 2 **Requirement Type**:UH

Description:The player should be able to freely interrupt the robots turn, or relinquish their turn.
Rationale: The user can have the freedom to choose to see the robots next move, or stop them for their own, at their will.
Fit Criterion: The robot can be interrupted or freely started 99% of the time.

Originator: Maxwell Moore

Customer Satisfaction: 1 **Customer Dissatisfaction**: 3
Priority: Medium **Conflicts**: Possibly with enforcing rules of game
Supporting Material: None

History: Created 03-NOV-2016

4.2.3 Performance Requirements

Requirement #: 1 **Requirement Type**:P

Description:The System will take shots quickly.
Rationale: The user will not have to wait too long to play their turn.
Fit Criterion: The robot will decide on a shot to take, and make that shot, in under 90 seconds 90% of the time.

Originator: Maxwell Moore

Customer Satisfaction: 1 **Customer Dissatisfaction**: 4
Priority: Medium **Conflicts**: None
Supporting Material: None

History: Created 03-NOV-2016

Requirement #: 2 **Requirement Type**:P

Description:The System will take shots precisely.
Rationale: The user will feel challenged by the robot.
Fit Criterion: The robot will decide on a shot to take, and make that shot in under 90 seconds 50% of the time.

Originator: Maxwell Moore

Customer Satisfaction: 4 **Customer Dissatisfaction**: 3
Priority: Medium **Conflicts**: None
Supporting Material: None

History: Created 03-NOV-2016

Requirement #: 3 **Requirement Type**: P

Description: Body parts needs to be light
Rationale: Robot needs to be light due to posible relocation, easier handling by user and to decrease power needed to move parts.
Fit Criterion: Requirement is satisfied if user can easily handle parts and acctuators don't overheat.

Originator: Ernest Selman

Customer Satisfaction: 0 **Customer Dissatisfaction**: 0
Priority: Low **Conflicts**: None
Supporting Material: None

History: Created 03-NOV-2016

Requirement #: 4 **Requirement Type**: P

Description: Body of robot needs to be rigid.
Rationale: Body of robot has to be rigid so that end effector doesn't move without activation of actuators.
Fit Criterion: Requirement is satisfied if end effector doesn't move if actuators are powered and not moving.

Originator: Ernest Selman

Customer Satisfaction: 0 **Customer Dissatisfaction**: 4
Priority: High **Conflicts**: None
Supporting Material: None

History: Created 03-NOV-2016

4.2.4 Operational & Environmental Requirements

Requirement #: 1 **Requirement Type**:OE

Description:The System will be in an environment in accordance to regular pool playing environments.
Rationale: The robot will not have unnecessary difficulties in making precise shots.
Fit Criterion: The system is indoors, at room temperature while running, and have a few feet of room on all sides.

Originator: Maxwell Moore

Customer Satisfaction: 1 **Customer Dissatisfaction**: 4
Priority: Medium **Conflicts**: None
Supporting Material: None

History: Created 03-NOV-2016

Requirement #: 2 **Requirement Type**:OE

Description:The system will be able to be powered using a standard power socket.
Rationale: The robot must have power to function.
Fit Criterion: A standard wall socket provides sufficient power to operate the system.

Originator: Maxwell Moore

Customer Satisfaction: 1 **Customer Dissatisfaction**: 5
Priority: High **Conflicts**: None
Supporting Material: None

History: Created 03-NOV-2016

Requirement #: 3 **Requirement Type**: OE

Description: Pool table properties need to be consistent throughout the table.
Rationale: In order to have proper functionality and consistent results, table properties, like rolling resistance and flatness need to be the same in all points of the table.
Fit Criterion: equirement is satisfied if the table has consistent properties.

Originator: Ernest Selman

Customer Satisfaction: 0 **Customer Dissatisfaction**: 3
Priority: Low **Conflicts**: None
Supporting Material: None

History: Created 03-NOV-2016

4.2.5 Maintainability & Support Requirements

Requirement #: 1 **Requirement Type**:MS

Description:The system will be tested weekly for its base functionality
Rationale: To ensure wear and tear of the system has not rendered it useless.
Fit Criterion: A short weekly test of previously completed functionalities is performed.

Originator: Maxwell Moore

Customer Satisfaction: 1 **Customer Dissatisfaction**: 1
Priority: Low **Conflicts**: None
Supporting Material: None

History: Created 03-NOV-2016

4.2.6 Security Requirements

Requirement #: 1 **Requirement Type**:S

Description:Even very advanced users will not be able to modify the power of a shot beyond a certain safe value
Rationale: The robot will not be able to be used in a dangerous fashion.
Fit Criterion: 99.9% of users must not be able to figure out a way of making the system perform an unsafe action.

Originator: Maxwell Moore

Customer Satisfaction: 1 **Customer Dissatisfaction**: 5
Priority: High **Conflicts**: none
Supporting Material: None

History: Created 03-NOV-2016

4.2.7 Cultural & Political Requirements

Requirement #: 1 **Requirement Type**:CP

Description:There will be no direct references to any political or religious groups
Rationale: This will avoid accidentally offending certain demographics.
Fit Criterion: 99% of users say there is no noticeable political or cultural relevance.

Originator: Maxwell Moore

Customer Satisfaction: 1 **Customer Dissatisfaction**: 1
Priority: low **Conflicts**: none
Supporting Material: None

History: Created 03-NOV-2016

4.2.8 Legal Requirements

Requirement #: 1 **Requirement Type**:L

Description:There will be no copyright infringement, unlicensed usage of software, or services that have not been properly licensed.
Rationale: This will avoid academic dishonesty and maintain the moral integrity of the group.
Fit Criterion: An outside consultant will verify that there has been no copyright infringement, unlicensed usage of software, or services that have not been properly licensed.

Originator: Maxwell Moore

Customer Satisfaction: 1 **Customer Dissatisfaction**: 1
Priority: low **Conflicts**: none
Supporting Material: None

History: Created 03-NOV-2016

Requirement #: 2 **Requirement Type**: L

Description: Sensible electrical equipment needs to be isolated from high voltage.
Rationale: Sensible electrical equipment like microcontroler and sensors can be damaged if connected to high voltage sourses.
Fit Criterion: Requirement is satisfied if Sensible electrical equipment is not connected to high voltage sourses.

Originator: Ernest Selman

Customer Satisfaction: 0 **Customer Dissatisfaction**: 0
Priority: High **Conflicts**: None
Supporting Material: None

History: Created 03-NOV-2016

5 Project Issues

The issues to be addressed consider marketability, competition, safety, liabilities, or any other noticeable concerns.

5.1 Existing Products

All known existing products are not publicly available. Nevertheless, these projects may affect the clients? view of the product and the overall marketability of the product.

5.2 Off-the-Shelf Solutions

5.3 Risks

The risks found in this project generally describe the safety considerations found with both the creation and operation of the product. This robot may have quite strong motor and actuators that may be high current/ high voltage devices. It is imperative that the user?s safety is taken into account and that even a player without any electrical experience will be able to at least be around the table.

5.4 User Documentation & Training

In order to market the product the user will need to be provided with documentation regarding the operation, safety, and maintenance of the system. Although the product should be designed in a way that promotes ease of use, there must be some form of training required before the user can comfortably use the product. This may include a user manual or videos.