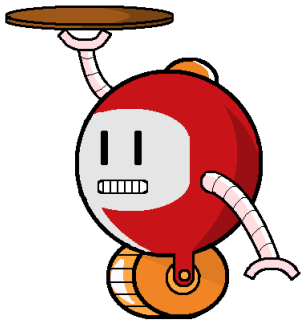

LazyBots

McMaster University

System Requirements

SE 4G06 & TRON 4TB6

Group 9

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1 Revisions

Date	Revision Number	Authors	Comments
November 6th, 2017	Revision 0	Karim Guirguis David Hemms Marko Laban Curtis Milo Keyur Patel Alexandra Rahman	-
December 15th, 2017	Revision 1	Karim Guirguis David Hemms Marko Laban Curtis Milo Keyur Patel Alexandra Rahman	Added the section 'Typical Order of Operations', removed some requirements and modified other requirements. Updated the cost subsection.
February 25th, 2018	Revision 2	Karim Guirguis David Hemms Marko Laban Curtis Milo Keyur Patel Alexandra Rahman	Added nomenclature to the monitored and controlled variables, modified the order of the sections. Fixed grammatical errors and updated the costs subsection.

Table 1: Table of Revisions

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 restaurants, drinks are served by waiters and waitresses, which hinders them from doing other tasks at that time. Alfred will be designed to make the serving drinks autonomous.

Alfred will allow users to request drinks through an interface. These requests will form a queue which Alfred will serve in order using a FIFO (first in, first out) protocol. Alfred will go to the table of each user and dispense the drinks ordered from said 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 non-functional 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 respective customers' 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 return to a Home Base for charging and refilling when desired.

2.3 Typical Operations Overview

A restaurant customer will order a set of drinks through an interface. The drink order will be sent to Alfred. Alfred will handle all incoming drink orders using the FIFO protocol. Alfred will navigate to the first customer's table. Alfred will dispense the first drink in the order and notify the customer when the drink is complete. Once the customer removes the drink from the platform and Alfred will dispense the second drink. Alfred will repeat this process until the drink order is complete. Once the drink order complete, Alfred will move the next customer's table in the queue.

If at any point the supply or power levels run low or the food safety standards are not being met, Alfred will send a notification to the administrative user and return to home base. Once the problem is solved, Alfred will continue to complete drink orders.

2.4 The Client, the Customer, and Other Stakeholders

2.4.1 Client and Customer

- Restaurant Owners
- Restaurant Staff
- Restaurant Clients

2.4.2 Stakeholders

Include Stakeholders

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

2.5 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 Alfred. The other group of users will be the restaurant staff, who will ensure that Alfred 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 25 kilograms, 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.

3.2 Naming Conventions and Definitions

3.2.1 Naming Conventions

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

Alfred	The name of the robot that will deliver drinks
T#	Table Order Identification Number
Tid#	Table identification and number
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.

Table 5: Requirements Naming Convention

3.2.2 Constants

1. **Steps/Revolution** - The number of steps within a revolution of the stepper motor
2. **Millilitres/Second** - 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.

Monitor Name	Monitor Type	Range	Units	Comment(s)
$w_{wheel_{left}}$	Speed	[0, 100]	rad/s	Left Wheel Speed
$w_{wheel_{right}}$	Speed	[0, 100]	rad/s	Right Wheel Speed
$m_{container}$	Mass	[0, 1.0]	Kg	Weight of the storage device
m_{drink}	Mass	[0, 1.0]	Kg	Weight of the drink
$b_{cuptaken}$	Boolean	[0,1]	N/A	If the cup has been taken
$d_{objects}$	Distance[]	[0, 10.0]	m	Set of distances to closest obstacle
V_{batt}	Voltage	[0, 20.0]	m	Voltage levels of batteries

Table 6: Monitored Variables

The following is a list of variables that will be controlled:

Controlled Name	Controlled Type	Range	Units	Comment(s)
w_{motor}	Speed	[0, 100]	rad/s	Motor Speed
$percent_{dutycycle_{left}}$	Percent	[0,1.0]	%	The duty cycle of the left side of the drive-train
$percent_{dutycycle_{right}}$	Percent	[0, 1.0]	%	The duty cycle of the right side of the drive-train
V_{pump}	Voltage	[0, 5.0]	m	Voltage going to the liquid pump

$errors_{drivetrain}$	Unsigned Byte	[0, 2^8]	N/A	Errors from drive-train
$errors_{pump}$	Unsigned Byte	[0, 2^8]	N/A	Errors from pumping system module
$errors_{Alfred}$	Unsigned Byte	[0, 2^8]	N/A	Errors from Alfred
$LED_{drinksignal}$	Boolean	[0, 1]	N/A	Signal of drink that it is ready to be picked up
Q_{pump}	Flow Rate	[0, 100]	(m^3/s)	Flow rate of the pump

Table 7: Controlled Variables

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 customers' discomfort when reaching for a drink.

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.

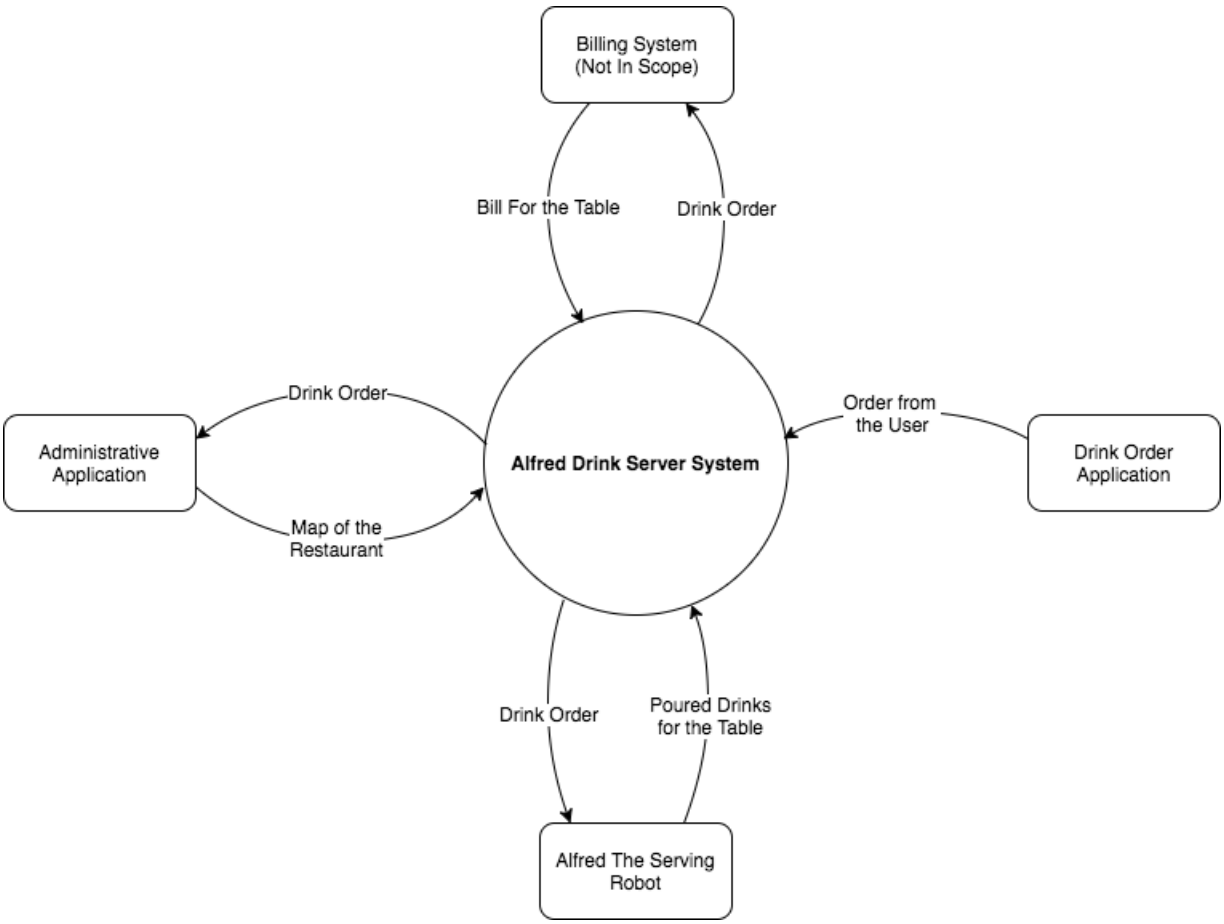

Figure 1: Drink Serving Robot Context Diagram

5 Functional Decomposition Diagrams

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

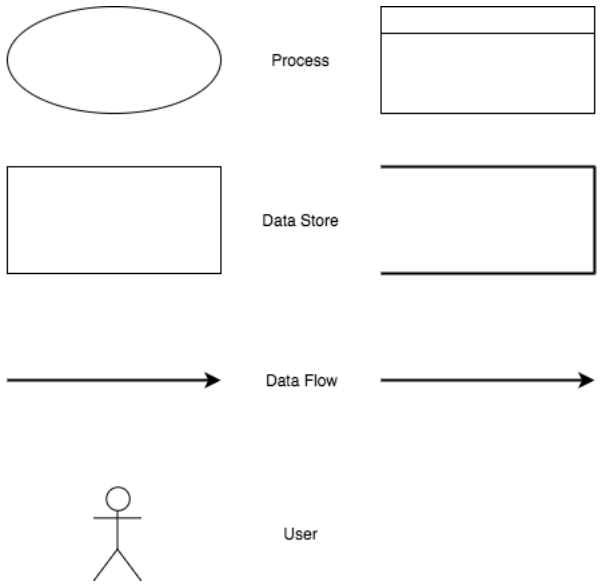

Figure 2: Legend for the User Diagram and the Data Flow Diagram

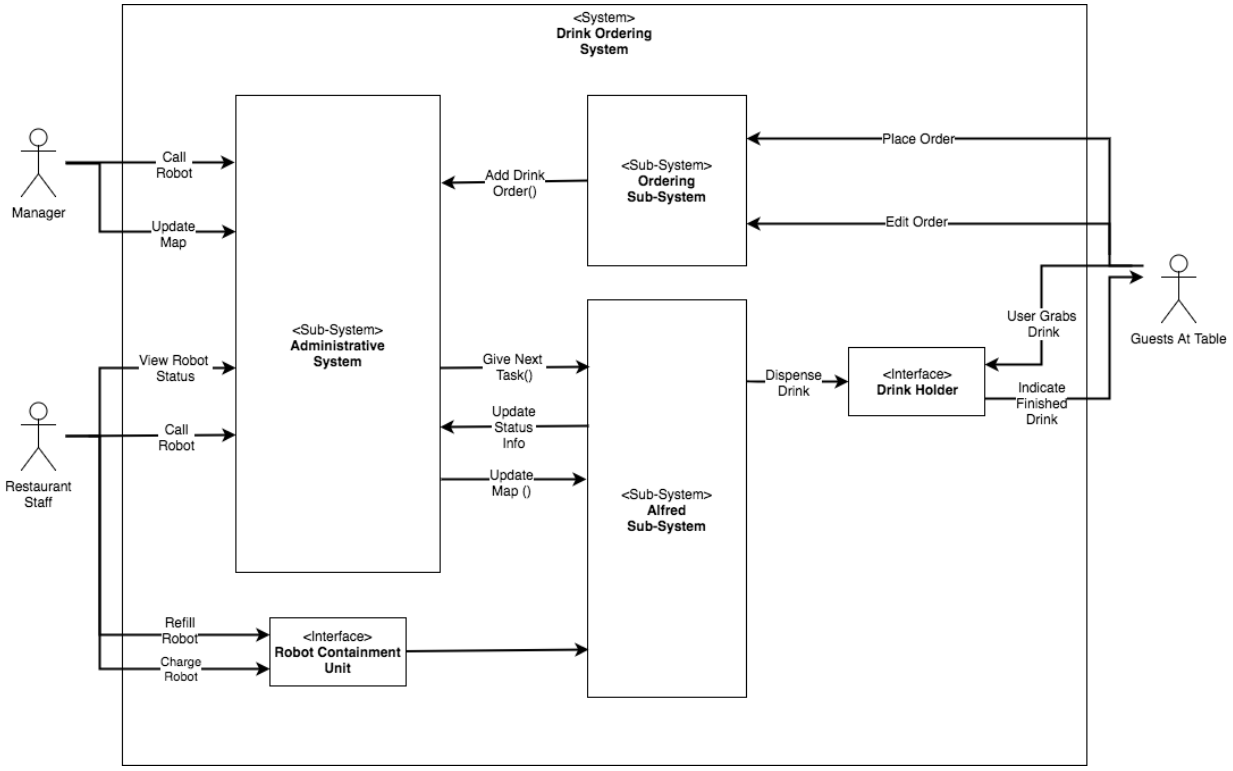

Figure 3: Alfred User Diagram

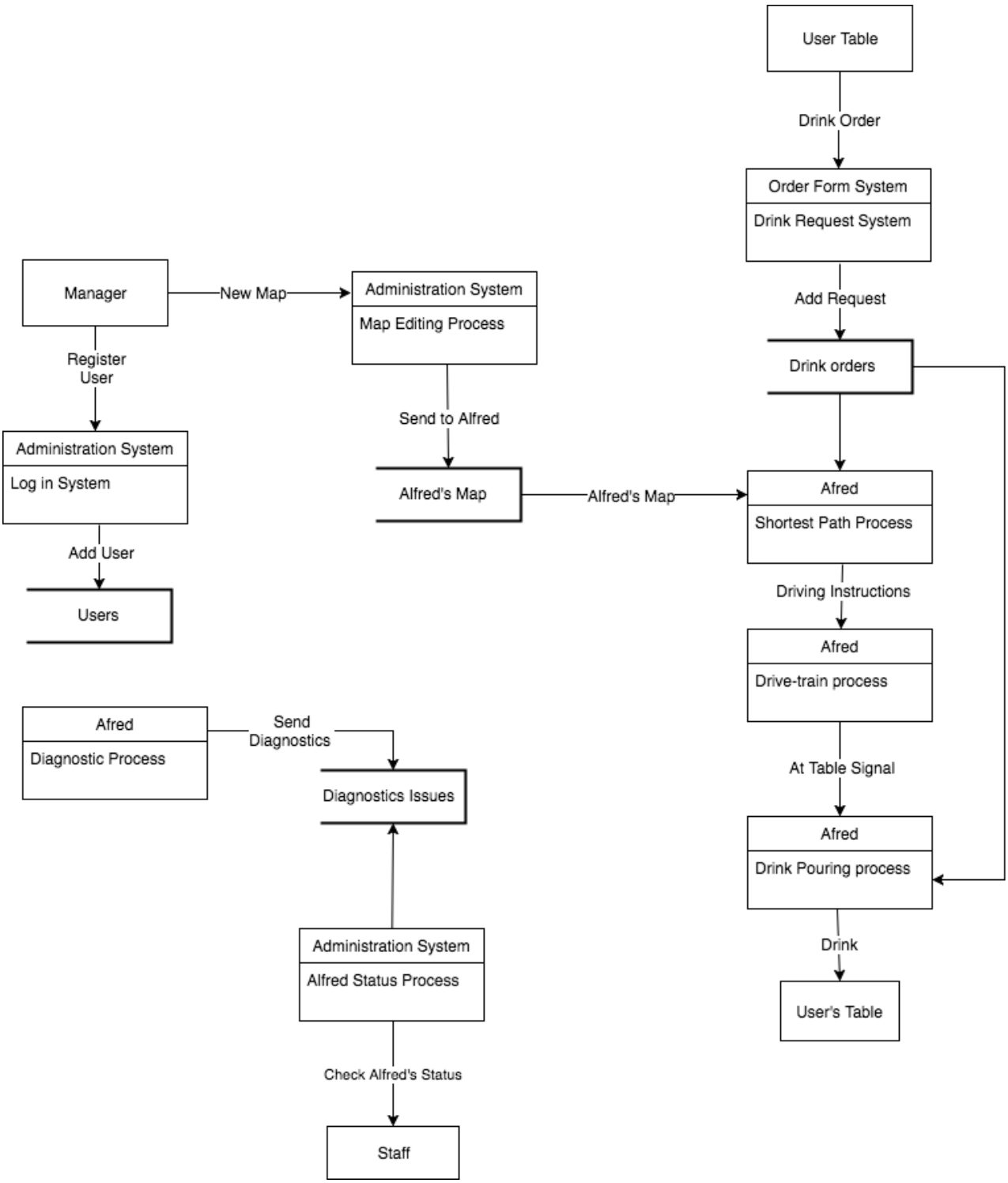

Figure 4: Alfred Data Flow Diagram

6 Functional Requirements

The following are the functional requirements of the project. They are separated into 3 main components: drink serving robot (Alfred), ordering and administration.

6.1 Alfred Functional Requirements

AF1	Alfred must 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 must 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 must be able to navigate to a table that corresponds to a specific drink order. Such that: OrderList(TO) -> T, G(T) -> path = {N1, N2 ...}
Rationale	Alfred should be able to move autonomously.

AF4	Alfred must be able to pour the correct drinks corresponding to the specific tables order. Such that: DrinkList(TO) = Drinks = {D1, D2 ...}
Rationale	This is so that Alfred will be able to pour the drinks for the customers without the need for any human interference.

AF5	Alfred must be able to dispense the correct amount for the drink based on the size of the cup specified. Such that: m_{cup}= $m_{DrinkMin}$ +h
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 must be able to determine when liquids within storage containers are not within the desired temperature range. Such that: $ErrorTemp = T_{min} < T_{Container} < T_{max}$
Rationale	In order to ensure that the drinks served meet FDA food regulation standards.

AF7	Alfred must 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 must be able to determine if any of the liquids within the storage containers are below the desired supply levels. Such that: $ErrorContainer = m_{ContainerMin} < m_{container}$
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 must 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 must be able to determine if an obstacle is in its path and come to a timely stop. Such that: S_{robot} = Speed(P_{right}, P_{left}, $D_{objects}$) where if $D_{objects} < D_{Min}$ -> $S_{robot} = 0$
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 low power levels. Such that: $ErrorLowPower = V_{batt} < V_{min}$
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 must be able to navigate back to the designated home base at any given point in time. Such that: G(H) -> path = {N1, N2 ...}
Rationale	To ensure safety of the customers and 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 must 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 must 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.

6.2 Table Ordering Application Functional Requirements

TO1	The Ordering Application must 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 must 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.

6.3 Administrator Application Functional Requirements

AD1	The Administrator Application must 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 must 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 must 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 must 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.

AD5	The Administrator Application must be able to view Alfred's current liquid status and modify the drinks offered.
Rationale	To ensure that staff are well informed of the drinks offered and what drinks are needed when resupplying the liquid containers.

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 Alfred 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 must 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 must not have any exposed electronic wiring.
Rationale	To ensure user safety.
NFR3	Alfred must be at the appropriate table height.
Rationale	To ensure user safety when Alfred is moving and to allow ease of use.

8.1.2 Style Requirements

NFR4	Alfred must 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 must 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 must 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 must 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 must 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 must 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 must 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 must be able to pour a drink within 30 seconds.
Rationale	Approximate time for a person to dispense a drink.
NFR13	Alfred must 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 Alfred's speed is not significant enough to cause harm or damage.
NFR14	Alfred must 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 must 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 must 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 must not dispense a drink if supplies are not within the desired temperature range.
Rationale	To abide by FDA standards (40 degreed Fahrenheit) and to ensure user safety.
NFR18	Alfred must 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 must 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 must 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 must 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 must not allow liquid containers to leak.
Rationale	In the case that Alfred 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 must be able to store 2 Litres of each 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 must 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. The layout of the restaurant will have to me created as well as training to all staff on how the system runs and is maintained.

8.3.8 Longevity Requirements

NFR25	Alfred must be able to keep drinks cold for 8 hours.
Rationale	To ensure that Alfred 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

NFR26	Alfred must be able to determine if certain functions cannot be completed.
Rationale	To ensure that error reports are clear and concise.
NFR27	Alfred must be able to determine the cause of a malfunction.
Rationale	To ensure that error reports are clear and concise.
NFR28	Alfred must 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

NFR29	The Administrator Application must 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 must 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 must encrypt all information.
Rationale	To ensure information security and prevent information loss during communication.

8.6.3 Privacy Requirements

NFR32	The ordering system must not display any information about other tables' drink orders.
Rationale	To ensure information is kept private.
NFR33	The system must use basic authentication protocols for the Administrator Application and Oauth protocols for communication between the client and Alfred.

Rationale	To ensure information is kept private.

8.6.4 Audit Requirements

- N/A

8.6.5 Immunity Requirements

NFR34	Alfred must have a cooling chamber to prevent drinks from large increases in temperature.
Rationale	To ensure that Alfred abides by the FDA standards (74 degrees Fahrenheit give or take 5 degrees) 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 must follow food and safety regulations.
Rationale	To ensure that the restaurant is not at risk of failing public health inspections.
NFR36	Alfred must not perform any actions that can be perceived as discriminatory to the user.
Rationale	To ensure that all users are comfortable using Alfred.
NFR37	Alfred must not serve 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 must 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 Alfred to move at the desired speed.

(ii) Rotation of Alfred 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 Alfred must not exceed $750. A breakdown of the individual part costs are 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.