February 5th, 2019
Dr. Craig Scratchley
School of Engineering Science
Simon Fraser University
British Columbia, V5A 1S6

RE: ENSC 405W/440 Requirements Specification for FoodSavr

Dear Dr. Scratchley,

The attached document specifies the requirements for our capstone project, the FoodSavr. Our goal for this project is to help people minimize the amount of food that gets wasted on a daily basis. FoodSavr is an autonomous robotic system that easily allows a user to keep track of what food they have in their home.

This document aims to list all requirements associated with our product including software, mechanical, electrical and more. They will be categorized as proof of concept, prototype, and final design to clarify our timeline for this project. Besides the general requirements, a list of engineering standards is included for which our product will conform to. Finally, a thorough analysis on the sustainability and safety of our product can be found at the end of this document, an important aspect to any device used within the home.

Our team at Savr Robotics would like to thank you in advance for taking the time to review this document. If there are any raised concerns or questions, feel free to contact me at loshaugh@sfu.ca.

Sincerely,

Liam O'Shaughnessy
Chief Executive Officer
Savr Robotics

Requirements Specification

Smart Food Storage Device

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Abstract:

With a growing sense of global responsibility, consumers are now looking at their lifestyles and finding ways, small and large, to lessen their negative impact and increase their positive impact on the world.

FoodSavr is an automated food tracking device that aims to address these growing concerns while saving money for the consumer. It will make use of robotics and image processing to aid the user in dealing with their grocery-bought items. From the moment foodstuff arrives on your counter, it will track the item along with its expiration date and amount to help with inventory management. It will prevent redundant purchases and food spoilage by providing an accessible, easy-to-use inventory list to reference during their next trip to the supermarket. It will also provide appropriate notifications when an item nears its expiration and will suggest ways to use the product.

This document lays out the numerous requirements needed to create such a product. It goes into detail of the System, Software, Mechanical, Electrical and Hardware requirements, providing justification and explanation of the requirements. It also discusses concerns with Engineering Standards and Sustainability and Safety and lays out requirements regarding these concerns.

With the requirements clearly stated and outlined, this document will provide a good reference during the product's development as well as detail what the product will do when finished.

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1. Introduction/Background

In recent times, consumers have enjoyed a surge in the variety and availability of various food products. Seasonal fruits and vegetables have now been a year-round staple, ever available in the produce aisle of the local grocery. Big-box retailers encourage consumers to buy large number of products with discounted prices.

With the arrival of the luxury of abundance and choices comes with its pitfall- waste, specifically food waste. The Food and Agriculture Organization of the United Nations have estimated that ⅓ of all food products are wasted. In North America, about 40% of the total food waste happens with the consumer, while 60% happens between the production and retailing life cycle of the products [1].

An increase in food waste also causes in an increase in harmful gas emissions. Landfills filled with food waste decompose and release methane gas, and they have become one of the largest contributors to greenhouse gases [2].

The aim of FoodSavr is to address the food waste on the consumer front by addressing the redundant product purchases and the eventual spoilage caused by unused or excessive food products.

There's currently no device on the market which organizes food items effectively and intelligently. We saw this as an opening to create a product which can be integrated into the home to easily catalog our food purchases. The FoodSavr can help consumers keep track of all the items in their fridge and pantry, as well as their expiry dates. The automation system we are creating will minimize user efforts in the cataloging process.

1.1 Scope

This document will outline each of the requirements of FoodSavr. It will also provide a system overview of the product, detailing the general architecture of the product's components. The document will contain points about the engineering standard that have provided a backbone to our initial design, as well as contain points about the sustainability and safety the product shall align with to be a viable and successful product.

1.2 Intended Audience

This document is written as a functional and structural requirement guide for the product, FoodSavr. The intended audience are the members of Savr Robotics, Craig Scratchley, Andrew Rawicz, teaching assistants, and any future partners or clients.

1.3 Requirement Classification

In this document, we are using the following qualifiers for each of our requirements:

Legend	Stage
C	Proof of Concept
E	Engineering Prototype
F	Final Product

2. System Overview

The FoodSavr system contains several electro-mechanical mechanisms. The main components include the object detection, mechanical arm, and camera system. The FoodSavr system is actuated when the pressure sensor detects an object placed on the base. The mechanical arm and LEDs will then be activated by the Arduino. The mechanical arm is controlled by different stepper motors to achieve the desired position. These motors are monitored by hall-effect sensors to provide position feedback. When the desired position is set, the camera system will be triggered through the Raspberry Pi to take an image. This image is then analysed on board in Raspberry Pi to extract barcode and expiry date information. The food item information will be transferred to the web server and displayed for the user. This system diagram is shown in figure 2.1

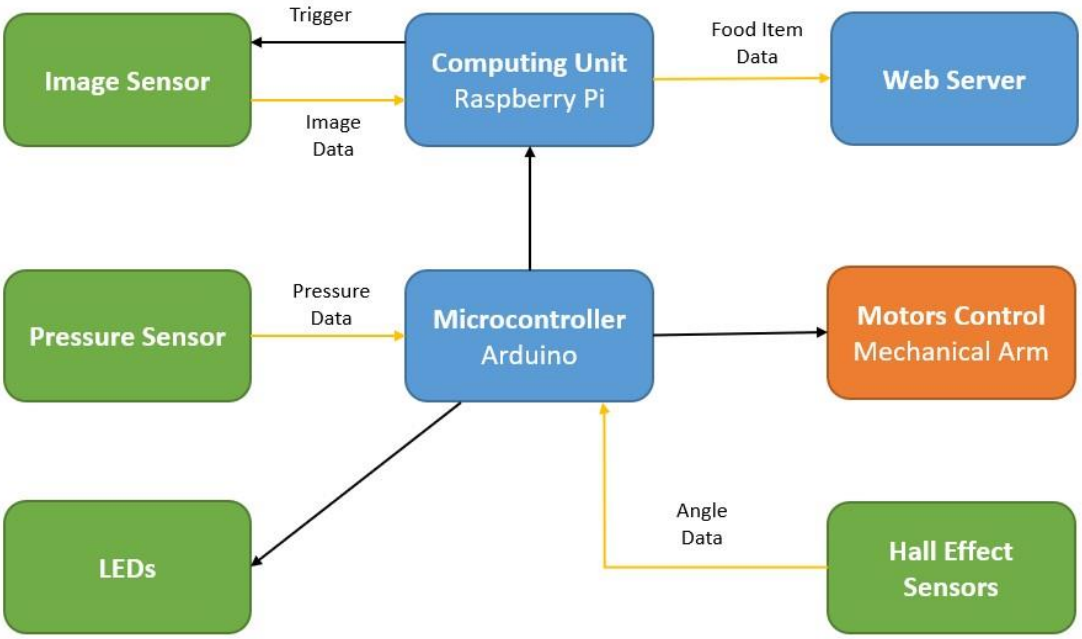

Figure 2.1: System Overview

3. General Requirements

The FoodSavr system aims to solve the problem of over-consumption, and over purchasing of food in the everyday household. This system is designed to automate the food inventory process inside a home. To achieve this process, the system is required to detect and analyze grocery items automatically and relay this information to the user in a coherent way. The following are general requirements for the FoodSavr system. More detailed requirements will follow in subsequent sections.

Table 3.1: General Requirements

3.1.1 – C	Device shall detect an object placed on the surface to start the scanning procedure
3.1.2 – E	Device shall maneuver the camera around the object
3.1.3 – C	Device shall scan object's surfaces for its barcode and expiry date
3.1.4 – E	Device shall keep track of all scanned items in an online database
3.1.5 – E	Device shall display all scanned items on a web User Interfaced
3.1.6 – E	If device fails to recognize item, an image of the item shall be stored on the database
3.1.7 – F	The device shall be able to fit on a countertop space

4. System Requirements

The FoodSvr device contains several electro-mechanical components, these components must work in parallel with one another. These include the mechanical component where the stepper motors are controlling the mechanical arm while receiving feedback from the hall effect sensors to adjust positions. In addition, there is the camera component where the image sensor and raspberry pi are working in conjunction with the Arduino to capture an image when the camera is at the right position. The object detection module containing the pressure sensor and Arduino microcontroller to activate the entire system. To achieve this, the Arduino will act as a controller for the entire system. Where all the signals and control must pass through this central controlling unit. An example flow chart is shown in figure 4.1

Table 4.1: System Requirements

4.1.1 – E	The device shall consist of an embedded raspberry pi computer, Arduino microcontroller, sensors, mechanical arm, LED lights
4.1.2 – E	The device shall monitor sensors to begin scanning procedure
4.1.3 – C	Arduino shall actuate and control the mechanical components
4.1.4 – C	Raspberry Pi shall be able to communicate to image sensor
4.1.5 – E	The device shall be able to transmit data over WiFi

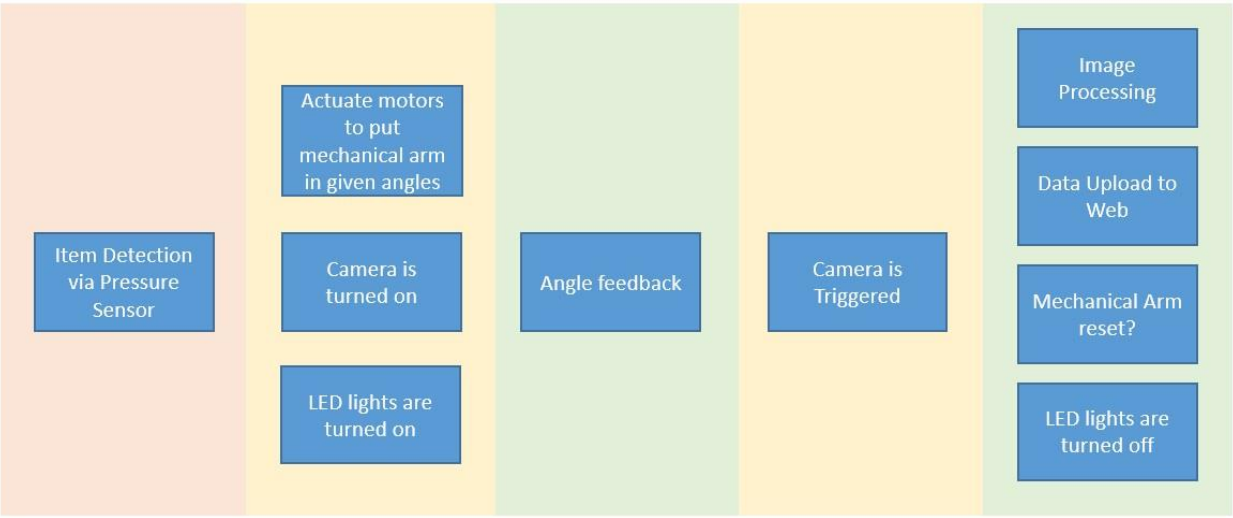

Figure 4.1: Flow diagram of FoodSavr System

5. Software Requirements

The device will need to have a central operating system to handle GPIO interrupts from the Arduino as well as perform time sensitive image processing. Since the device will be driven by a Raspberry Pi based platform, Raspbian OS is the logical choice.

Table 5.1: General Software Requirements

5.1.1 – C	Device shall be capable of running Raspbian operating system
5.1.2 – C	Device shall handle all incoming GPIO interrupts from the microcontroller
5.1.3 – E	Device shall have software-based image processing capabilities
5.1.4 – E	Device shall be able to store data and upload to a web server with a web UI
5.1.5 – E	System shall suggest recipes for soon to expire items on the web interface

5.1 Image Processing Requirements

Image processing will be the most taxing software component on the system when extracting the barcode and expiry date from a food item. It will be done using python modules for optical character recognition. Processing will be performed immediately after all required images have been captured. This will allow the user to get an update on whether the scanning process had succeeded or not. The image processing time is critical in our product.

Table 5.2: Image Processing Requirements

5.2.1 – C	Device shall be able to identify a barcode from an image
5.2.2 – C	Device shall be able to identify an expiry date from an image

5.2 User Interface Requirements

Once an image has been processed, the extracted data will be stored locally on the device and will update the entries in the server's database. When the user accesses the web page interface, there will be a recipe suggestion based on the items listed.

Table 5.3: Image Processing Requirements

5.3.1 – E	The UI shall display a list of all scanned food items
5.3.2 – E	The UI shall show name, expiry date, unit of scanned items
5.3.3 – E	The UI shall allow users to manually edit/delete items
5.3.4 – E	The web page shall use an ingredients API to suggest recipes

6. Mechanical Requirements

The mechanical arm shall contain four degrees of freedom. The first degree of freedom allows the arm to rotate 360 degrees around the base of the device. The second and third degree of freedom will allow the robotic arm to move vertically. The fourth degree of freedom allows the camera unit to tilt forward or backwards.

The device shall withstand grocery items of maximum size of 35cmx35cmx45cm and maximum weight of 5 kilograms. All items larger than the threshold should be manually entered by the user. This design requirement is selected through comparing size of common grocery items and the available space for a countertop.

Table 6.1: Mechanical Requirements

6.1.1 – E	The device shall contain mechanical arm segments
6.1.2 – E	Device shall control four motors, each motor controls one degree of freedom for the robotic device
6.1.3 – C	The motors shall move smoothly to minimize vibrations induced to the system and the camera, in particular
6.1.4 – C	The camera shall be held stable to capture clear image
6.1.5 – E	The camera shall attach to the arm’s last joint
6.1.6 – E	The device shall contain a base
6.1.7 – C	The base shall contain a pressure sensor for object detection
6.1.8 – E	The device shall be able to scan items up to the size of 35cm x 35cm base and a height of 45cm
6.1.9 – E	The device shall be able to safely support a weight of 5 kg
6.1.10 – F	All the components shall securely mount together with a case

7. Electrical Requirements

For this product, the power mainly come from onboard power supply and the power management unit on the Raspberry Pi. The Raspberry Pi will supply power for all the peripherals.

Table 7.1: Electrical Requirements

7.1.1 – C	The Raspberry Pi shall take 5V/2.5A DC via micro USB connector, or 5V DC via GPIO header as input voltage
7.1.2 – C	The image sensor Raspberry Pi Camera shall take 3.3V via 15 pin ribbon cable from a Raspberry Pi
7.1.3 – C	The arrays of LEDs shall take 3.1V 60mA individually
7.1.4 – C	The pressure sensor shall take 3.3V/5V from Raspberry Pi
7.1.5 – C	The hall effect sensor shall take 3.3V/5V from Raspberry Pi
7.1.6 – C	The stepper motors shall take 5V input from stepper motor driver break boards

8. Hardware Requirements

Table 8.1: Hardware Requirements

8.1.1 – E	The Raspberry Pi shall host the system that will process data coming from or sending out to all peripherals
8.1.2 – E	The Arduino microcontroller shall control the motors and sensors, then talk to Raspberry Pi to trigger the scanning process
8.1.3 – C	The LED lights shall turn on when the system is activated
8.1.4 – C	The pressure sensor shall detect when an object is placed on the base
8.1.5 – E	The image sensor shall take image of the items when the mechanical arm is placed in the desired angle
8.1.6 – E	The stepper motors (x4) shall control each link of the robotic arm
8.1.7 – C	The hall effect sensors (x4) shall monitor the angles for each joint of the robotic arm
8.1.8 – C	The motors shall be powered by an external source

9. Engineering Standard

Due to the electro-mechanical complexity of our product, it is crucial to follow proper standards for both the design and development process. As we plan on selling our product in the Canadian market and eventually in the global market, we must follow the standards of the International Organization for Standardization (ISO), and the international Electrotechnical Commission (IEC), as well as the Canadian Standards Authority (CSA). The development the product FoodSavr shall comply with the following engineering standards.

Table 9.1: Engineering Standard Requirements

9.1.1 – E	The device shall adhere to IEEE's Wireless Communication Standards: **IEEE 802.11,** the IEEE Standard for implementing wireless local area networks between computers in the 2.4GHz and 5GHz range [3] and **IEEE 802.15.1,** the IEEE Standard specification based on Bluetooth technology for portable devices [4]
9.1.2 – E	**CISPR 22: EN 55022** EMC Standard - information for information technology equipment, ITE for the radio disturbance characteristics for electromagnetic compatibility compliance
9.1.3 – E	**CAN/CSA-C22.2 NO. 60335-1:16** - Household and similar electrical appliances - Safety - Part 1: General requirements [5]
9.1.4 – E	**C22.1-18** Canadian Electrical Code, Part I (24th edition), Safety Standard for Electrical Installations [6]
9.1.5 – E	The mechanical arm design shall comply with the safety requirements of **ISO/TS 15066:2016** Robots and robotic devices -- Collaborative robots [7]
9.1.6 – E	**UL 1740** Standard for Robots and Robotic Equipment [8]
9.1.7 – E	**ISO/IEC JTC 1/SC 24** Computer graphics, image processing and environmental data representation [9]
9.1.8 – E	**IEC 60730**: Safety Standard for Household Appliances [10]

10. Sustainability and Safety

FoodSavr's main concern is to address the growing waste problem, it is important the development and production cycles, and the product itself are not detriments to the very problem it is trying to solve.

The development cycle's environmental impact is brought into account. In line with the cradle-to-cradle (C2C) design philosophy, the development of the product aims to fulfill C2C's certification criteria:

Criteria	Description
Material Health	Considerations are made regarding materials that make up the product. Materials that have a lower risk factor are prioritized
Material Reutilization	Materials that are reusable are sought after and are reused after the prototype's life cycle.
Assessment of Energy	Renewable energy is highly prioritized.
Water Stewardship	Usage of water must be monitored so that the water discharge or refuse is deemed safe and non-toxic.
Social Fairness	Fair Labour Practices must be followed and promoted.

For the device's major components, the 2 materials that are being considered for use, wood and 3D printing filaments.

From a safety standpoint, wood is considered suitable for direct food contact [10]. The biggest concern is often the build up of microbes and moisture on the wood's surface, but because our product will not have prolonged contact with a food product, this risk is minimized. In addition, wood in the food business is in the form of cutting boards or cooking stations, where the wear and tear resulting from the use of sharp utensils such as knives causes grooves to form on the wood's surface where microbes can collect, this is not the case for FoodSavr.

In terms of reuse, it is possible to reuse wood to a reasonable degree, it can be cut to smaller pieces and joined using food safe adhesive depending on the design needs. Thought must be given when distinguishing between adhesives that are deemed safe for *direct* or *indirect* food contact.

When the wood is not able to be reused in the next design, it can be disposed of as a biodegradable material thus minimizing the environmental impact of prototyping.

For the 3D printing material, the 2 most available variants are Acrylonitrile Butadiene Styrene (ABS) and Polylactic Acid (PLA). PLA is accepted to be “Recognized as Safe” for use in objects in contact with food [11] and is available in variants specifically made and labeled for use with food. On the other hand, ABS is not generally accepted as food safe, so if 3D printing is used, PLA material is prioritized. If one is unsure whether the material is safe, they must refer to the manufacturer’s data sheet where it will be stated if it’s rated for food.

Additionally, we must remember that the 3D printing machine, especially its nozzle must also be clear from any unsafe material, this often means that the nozzle needs to be replaced.

For both PLA, or any 3D printing material, reuse is difficult because trying to split it into smaller pieces can result it in shattering or deforming, and you can’t remold the material using conventional means. Despite this, most recycling facilities consider PLA to be a recyclable plastic and can be disposed of safely.

Canada is one of the largest producers of renewable energy, 60% of its electricity is produced from hydroelectricity [12]. BC itself has the 2nd largest hydroelectric capacity between the provinces. These factors must play into the choices made during the production stage of the product. It is also important to note the power consumption of the product itself, it will have a direct power supply, so it must minimize its use of electrical power when not in use.

Lastly, during production we want to make sure that all workers involved with FoodSavr are fairly treated and they follow the guidelines laid out by Worksafe BC in the form of the Workers Compensation Act.

With all these considerations, the following sustainability and safety requirements must be fulfilled:

Table 10.1: Sustainability Requirements

10.1.1 – E	Minimizing power consumption by switching to a low-power idle state if not in use
10.1.2 – E	Device shall use recyclable alternatives for materials when affordable and attainable options are present.
10.1.3 – P	Excess scraps and electronic materials will be brought to electronic recycling facilities to ensure parts are returned to the industry
10.1.4 – E	The casing of the device shall use PLA or other sustainable materials
10.1.5 – E	The materials used for the product shall be food-safe
10.1.6 – E	The device shall void of sharp edges that could harm its users as well as damage products to be scanned
10.1.7 – E	The device shall be resistant to any possible leakage or moisture from items

10.1.8 – E	The electronics shall be fully enclosed and under normal operating conditions shall not pose an electrical hazard.
10.1.9 – E	The device shall safely power off in the event where any electronic components overheat.

11. Conclusion

This document details the function requirements set out for FoodSavr, a product the team hopes can help with the reduction of consumer's total food waste and keep their food spending in check.

This requirements specification includes the System, Software, Mechanical, Electrical and hardware perspective which must work correctly individually and as a cohesive unit to accomplish FoodSavr's goal. The document goes into the team's reasoning behind the requirements. The adherence of the product with engineering standards as well as its sustainability and safety are also detailed and discussed. This document also includes an Acceptance test plan which can be used to evaluate the team's body of work, but also test its fulfillment of the previously laid out requirements.

It is important that these requirements are fulfilled to deliver a full working product, and the document aims to shed some light into FoodSavr's functionality.

12. References

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13. Acceptance Test Plan

This appendix document describes our acceptance test plan for the FoodSavr. This includes end to end system tests as well as specific module tests.

13.1 Mechanical Testing

The following tests will be performed on the mechanical components of the FoodSavr device, mainly the motors and arm.

Date:	**Test Name**: Arm Adjustment Test
Test Description: Ensure motors can properly drive the arm and can maneuver around food item with four degrees of freedom	
Expected Outcome: Once the scanning procedure has started, the mechanical arm should be able to move freely around the food item to reach its desired position.	
Actual Outcome:	

13.2 System Testing

The following tests will be performed on the system components of the FoodSavr device, concerning the inter-device communications.

Date:	**Test Name**: Sensors and Actuators Test
Test Description: Ensure each sensor is reading proper values to actuate its corresponding components. Such as the pressure sensor and the hall effect sensors.	
Expected Outcome: Pressure sensor should send signal to Arduino to activate the entire system. Hall effect sensors should monitor the arm positions and deliver feedback to Arduino.	
Actual Outcome:	

Date:	**Test Name**: Arduino and Raspberry Pi Communication
Test Description: Ensure the Arduino can send signals to Raspberry Pi in real time to activate camera.	
Expected Outcome: Once the mechanical arms have reached its desired position, the Arduino should immediately send signal to Raspberry Pi to activate the camera system.	
Actual Outcome:	

13.3 Software Testing

The following tests will be performed to ensure that the data extraction and upload work as intended.

Date:	**Test Name**: Data Extraction
Test Description: Once pictures have been taken by image sensor, the system will start processing images	
Expected Outcome: After images have been processed, the correct barcode number and expiry date should be correct.	
Actual Outcome:	

Date:	**Test Name**: Data Upload
Test Description: Once images have been processed, the data will be uploaded to the database	
Expected Outcome: Database should be updated with the barcode number and expiry date of the item	
Actual Outcome:	

13.4 User Interface Testing

The following test will be performed on the user interface to ensure users can easily view and edit their inventory list.

Date:	**Test Name**: View and Delete Items
Test Description: Once scanning procedure has completed and data has been sent to server, the user will access web page	
Expected Outcome: User should be able to see all items that have been scanned by the device and be able to remove them if desired	
Actual Outcome:	