

**DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING
THE UNIVERSITY OF TEXAS AT ARLINGTON**

**SYSTEM REQUIREMENTS SPECIFICATION
CSE 4316: SENIOR DESIGN I
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**MECHAMOCHA
ERBIE**

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1 PRODUCT CONCEPT

This section describes the purpose, use and intended user audience for Erbie. Erbie is a robot that dispenses Arabic coffee in a manner consistent with consumer expectations. Operators of Erbie will be able to reduce their overhead costs by using the product to replace paid employees.

1.1 PURPOSE AND USE

A service robot that goes around the room serving Arabic coffee to guest.

1.2 INTENDED AUDIENCE

The intended audience would be middle eastern homeowners, cafe houses, and special event hosts.

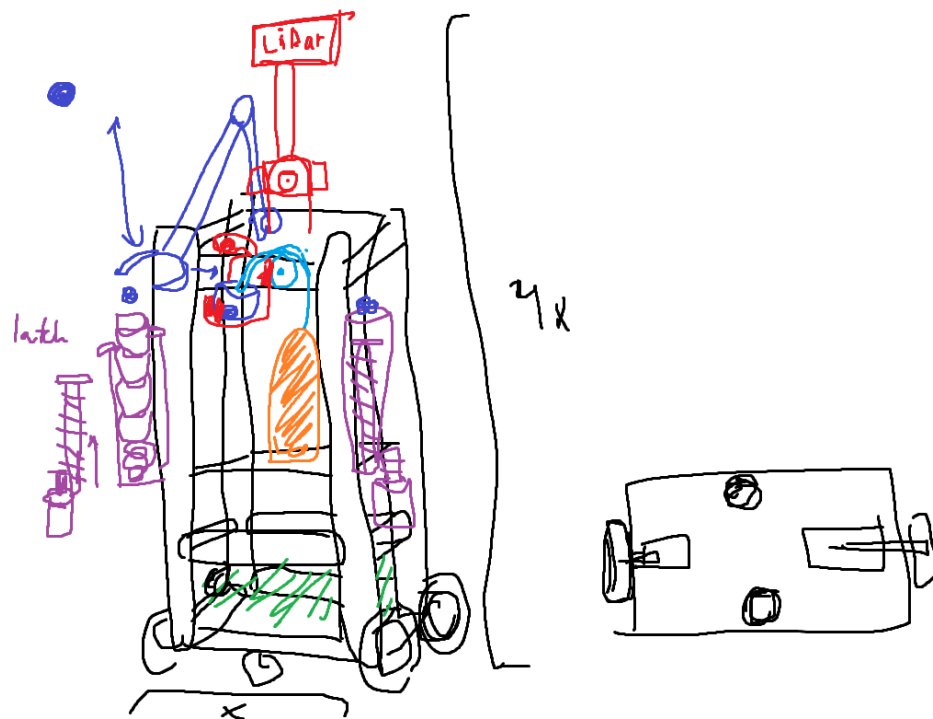


Figure 1: Drawing of robot design

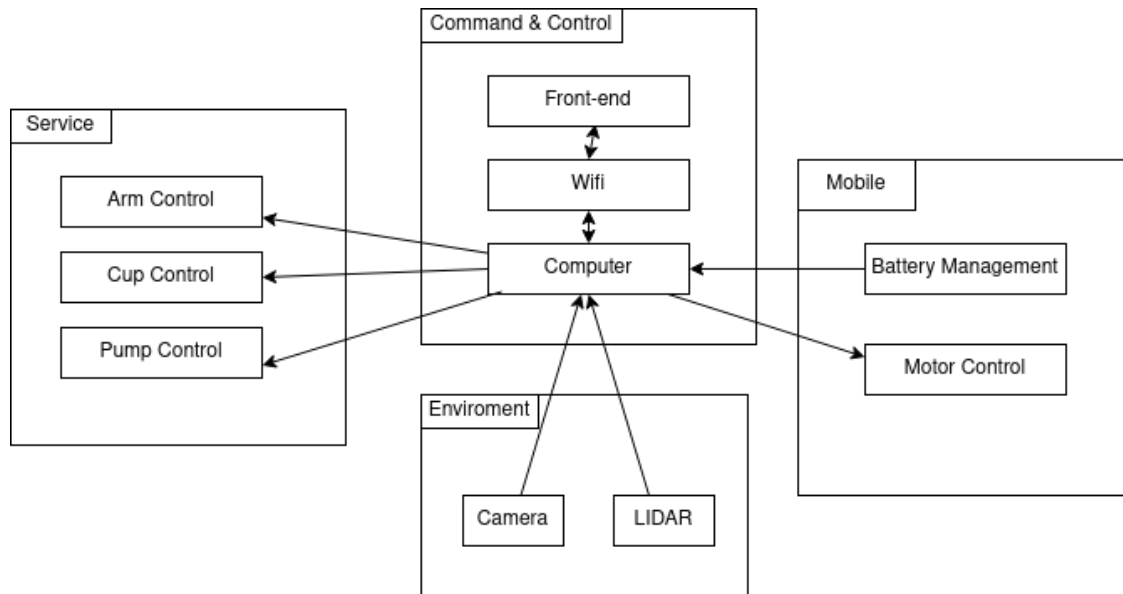


Figure 2: Layer design

2 PRODUCT DESCRIPTION

This section provides the reader with an overview of Erbie. The primary operational aspects of the product, from the perspective of end users, maintainers and administrators, are defined here. The key features and functions found in the product, as well as critical user interactions and user interfaces are described in detail

2.1 FEATURES & FUNCTIONS

Figure 1 shows a conceptual diagram of the robot. The green area would contain the central computer along with the batteries and motors. To the right you see the wheel layout where a Segway like design is used with quickly pivoting wheels for stabilization. The orange container is the reservoir which will contain the coffee. Above it in blue is the pump which will deliver the coffee to the cup. In purple you can see the cup feeding system that uses a screw design to push cups up and down in storage. In dark blue is the robots arm which will be used to move the cups between the designed points for service, storage, and presentation to the end user. in red you can see our external sensor system which consists of two camera which will detect gestures and recognize how much coffee is in the collected cup. And further on top of that would be our LIDAR sensor which is used to monitor the state of the environment.

2.2 EXTERNAL INPUTS & OUTPUTS

Figure 2 shows all 4 layers and the subsequent components. Below is the tabular description of Figure 2's data flow.

Data flow			
Name	Input	Output	Usage
Computer	1080p video, point cloud, battery state, REST API	Arm, cup, pump commands REST API	Provide the brain of the robot
Wifi	REST API	REST API	Connection to the end user
Front-end	REST API	REST API	Show the end user the state of the battery and if service is needed
Camera	N/A	1080p video	Collect information about the world
LIDAR	N/A	point cloud	Collect information about the world
Battery Management	N/A	Battery State	Collect information about the remaining battery
Motor Control	Control signal for H-bridge	N/A	Command the motors to move
Arm Control	Control signal	N/A	Control the robotic arm
Cup Control	Control signal	N/A	Control the motors on the cup dispenser/storage
Pump Control	Control signal	N/A	Control how much coffee is dispensed

2.3 PRODUCT INTERFACES

Figure 3 is the expected front-end design.

Components:

Battery left - A sliding bar showing the current remaining battery

Coffee left - A sliding bar showing the coffee remaining in the reservoir

Number of cups left - A count of the current clean cups left in the dispenser

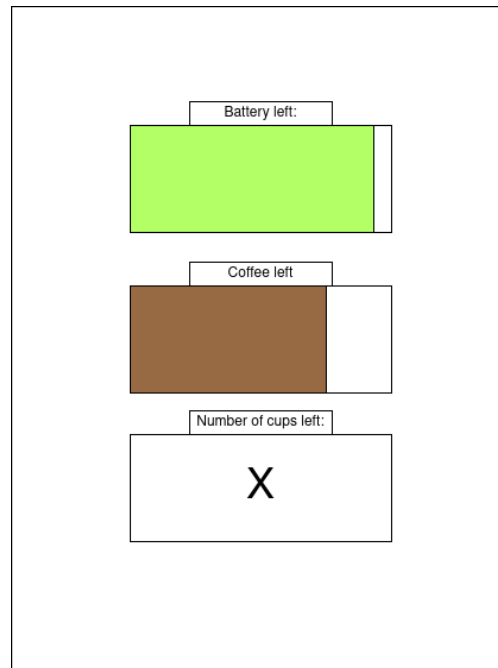


Figure 3: UI design

3 CUSTOMER REQUIREMENTS

Arabic coffee is served according to specific rules that arise from cultural customs. Consumers of Arabic coffee expect the servers and serving establishment to adhere strictly to these rules; failure to do so may cause offense. Erbie will serve Arabic coffee in a manner that is safe, convenient, and desired by customers.

Requirements are listed here in order of importance, which is designated as follows:

- Critical (must have or product is a failure)
- High (very important to customer acceptance, desirability)
- Moderate (should have for proper product functionality);
- Low (nice to have, will include if time/resource permits)
- Future (not feasible in this version of the product, but should be considered for a future release).

3.1 STORAGE OF COFFEE

3.1.1 DESCRIPTION

Erbie shall store hot coffee in an insulated container. The container shall be secured to the robot so that it cannot fall or spill coffee. The container shall have a covering that allows coffee to be removed from it when desired while preventing coffee from spilling if the robot falls on its front, back, or sides. The container shall be removable to facilitate cleaning and refilling.

3.1.2 SOURCE

This requirement is derived from known consumer expectations.

3.1.3 CONSTRAINTS

As discussed in Section 6, the container must be made of food-safe materials. Due to the use of very small cups to serve Arabic coffee, it can be expected that the robot might remain in the serving area for a significant length of time before its container is refilled. The container must therefore be very well-insulated. It is likely that a commercial product will be used to fulfill this role.

3.1.4 STANDARDS

Arabic Coffee Service Protocol [?]

3.1.5 PRIORITY

Critical

3.2 DISPENSING OF COFFEE

3.2.1 DESCRIPTION

Erbie shall dispense hot coffee into an empty cup that has been given to it by a consumer who desires a refill or into a cup that will be given to a new consumer. Erbie shall not overfill a cup or splash coffee outside of the cup during the dispensing process.

3.2.2 SOURCE

This requirement is derived from known consumer and operator expectations.

3.2.3 CONSTRAINTS

As discussed in Section 6, all components which touch the coffee must be made of food-safe materials. The device used to move coffee from the container to the cup must be able to regulate the amount of coffee dispensed. If tubing is used, its length must be minimised and it must be insulated to prevent the coffee remaining in it from becoming cold between servings.

3.2.4 STANDARDS

Arabic Coffee Service Protocol [?]

3.2.5 PRIORITY

Critical

3.3 NAVIGATION AND MOVEMENT

3.3.1 DESCRIPTION

Erbie shall remain near or patrol around a designated serving area until one of the following conditions is detected:

- It is signaled to return to a storage or servicing area
- It is signaled by a customer who desires an initial serving, a refill, or who is finished drinking coffee
- Its battery is nearly out of charge
- It is out of coffee
- It is out of clean cups
- It cannot accept any more dirty cups

Erbie shall not require active control over its movement beyond initial configuration, preprogrammed route(s), preprogrammed serving/storage locations, and orders given to it to begin a general task (e.g. "move to serving area," or "return to storage area"). Erbie shall navigate around obstacles or wait for their removal from its path.

3.3.2 SOURCE

This requirement is derived from known consumer and operator expectations.

3.3.3 CONSTRAINTS

A computer vision solution is necessary to determine the location of obstacles and potential paths around them.

3.3.4 STANDARDS

Arabic Coffee Service Protocol [?]

3.3.5 PRIORITY

Critical

3.4 INTERPRETATION OF CONSUMER INTENT

3.4.1 DESCRIPTION

Erbie will determine when it has been signaled to approach a consumer. When given a cup by a consumer, Erbie shall determine whether the consumer desires a refill or wishes for Erbie to keep the cup. The determination shall be made by observing the cup while it is being returned. Shaking of the cup or covering the rim with a hand shall indicate that the consumer does not desire a refill.

3.4.2 SOURCE

This requirement is derived from known consumer expectations.

3.4.3 CONSTRAINTS

A computer vision solution is necessary to determine consumer intent. As one who serves Arabic coffee is not supposed to talk or be talked to, voice recognition cannot be used to satisfy this requirement.

3.4.4 STANDARDS

Arabic Coffee Service Protocol [?]

3.4.5 PRIORITY

High

3.5 ACCEPTANCE/MOVEMENT/RETRIEVAL OF CUPS

3.5.1 DESCRIPTION

When accepting cups from consumers, Erbie shall extend an implement that the cup may be placed on or into. Erbie shall use that implement to store or refill the cup as required. The same implement shall be used to retrieve and fill a cup for a new consumer.

3.5.2 SOURCE

This requirement is derived from known consumer expectations.

3.5.3 CONSTRAINTS

Articulation of additional joints on a robot arm exponentially increases the difficulty of controlling said arm. A simplified arm, however, cannot take as many paths to reach as many positions as a more complex arm could, and therefore might require more complicated machinery elsewhere on the robot to fulfill this requirement.

3.5.4 STANDARDS

Arabic Coffee Service Protocol [?]

3.5.5 PRIORITY

High

3.6 STORAGE OF CUPS

3.6.1 DESCRIPTION

Erbie shall store enough clean cups to serve one table. Erbie shall store the same amount of dirty cups.

3.6.2 SOURCE

This requirement is derived from known consumer and operator expectations.

3.6.3 CONSTRAINTS

Increasing the number of stored cups will increase the weight of the robot and may complicate cup retrieval. Clean and dirty cups must be stored separately, which requires the use of two separate storage containers or areas. The number of cups stored must be tracked to prevent attempting to overfill a container or running out of cups.

3.6.4 STANDARDS

Arabic Coffee Service Protocol [?]

3.6.5 PRIORITY

Moderate

3.7 MONITORING SOFTWARE

3.7.1 DESCRIPTION

Erbie shall interface with monitoring software that is capable of displaying necessary information and statistics to an operator. Erbie and the monitoring software shall be capable of back-and-forth communication.

3.7.2 SOURCE

This requirement is derived from known consumer and operator expectations.

3.7.3 CONSTRAINTS

Creation of user-friendly monitoring software requires a substantial amount of work.

3.7.4 STANDARDS

Designing Software that is Accessible to Individuals with Disabilities [?]

3.7.5 PRIORITY

Moderate

3.8 CUSTOMER IDENTIFICATION AND CHARGING

3.8.1 DESCRIPTION

Erbie shall identify consumers based on their seat within the serving establishment and shall communicate information about products served to the monitoring software. The monitoring software will determine the amount of money to charge a consumer.

3.8.2 SOURCE

This requirement is derived from potential operator expectations.

3.8.3 CONSTRAINTS

Because the intent of Erbie is to replace a human server, it is necessary for the product to somehow track the amount of money a consumer owes. Given the current scope of development (proof-of-concept) and the available time and resources, this requirement is not presently feasible.

3.8.4 STANDARDS

N/A

3.8.5 PRIORITY

Future

3.9 SPICE DISPENSER

3.9.1 DESCRIPTION

Erbie shall dispense spices and/or other additional ingredients into a served cup of coffee if requested by a consumer.

3.9.2 SOURCE

This requirement is derived from consumer expectations.

3.9.3 CONSTRAINTS

The dispensing of spices requires the addition of multiple different containers and dispensing mechanisms. If included in the product, these must be physically separate from each other to prevent contamination of cups not deliberately spiced. Given the current scope of development (proof-of-concept) and the available time and resources, this requirement is not presently feasible.

3.9.4 STANDARDS

N/A

3.9.5 PRIORITY

Future

4 PACKAGING REQUIREMENTS

Erbie will consist of two components. The first and most visible component is the robot itself, which shall be delivered preassembled and loaded with all necessary firmware and software. The second component is the monitoring software, which shall be available to operators for download. Any additional components provided (e.g. extra batteries or cups) shall be separately packaged and delivered to the operator.

4.1 ASSEMBLY

4.1.1 DESCRIPTION

The robot shall be fully assembled prior to delivery.

4.1.2 SOURCE

This requirement is derived from operator expectations.

4.1.3 CONSTRAINTS

Special packaging/transportation arrangements must be made if the robot is to be shipped to a customer not in the immediate area. The robot must not contain cups or coffee during shipping, and the installed battery must be disconnected.

4.1.4 STANDARDS

N/A

4.1.5 PRIORITY

Critical

4.2 SOFTWARE DOWNLOAD

4.2.1 DESCRIPTION

The monitoring software shall be made available online to operators. Source code and debug information shall not be delivered to the customer as part of the product, but release will be considered for educational purposes.

4.2.2 SOURCE

This requirement is derived from operator expectations.

4.2.3 CONSTRAINTS

It may be necessary to run or rent a server to provide access to the monitoring software.

4.2.4 STANDARDS

N/A

4.2.5 PRIORITY

Critical

4.3 SOFTWARE INSTALLATION

4.3.1 DESCRIPTION

The monitoring software shall be easily installed and run by the operator, or shall not require installation.

4.3.2 SOURCE

This requirement is derived from operator expectations.

4.3.3 CONSTRAINTS

A lack of installation implies the use of a scripting or interpreted language, which potentially implies more difficult access to low-level operating system features.

4.3.4 STANDARDS

Designing Software that is Accessible to Individuals with Disabilities [?]

4.3.5 PRIORITY

Moderate

4.4 ADDITIONAL ITEMS

4.4.1 DESCRIPTION

Additional or extra items (e.g. extra batteries) shall be provided if ordered by an operator.

4.4.2 SOURCE

This requirement is derived from operator expectations.

4.4.3 CONSTRAINTS

An inventory of spare parts and extra items must be maintained, and a system must be set up for ordering and tracking them. Given the current scope of development (proof-of- concept) and the available time and resources, this requirement is not presently feasible.

4.4.4 STANDARDS

N/A

4.4.5 PRIORITY

Future

5 PERFORMANCE REQUIREMENTS

Performance requirements of Erbie have been determined in consideration of operator/consumer satisfaction and safety.

5.1 RECHARGEABLE BATTERIES

5.1.1 DESCRIPTION

The robot component of Erbie shall be powered by a rechargeable battery pack. The battery pack shall not be charged while within the robot.

5.1.2 SOURCE

This requirement is derived from known consumer and operator expectations.

5.1.3 CONSTRAINTS

Rechargeable batteries are a potential fire hazard and require the use of charging equipment.

5.1.4 STANDARDS

Rechargeable Battery Safety Guidelines [?]

5.1.5 PRIORITY

Critical

5.2 BATTERY LIFE AND REPLACEMENT

5.2.1 DESCRIPTION

When new, the battery packs used by Erbie shall provide no less than 30 minutes of continuous use in normal conditions. The battery pack within the robot shall be replaceable within no more than five minutes to minimize interruption of the consumer experience.

5.2.2 SOURCE

This requirement is derived from known consumer and operator expectations.

5.2.3 CONSTRAINTS

Rechargeable batteries are a potential fire hazard and require the use of charging equipment. A longer battery life would reduce the number of battery packs that an operator must purchase. A shorter battery life would reduce the weight of the robot and improve efficiency.

5.2.4 STANDARDS

Rechargeable Battery Safety Guidelines [?]

5.2.5 PRIORITY

High

5.3 BATTERY CHARGE MONITORING

5.3.1 DESCRIPTION

Erbie shall monitor the amount of charge remaining on the installed battery pack and return to a serving area when less than 5% of it is left. Erbie shall communicate its remaining charge level to the monitoring software. The monitoring software shall alert the operator when notified of a low charge condition.

5.3.2 SOURCE

This requirement is derived from known operator expectations.

5.3.3 CONSTRAINTS

Depending on the rate of use, a warning at 5% remaining charge might not be soon enough. The exact charge level at which to alert/return is subject to change.

5.3.4 STANDARDS

Rechargeable Battery Safety Guidelines [?]

5.3.5 PRIORITY

High

5.4 MAXIMUM WEIGHT

5.4.1 DESCRIPTION

The robot shall weigh no more than 15 kilograms when fully loaded with cups and coffee.

5.4.2 SOURCE

This requirement is derived from consideration of structural components, drive system components, maximum speed requirement, and battery life requirement.

5.4.3 CONSTRAINTS

After the results of testing an initial prototype are considered, it may become necessary to save weight by reducing the strength of structural components, reducing the amount of stored coffee, or reducing the size of the battery pack.

5.4.4 STANDARDS

N/A

5.4.5 PRIORITY

High

5.5 SPEED AND ACCELERATION

5.5.1 DESCRIPTION

When not navigating near persons or objects, Erbie shall move at a speed of between $1.0m/s$ and $1.5m/s$ and shall accelerate at a rate between $1.0m/s^2$ and $1.2m/s^2$.

5.5.2 SOURCE

This requirement is derived from consideration of drive system components, battery life requirement, the average walking speed and acceleration of a person, and safety requirements.

5.5.3 CONSTRAINTS

Additional weight will likely decrease the maximum speed of the robot. Meeting this requirement may require the use of larger motors, which will in turn hinder meeting the weight requirement.

5.5.4 STANDARDS

Guidelines for Robotics Safety [?]

5.5.5 PRIORITY

Medium

5.6 AMOUNT OF STORED COFFEE

5.6.1 DESCRIPTION

Erbie shall store a maximum of no less than 1L of hot coffee.

5.6.2 SOURCE

This requirement is derived from known consumer and operator expectations.

5.6.3 CONSTRAINTS

See section 3.

5.6.4 STANDARDS

N/A

5.6.5 PRIORITY

Medium

6 SAFETY REQUIREMENTS

As Erbie handles coffee, it must comply with all applicable food safety rules and regulations. Erbie is being developed as a proof-of-concept for an audience which may partially come from out of state, and therefore will initially comply with federal regulations only.

6.1 FOOD SAFETY

6.1.1 DESCRIPTION

All components of Erbie which come into contact with food shall be made of food-safe materials that retain their properties at or are rated for use at temperatures up to 100 degrees Celsius.

6.1.2 SOURCE

Federal Law

6.1.3 CONSTRAINTS

Food-safe materials must be sourced. Materials used must be FDA-approved.

6.1.4 STANDARDS

Inventory of Food Contact Substances Listed in 21 CFR [?]

6.1.5 PRIORITY

Critical

6.2 ELECTRICAL SAFETY

6.2.1 DESCRIPTION

All electrical components shall be shielded from splashes and spills.

6.2.2 SOURCE

Consumer and operator safety.

6.2.3 CONSTRAINTS

Due to the potential for overheating, watertight compartments may not be used.

6.2.4 STANDARDS

N/A

6.2.5 PRIORITY

Critical

6.3 MOVEMENT SAFETY

6.3.1 DESCRIPTION

Erbie shall immediately cease movement of the robot when it is in danger of striking a person or object. Erbie shall cease movement of any appendages when it is in danger of striking a person or object.

6.3.2 SOURCE

Consumer and operator safety.

6.3.3 CONSTRAINTS

Cessation of movement might not be sufficient to maintain safety. The inclusion of an alerting mechanism such as an audible warning may become necessary during the development process.

6.3.4 STANDARDS

OSHA Guidelines for Robotics Safety in Industry [?]

6.3.5 PRIORITY

Critical

7 MAINTENANCE & SUPPORT REQUIREMENTS

Maintenance of Erbie will typically consist of replacement of motors, servos, batteries, and wheels. Replacement of controlling ICs and computer vision peripherals may also become necessary.

7.1 PARTS LIST

7.1.1 DESCRIPTION

A full parts list shall be included with Erbie so that replacement parts may be ordered by the operator.

7.1.2 SOURCE

This requirement is derived from known operator expectations.

7.1.3 CONSTRAINTS

This will not cover custom 3d-printed parts.

7.1.4 STANDARDS

N/A

7.1.5 PRIORITY

High

7.2 3D-PRINTED PART DESIGNS

7.2.1 DESCRIPTION

Design files for 3d-printed components will be made available with the Erbie monitoring software download.

7.2.2 SOURCE

This requirement is derived from known operator expectations.

7.2.3 CONSTRAINTS

Design files used must be compatible with the printers used in UT Arlington's Makerspace.

7.2.4 STANDARDS

Product Definition for Additive Manufacturing [?]

7.2.5 PRIORITY

High

7.3 USAGE GUIDE

7.3.1 DESCRIPTION

A brief guide to the use of Erbie robot and monitoring software will be made available with the Erbie monitoring software download.

7.3.2 SOURCE

This requirement is derived from known operator expectations.

7.3.3 CONSTRAINTS

This will not cover custom 3d-printed parts.

7.3.4 STANDARDS

N/A

7.3.5 PRIORITY

High

7.4 FAQ/TROUBLESHOOTING MANUAL

7.4.1 DESCRIPTION

A troubleshooting manual with FAQ section will be made available with the Erbie monitoring software download. The manual will source the experiences of the engineers during product development.

7.4.2 SOURCE

This requirement is derived from known operator expectations.

7.4.3 CONSTRAINTS

This manual will not cover all potential scenarios.

7.4.4 STANDARDS

N/A

7.4.5 PRIORITY

Medium

7.5 TOOLING LIST

7.5.1 DESCRIPTION

A list of tools required for expected maintenance will be made available with the Erbie monitoring software download.

7.5.2 SOURCE

This requirement is derived from known operator expectations.

7.5.3 CONSTRAINTS

N/A

7.5.4 STANDARDS

N/A

7.5.5 PRIORITY

Medium

8 OTHER REQUIREMENTS

Minor configuration of Erbie and its operating environment will be necessary for proper operation.

8.1 WI-FI CONNECTION

8.1.1 DESCRIPTION

A Wi-Fi connection must be available at the operating location in order for the robot to communicate with the monitoring software.

8.1.2 SOURCE

This requirement is derived from the design of the product.

8.1.3 CONSTRAINTS

The robot will not be able to communicate to the monitoring system if it is out-of-range.

8.1.4 STANDARDS

IEEE 802.11 Wireless Standards [?]

8.1.5 PRIORITY

High

8.2 MONITORING SOFTWARE COMPATIBILITY

8.2.1 DESCRIPTION

The monitoring software shall be usable on Windows 10/11, Mac, and debian-based Linux systems.

8.2.2 SOURCE

This requirement is derived from a desire to prevent a potential operator from rejecting a product that is incompatible with existing computer infrastructure.

8.2.3 CONSTRAINTS

Creation of user-friendly monitoring software that runs identically on multiple operating systems requires an even more substantial amount of work. Given the current scope of development (proof-of-concept) and the available time and resources, this requirement is not presently feasible.

8.2.4 STANDARDS

N/A

8.2.5 PRIORITY

Future

9 FUTURE ITEMS

The following requirements and functions were considered, but cannot be implemented in the current iteration of development.

9.1 CUSTOMER IDENTIFICATION AND CHARGING

9.1.1 DESCRIPTION

Erbie shall identify consumers based on their seat within the serving establishment and shall communicate information about products served to the monitoring software. The monitoring software will determine the amount of money to charge a consumer.

9.1.2 SOURCE

This requirement is derived from potential operator expectations.

9.1.3 CONSTRAINTS

Because the intent of Erbie is to replace a human server, it is necessary for the product to somehow track the amount of money a consumer owes. Given the current scope of development (proof-of-concept) and the available time and resources, this requirement is not presently feasible.

9.1.4 STANDARDS

N/A

9.1.5 PRIORITY

Future

9.2 SPICE DISPENSER

9.2.1 DESCRIPTION

Erbie shall dispense spices and/or other additional ingredients into a served cup of coffee if requested by a consumer.

9.2.2 SOURCE

This requirement is derived from consumer expectations.

9.2.3 CONSTRAINTS

The dispensing of spices requires the addition of multiple different containers and dispensing mechanisms. If included in the product, these must be physically separate from each other to prevent contamination of cups not deliberately spiced. Given the current scope of development (proof-of-concept) and the available time and resources, this requirement is not presently feasible.

9.2.4 STANDARDS

N/A

9.2.5 PRIORITY

Future

9.3 ADDITIONAL ITEMS

9.3.1 DESCRIPTION

Additional or extra items (e.g. extra batteries) shall be provided if ordered by an operator.

9.3.2 SOURCE

This requirement is derived from operator expectations.

9.3.3 CONSTRAINTS

An inventory of spare parts and extra items must be maintained, and a system must be set up for ordering and tracking them. Given the current scope of development (proof-of- concept) and the available time and resources, this requirement is not presently feasible.

9.3.4 STANDARDS

List of applicable standards

9.3.5 PRIORITY

Future

9.4 MONITORING SOFTWARE COMPATIBILITY

9.4.1 DESCRIPTION

The monitoring software shall be usable on Windows 10/11, Mac, and debian-based Linux systems.

9.4.2 SOURCE

This requirement is derived from a desire to prevent a potential operator from rejecting a product that is incompatible with existing computer infrastructure.

9.4.3 CONSTRAINTS

Creation of user-friendly monitoring software that runs identically on multiple operating systems requires an even more substantial amount of work. Given the current scope of development (proof-of-concept) and the available time and resources, this requirement is not presently feasible.

9.4.4 STANDARDS

N/A

9.4.5 PRIORITY

Future

REFERENCES

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