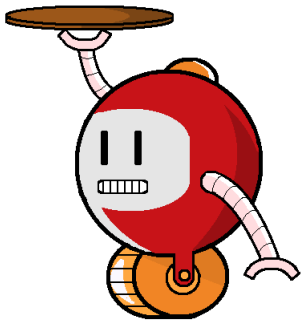

LazyBots

McMaster University

System Requirements

SE 4G06 & TRON 4TB6

Group 9

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1 Revisions

Table 1: LazyBots Revision Table

Date	Revision Number	Authors	Comments
November 6th, 2017	Revision 0	Karim Guirguis David Hemms Marko Laban Curtis Milo Keyur Patel Alexandra Rahman	N/A

2 Project Drivers

2.1 The Purpose of the Project

The purpose of this project will be to create an autonomous robot that will navigate to and serve the requested drink to the user who requests a drink. Currently in an office setting, workers must leave their offices to get their own drinks. Also, in restaurants, drinks are served by waiters and waitresses, which hinders them from doing other work at that time. Alfred will be designed to make the serving drinks autonomous.

Alfred will allow users to request drinks. These requests will form a queue which Alfred will serve in order using a FIFO protocol. Alfred will go to the table of each user and pour the drinks ordered from that table. Alfred will also have an administrator user which will be able to call Alfred back and override any action that is being taken at the time.

The following document will outline the functional and nonfunctional requirements of Alfred. Other topics that will be covered pertaining to Alfred will include: Scope, Project Constraints, Likely Changes and Project Issues.

2.2 Scope

The system implemented is one that is meant to automate the dispensing of beverages to customers within a restaurant at the respected customerĂŹs' table. The customer will be able to order a drink from their table which will be followed by Alfred arriving at their table and dispensing the requested drinks. The staff will be able to request Alfred to come back for charging and refilling when desired.

2.3 The Client, the Customer, and Other Stakeholders

2.3.1 Client and Customer

- Restaurant Owners
- Restaurant Staff
- Restaurant Clients
- People who are working in a office environment

2.3.2 Stakeholders

Include Stakeholders

- GM, Project Proposers
- Dr. Alan Wassyng, the Project Supervisor
- Stephen Wynn-Williams and Bennett Mackenzie , The Teaching Assistants

2.4 Users of the Product

This product will be used in a restaurant setting, and the users can be divided into two groups. The first group of users will be the customers of the restaurant, who will be placing drink orders and will be served by the robot. The other group of users will be the restaurant staff, who will ensure that the robot is operating properly and keep the fluid levels topped up.

3 Project Constraints

3.1 Mandated Constraints

The following is a list of constraints that will be followed during the design of this system.

MC1	**The cost of the project must not exceed $750 dollars.**
Rationale	The project must be economically feasible and cannot be an off-the-shelf solution.

MC2	**Weight must not exceed what could the motor would be able to move, given torque limitations of motor.**
Rationale	Robot must be able to move with all drink containers filled.

MC3	**Project must be finished within the course of the academic year.**
Rationale	Must submit finished project by end of academic year as per project requirements.

MC4	**Workload must be achievable by 6 people (size of group) in given alloted time.**
Rationale	Must be physically possible given alloted manpower and time.

3.2 Naming Conventions and Definitions

3.2.1 Naming Conventions

Note: The following naming conventions apply to this document specifically.

R#	Robot Name
Alfred#	The name of the robot that will deliver drinks
T#	Table Order Identification Number
Tid#	Table identification and number
G#	Graphing notation
N#	A node within a graph representing a table or any other point of interest.
G#	A graph representing the tables as well as the distance from the current table.

3.2.2 Constants

1. **Steps/Revolution** - The number of steps within a revolution of the stepper motor
2. **Pump Flow rate** - The amount of liquid that will be pumped at a specific voltage

3.2.3 Monitored and Controlled Variables

The following is a list of variables that will be monitored.

- Speed of the wheels (rad/s)
- Weight of the storage device (kg)
- If the cup has been taken (boolean)
- Distance of any obstacles (m)
- Voltage levels of batteries (V)

The following is a list of variables that will be controlled

- Speed of the motor (rad/s)
- Voltage going to the liquid pumps. (V)
- Signal of drink that it is ready to be picked up (boolean) «««< HEAD
- Error codes sent (unsigned byte) =======
- Error codes sent from Alfred (unsigned byte) »»»> bb878a034c7372cc85fa69f8569b402501b7f1b8

3.3 Relevant Facts and Assumptions

3.3.1 Relevant Facts

- A standard cup size contains 12 ounces of fluid
- All food or drink should not be served below the height of a table
- Food Safety and Industry standards state that drinks should be kept at a temperature below 4 degrees Celsius

3.3.2 Assumptions

Alfred's assumption are represented in the tables below.

A1	The environment will only be comprised of a one story building with no steps.
Rationale	Different environment elevations are beyond the scope of the project.

A2	The width of the walkways will be wide enough to accommodate all people.
Rationale	If a table is not accessible to a human, it will not be accessible for Alfred.

A3	Orders will be placed via an Android or iOS application.
Rationale	Eliminates the need for human interactions, making Alfred completely autonomous.

A4	The height of a table will not exceed 30".
Rationale	This will help simplify the scope of the project and reduce the amount of drink waste.

A5	The serving size of a medium sized cup will not vary largely in terms of ounces.
Rationale	The standard ounces in a cup will be restricted to 12oz. to accommodate as many users as possible and to limit the scope.

4 Context Diagrams

The following is a context diagram of the drink serving robot, Alfred.

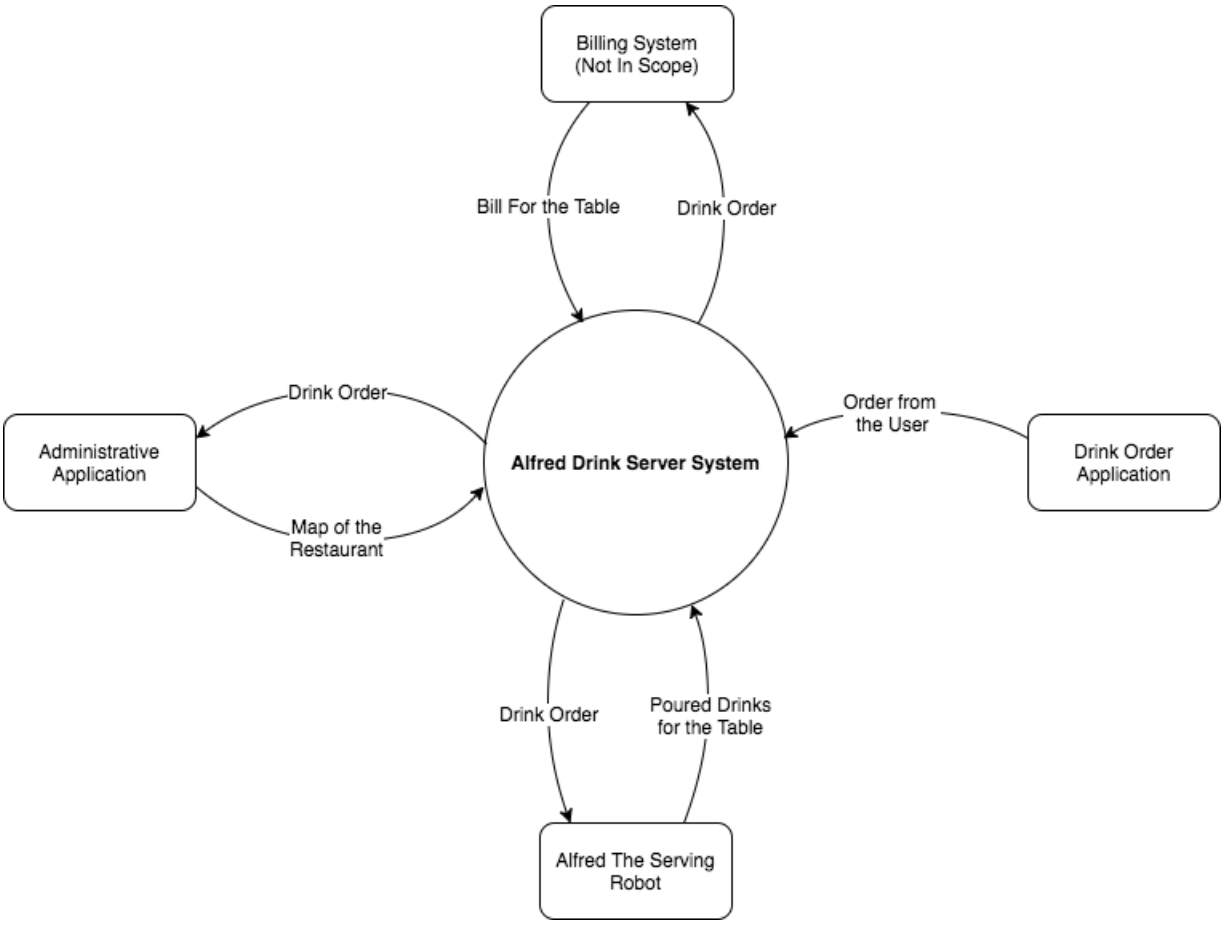

Figure 1: Drink Serving Robot Context Diagram

5 Functional Requirements

The following are the functional requirements of the project. They are separated into # main components: drink serving robot (Alfred), ordering and administration.

5.1 Alfred Functional Requirements

AF1	Alfred shall be able to differentiate between the different drink types and dispense the correct drink.
Rationale	Alfred should be able to dispense the correct drinks for the customers.

AF2	Alfred shall be able to identify to correlate a drink order to the requesting table.
Rationale	Alfred will be able to able to dispense the desired drinks to the correct table.

AF3	Alfred shall be able to navigate to a table that corresponds to a specific drink order.
Rationale	Alfred should be able to move autonomously.

AF4	Alfred shall be able to pour the correct drinks corresponding to the specific tables order.
Rationale	This is that Alfred will be able to pour the drinks for the customers without the need for any human interference.

AF5	Alfred shall be able to dispense the correct amount for the drink based on the size of the cup specified.
Rationale	Alfred will be able to dispense the correct amount of liquid for the user so it will not be under or over filled.

AF6	Alfred shall be able to determine when liquids within storage containers are not within the desired temperature range.
Rationale	In order to ensure that the drinks served meet FDA food regulation standards.

AF7	Alfred shall be able to notify the staff when the liquids within the storage containers are not within the desired temperature range.
Rationale	So that the staff will be able to make the appropriate action to cool the drinks down.

AF8	Alfred shall be able to determine if any of the liquids within the storage containers are below the desired supply levels.
Rationale	Alfred should be able to know when it will need to be refilled and should not dispense any drink with insufficient supply levels.

AF9	Alfred shall be able to notify the staff when any of the liquids within the storage containers are below the desired supply levels.
Rationale	Staff should be able to replenish liquid supplies when they run low so that Alfred can continue serving customers.

AF10	Alfred shall be able to determine if an obstacle is in its path and come to a timely stop.
Rationale	To ensure the safety of the users and prevent destruction of property.

AF11	Alfred shall be able to determine when a component will no longer be operational due to insufficient power levels.
Rationale	To ensure that no internal components get abused or destroyed proper safety measures are in place; Alfred returns to home base before shutting down.

AF12	Alfred shall be able to navigate back to the designated home base at any given point in time.
Rationale	To ensure safety of the customers and the robot, Alfred shall return to a designated home base when any issue pertaining to supply temperature, supply levels or power levels. This is also in place so that the staff an request Alfred to return to home base at the end of the business day.

AF13	Alfred shall be able to indicate to the user when the drink has finished dispensing.
Rationale	To prevent drink waste and confusion among users, Alfred should notify the user when a drink is complete.

AF14	Alfred shall be able to complete drink orders in the order that they were received.
Rationale	To ensure that all customers are served and fairness is preserved.

5.2 Table Ordering Application Functional Requirements

TO1	The ordering application shall allow the user to be able to place an order to Alfred.

Rationale	This is so that Alfred will be able to bring the beverages of the table.

TO2	The ordering application shall be able to add the incoming order to Alfred's the serving queue.
Rationale	This is so that Alfred will be able to receive the specific order from the application.

5.3 Administrator Application Functional Requirements

AD1	The Administrator Application shall allow the user to create a map of the restaurant for Alfred.
Rationale	To ensure that Alfred successfully navigates the layout and abides the users' table ordering convention.

AD2	The Administrator Application shall allow the user to modify the map by adding or removing tables, obstacles and walkways.
Rationale	To ensure that Alfred map is up to date and prevent damage of property.

AD3	The Administrator Application shall allow the user to view a log of the orders that were created by the ordering application.
Rationale	This is so that the restaurant shall be able to make bills based on this information.

AD4	The Administrator Application shall be able to view Alfred's status at any given point in time.
Rationale	To ensure that staff are well informed of Alfred's conditions and are certain that Alfred will remain operational.

6 Functional Decomposition Diagrams

The following is a data flow diagram of the drink serving robot, Alfred.

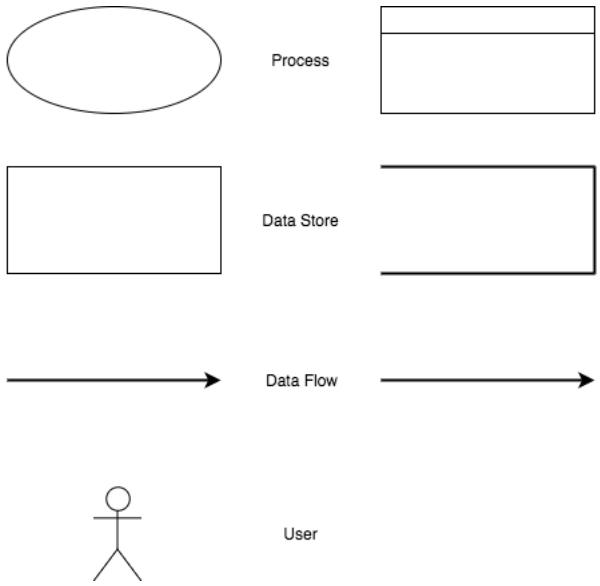

Figure 2: Legend for the User Diagram and the Data Flow Diagram

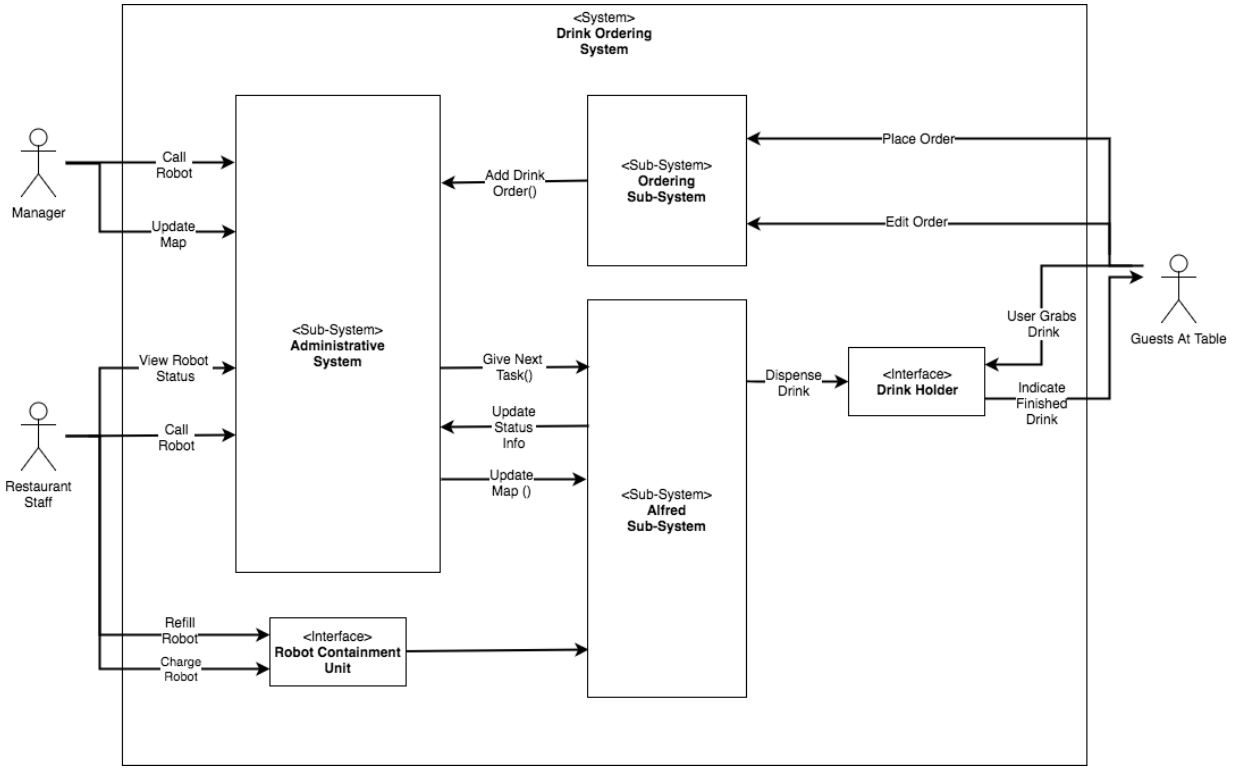

Figure 3: Drink Serving Robot User Diagram

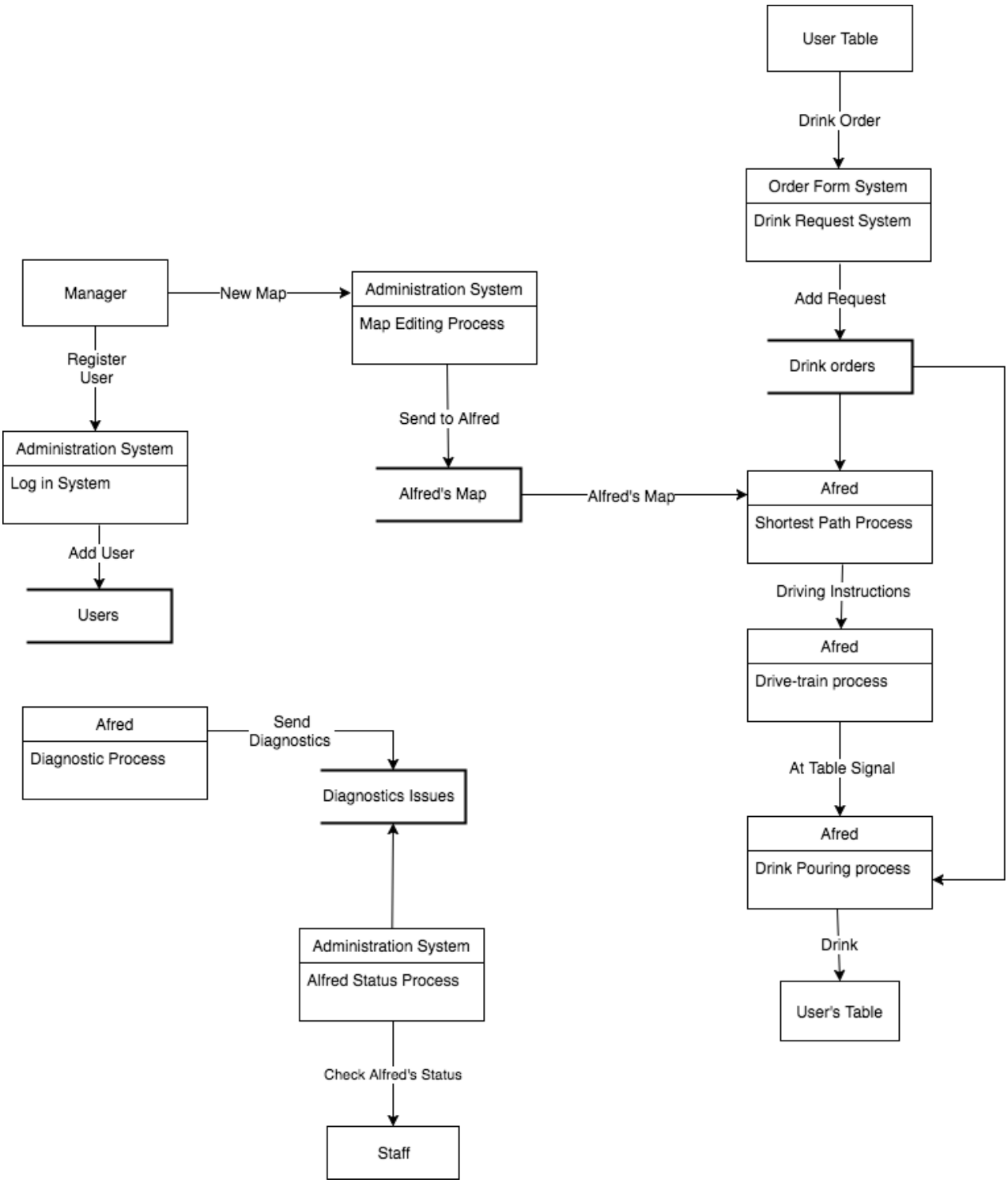

Figure 4: Drink Serving Robot Data Flow Diagram

7 Functional Requirements Likelihood of Change

7.1 Alfred Functional Requirements

Requirement	Likelihood of Change	Rationale	Ways to Change
AF1	Very Unlikely	Key implementation aspect	N/A
AF2	Ver Unlikely	Key implementation aspect	N/A
AF3	Very Unlikely	Key implementation aspect	N/A
AF4	Very Unlikely	Key implementation aspect	N/A
AF5	Unlikely	Subject to scope definition and time constraints.	Cup size might be restricted to a single size.
AF6	Very Unlikely	Key implementation aspect	N/A
AF7	Very Unlikely	Ensures Food Safety Standards are met	N/A
AF8	Very Unlikely	Key implementation Aspect	N/A
AF9	Very unlikely	Key implementation aspect	N/A
AF10	Very Unlikely	Ensures safety of users	N/A
AF11	Very Unlikely	Ensures robot safety	N/A
AF12	Unlikely	Administrator can override the system	Restrictions on when the robot can be called back to home base may be implemented.
AF13	Unlikely	Key implementation aspect	N/A
AF14	Unlikely	Subject to scope definition and time constraints.	Orders might be fulfilled based on resource availability.

7.2 Table Ordering Application Functional Requirements

Requirement	Likelihood of Change	Rationale	Ways to Change
TO1	Very Unlikely	Key implementation aspect	N/A
TO2	Very Unlikely	Key implementation	N/A

7.3 Administrator Application Functional Requirements

Requirement	Likelihood of Change	Rationale	Ways to Change

AD1	Likely	Subject to scope definition and time constraints, a predetermined map may be supplied	Requirement may be removed.
AD2	Likely	Subject to scope definition and time constraints, the requirement has a lower priority compared to other requirement	Requirement may be removed.
AD3	Likely	Subject to scope definition and time constraints	Requirement may be removed.
AD4	Very Unlikely	Key implementation aspect	N/A

8 Non-Functional Requirements

8.1 Look and Feel Requirements

8.1.1 Appearance Requirements

NFR1	Alfred shall have any functional equipment hidden within its containment unit unless the user needs to interact with it.
Rationale	Users should not have easy access to electrical or mechanical components for safety issues.
NFR2	Alfred shall not have any exposed electronic wiring.
Rationale	To ensure user safety.
NFR3	Alfred shall be at the appropriate table height.
Rationale	To ensure user safety when the robot is moving and to allow ease of use.

8.1.2 Style Requirements

NFR4	Alfred shall be painted non-offensive and appealing colours.
Rationale	To ensure that no group of users is offended the choice of colours.
NFR5	The drink ordering application shall not be visually cluttered.
Rationale	To ensure ease of use and prevent overwhelming the user with information.

8.2 Usability and Humanity Requirements

8.2.1 Ease of Use Requirements

NFR6	Alfred shall make the drinks easy to grab and should only take the user 10 seconds to recognize the drink is ready and grab it.
Rationale	This is about the amount of time to determine that the cup is ready to grab it.

NFR7	Alfred shall make it so the user to be able to tell when a drink is done within one second.
Rationale	This is so that the user will not have to wait a large amount of time.

8.2.2 Personalization and Internationalization Requirements

- N/A

8.2.3 Learning Requirements

NFR8	The ordering application shall make it so that the user can learn to order a drink within 2 minutes of use.
Rationale	This is the estimated amount of time the user would take to place their order with a wait staff.

8.2.4 Understandability and Politeness Requirements

NFR9	Alfred shall not say or portray anything that will offend a user of call out a specific group of users.
Rationale	To ensure that the user is not offended.

8.2.5 Accessibility Requirements

NF10	Auditory and visual queues will be used to notify the user when a drink is complete.
Rationale	To ensure that users with impaired vision are able to use the application.

8.3 Performance Requirements

NFR11	Alfred shall be able to determine the shortest path within 30 seconds.
Rationale	The estimated amount of time that the user will not feel neglected.

8.3.1 Speed Requirements

NF12	Alfred shall be able to pour a drink within 30 seconds.
Rationale	Approximate time for a person to dispense a drink.
NFR13	Alfred shall be able to move at the walking speed of a human.
Rationale	The user will not be waiting any longer than the current system, ensures that the robot speed is not significant enough to cause harm or damage.
NFR14	Alfred shall be able to receive an order within 30 seconds.

Rationale	Ensures that the speed of communication is not a limiting factor when considering user satisfaction.
NFR15	The ordering application be able to send an order to the administrative program within 30 seconds.
Rationale	Ensures that the speed of communication will not cause significant harm or damage.

8.3.2 Safety-Critical Requirements

NFR16	Alfred shall be able to determine when an obstacle is three feet in front of it in order to stop.
Rationale	The estimated distance required to be able to decelerate properly.
NFR17	Alfred shall not dispense a drink if supplies are not within the desired temperature range.
Rationale	To abide by FDA standards and to ensure user safety.
NFR18	Alfred shall not exceed human walking speed.
Rationale	To ensure that there is no property damage or harm to users.

8.3.3 Precision Requirements

NFR19	Alfred shall be able to fill a cup within 75 to 85 percent of maximum capacity.
Rationale	The estimated amount so that the user will be satisfied as well as not overflowing the cup.
NFR20	Alfred shall be able to get within one foot of any programmed node.
Rationale	To ensure ease of use with the user; they do not have to over reach for their drink.
NFR21	The system shall not distort the users order at any point if the drink order will not be able to be translated back.
Rationale	To ensure that the user will get the drink they ordered.

8.3.4 Reliability or Availability Requirements

NFR22	Alfred shall not allow liquid containers to leak.
Rationale	In the case that the robot is tipped over, no electrical components shall be affected.

8.3.5 Robustness or Fault-Tolerance Requirements

- N/A

8.3.6 Capacity Requirements

NFR23	Alfred shall be able to store 2 Litres of any liquid.
Rationale	To ensure that Alfred has enough supply levels to fill multiple orders, and not too much liquid that the drive train cannot support the weight.

8.3.7 Scalability or Extensibility Requirements

NFR24	The system shall only require one work week to implement within any establishment.
Rationale	So that the system will be able to be introduced into a restaurant without disturbing workflow for extended periods of time.

8.3.8 Longevity Requirements

NFR24	Alfred shall be able to keep drinks cold for 8 hours.
Rationale	To ensure that the robot does not return to home base frequently. This time period also correlates with a typical work shift.

8.4 Operational and Environmental Requirements

8.4.1 Expected Physical Environment

- N/A

8.4.2 Requirements for Interacting with Adjacent Systems

- N/A

8.5 Maintainability and Support Requirements

8.5.1 Maintenance Requirements

NFR25	Alfred shall be able to determine if certain functions cannot be completed.
Rationale	To ensure that error reports are clear and concise.
NFR26	Alfred shall be able to determine the cause of a malfunction.
Rationale	To ensure that error reports are clear and concise.
NFR27	Alfred shall be built so that components can be easily removed.
Rationale	To ensure that components can be easily replaced if they malfunction.

8.5.2 Supportability Requirements

NFR28	The Administrator Application shall have help documentation available to the user.
Rationale	To ensure that the user is able to get additional information if needed.
NFR29	The Table Ordering Application shall have help documentation available to the user.
Rationale	To ensure that the user is able to get additional information if needed.

8.5.3 Adaptability Requirements

- N/A

8.6 Security Requirements

8.6.1 Access Requirements

NFR30	The Table Ordering Application shall allow the user to see what they have ordered.
Rationale	To allow the user to verify their drink order before sending it to Alfred.

8.6.2 Integrity Requirements

NFR31	The system shall encrypt all information.
Rationale	To ensure information security and prevent information loss during communication.

8.6.3 Privacy Requirements

NFR32	The ordering system shall not display any information about other tables' drink orders.
Rationale	To ensure information is kept private.
NFR33	The system shall use secure protocols for any communication.
Rationale	To ensure information is kept private.

8.6.4 Audit Requirements

- N/A

8.6.5 Immunity Requirements

NFR34	Alfred shall have a cooling chamber to prevent drinks large increases in temperature.

Rationale	To ensure that Alfred abides by the FDA standards and to reduce the amount of trips to home base.

8.7 Cultural and Political Requirements

8.7.1 Cultural Requirements

- N/A

8.7.2 Political Requirements

- N/A

8.8 Legal Requirements

8.8.1 Compliance Requirements

NFR35	Alfred Shall follow food and safety regulations.
Rationale	To ensure that the restaurant is not at risk of failing public health inspections.
NFR36	Alfred shall not preform any actions that can be perceived as discriminatory to the user.
Rationale	To ensure that all users are comfortable using Alfred.
NFR37	Alfred shall not server any alcoholic beverages or prohibited substances.
Rationale	To ensure Alfred abides by Canadian Laws and that users under the drinking age can be served.

8.8.2 Standards Requirements

NFR38	Alfred shall follow the law of robotics.
Rationale	To ensure that users are safe when using Alfred.

9 Project Issues

9.1 Open Issues

(i) Weight of the containers requires a lot of torque to get the robot to move at the desired speed.

(ii) Rotation of the robot causes the liquids to sway inside their storage containers causing momentum opposing that of the desired direction of motion.

(iii) Smooth acceleration and deceleration to prevent liquid spills and undesired momentum.

(iv) Pumping mechanism runs using an Arduino while drive-train uses a raspberry pi therefor low latency communication between the two boards is vital.

(v) Robust communication to server in the case of sensor or board failure.

9.2 Off-the-Shelf Solutions

9.2.1 Ready-Made Products

(i) Bar2D2 - a radio-controlled, mobile bar that features a motorized beer elevator, motorized ice/mixer drawer, six-bottle shot dispenser, and sound activated neon lighting.

(ii) Laskmi-Do Corporation Table Robot - a robot two wheeled robot that delivers drinks.

9.3 Risks

(i) Components break over time and due to accidents.

(ii) Alfred gets stuck behind an obstacle (if someone places chair in front as opposed to someone walking by).

(iii) Alfred spills drinks or has drinks spilled on it.

(iv) User error during interaction with Alfred.

(v) User error during interaction with the client side application.

(vi) Alfred harms someone.

(vii) Alfred is not cleaned properly.

(viii) There is a major roadblock in development or construction.

9.4 Costs

The budget for the all components of the robot must not exceed $750. A breakdown of the individual part costs is as follows:

Product	**Price**
Raspberry Pi	$50
Arduino	$10
Storage Containers	$25
Piping	$20
Pumps	$30
Motors	$60
Wheels	$40
Structural Materials (wood, metal etc.)	$100
Electrical Components (zener diodes, mosfets, etc.)	$30
Motor Drivers	$40
Battery Power	$50
Total	**$460**

9.5 Waiting Room

(i) Having Alfred being able to recognize objects using image recognition.

(ii) Developing a more robust advanced administrative application to include billing and table availability.