S.P.I.C.E.

Critical Design Review

Salty Seniors

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1 Introduction

Disability is on the rise in the United States. Approximately 39 million Americans in all age groups suffer from motor impairment disabilities [1]. A large portion of this demographic includes adults aged over 60, as motor disability becomes more common with age. There's a great need for accessibility tools that give these groups the opportunity to cook for themselves. Considering the increase in adults over 60 in America who are living by themselves [2], as well as the large demographic of adults with motor impairments, there is no better time for development of a tool that can give back some independence.

S.P.I.C.E. is an automated spice dispenser designed to make cooking more accessible and convenient. One of the main goals of S.P.I.C.E. is to eliminate the need for complex dexterity in the measurement of spices. By providing an accessible and convenient way to dispense spices, this project has the potential to improve the quality of life for people with disabilities and older adults living alone. Overall, the development of S.P.I.C.E. is meant to simplify the cooking process and create a more convenient way for people to home cook meals.

As the development process of S.P.I.C.E. continues, several constraints need to be considered in order to ensure the final product meets the needs of its users. During the initial proposal, S.P.I.C.E. was set to include a minimum of four spices for testing. This has since been increased to 8 for completeness of the project scope. Another big constraint for S.P.I.C.E. is ease of use. As an accessibility tool, it's important that the end user is able to quickly understand the user interface and use S.P.I.C.E. effectively. Creating a tool that is over complicated would defeat the purpose of the project entirely. Therefore, physical components along with the user interface will be made with intuitiveness in mind. For example, the spice containers should attach and detach in a way that is easy for people to understand. Likewise, the user interface should guide users through the process of adding spices, dispensing spices, and selecting recipes.

In order to validate S.P.I.C.E., multiple tests will be done incrementally. The first round of testing will be done on individual components, ensuring that their purpose is fulfilled in an isolated environment. This provides the opportunity to fix issues at a component level before having to deal with issues on a product level that may arise from the connection of components. Next, S.P.I.C.E. will be tested as a complete system in order to validate its intended functionality. This will include measuring dispensing amounts as well as testing spice mixes When testing amounts of spice, a specific tolerance will be chosen in order to determine whether the test was passed or failed. For spice mixes, performance will be determined by time to complete and correctness of spices chosen. The last stage of validation will be done on the user interface and will test the natural flow of the user interaction. Changes at this level of validation will not change the functionality of S.P.I.C.E. but instead alter how users interact with the device.

It's important that S.P.I.C.E. performs its intended function well, but it's equally important to consider the accessibility features and ease of use. S.P.I.C.E. can be a valuable tool for anyone that loves cooking or wants to simplify the process. However, with a target demographic including people with motor impairments and adults over 60, it's important that S.P.I.C.E. fulfills the needs of its target demographic. Rather than being considered a novelty cooking appliance, this project seeks to empower those who may find cooking to be a difficult process.

2 Proposed design

2.1 Updates to the proposal design

Major Changes:

Container Change (Spice Bottle)

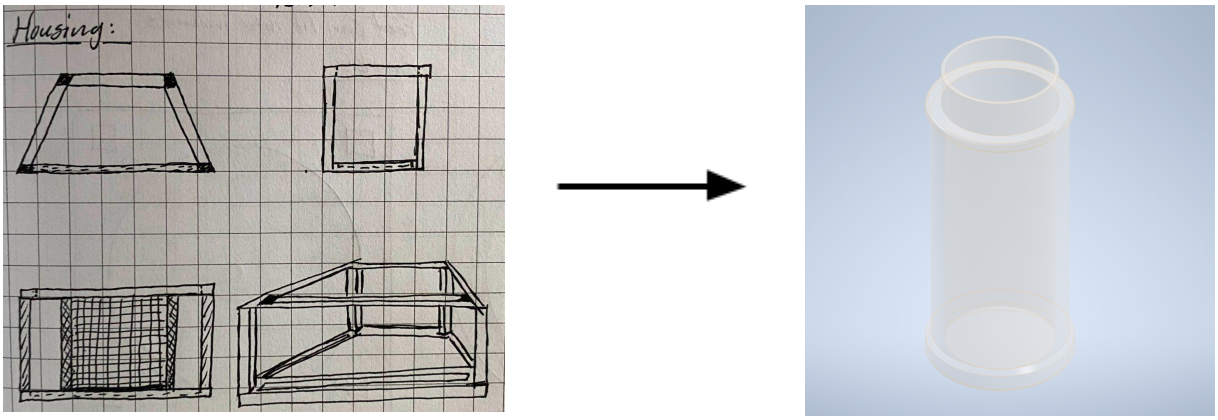


Figure 1: Design change for spice containers

The original container design for S.P.I.C.E. was a lightweight frame that would house clear polycarbonate sheets. This allowed for easy monitoring of spice levels as well as recognition of what spice was being dispensed. While there was nothing inherently wrong with the container, it added an additional level of complexity to S.P.I.C.E. In an attempt to simplify the design, the container has now been changed to something that does not need to be 3D printed. A commercial spice container! Fiesta brand specifically. This change accomplishes a couple things. First, the container is already approved for food, meaning that no additional coating or material will need to be added to it. Second, the change makes the connection between container and housing much simpler, and requires less time on the 3D printer. In conjunction with the changing of a couple other design features, this update will help keep the S.P.I.C.E. prototype timeline on track.

Changed Coupling System (Multiple Motors)

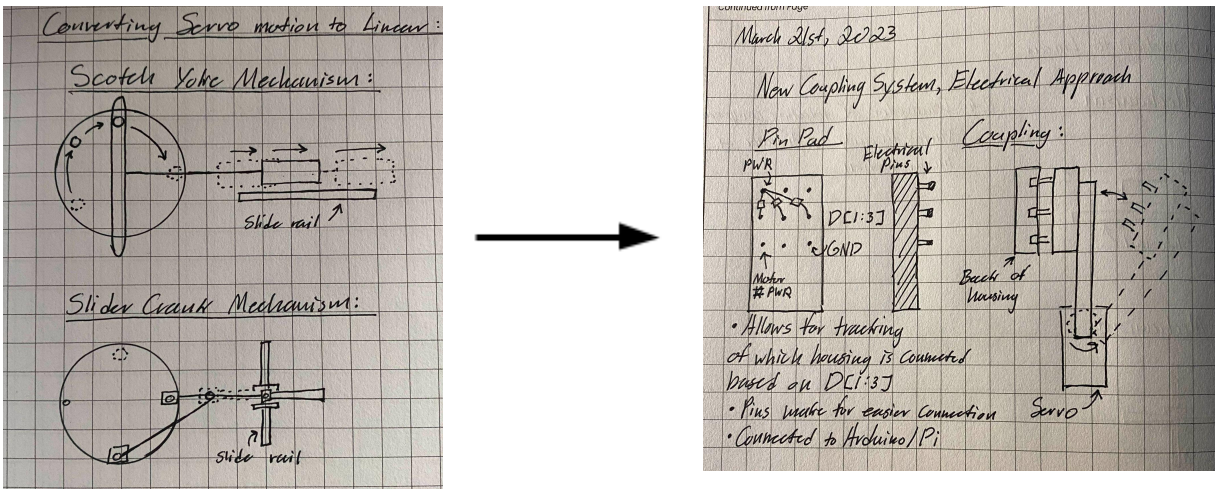


Figure 2: Design change for coupling change

Originally, S.P.I.C.E. was going to operate with two motors and one servo. By rotating the base and using a mechanical system to attach a driver motor to housings, S.P.I.C.E. would be able to effectively dispense a preset mixture of available spices. This approach however, leaned heavily on mechanical knowledge for the design and fabrication of the coupling system. Rather than investing in a mechanical system that could take an excessive amount of development time, the system was changed to something more appropriate for a computer engineering project. The new coupling system will have a simplified mechanical design, but include electrical pins that power individual motors now included in the housings. Additionally, the pins will be used to differentiate housings by giving feedback as to which container is in the dispensing position. This feature will also simplify the software requirements by eliminating a need to track container position on the base.

Using Multiple Motors (Each housing has motor)

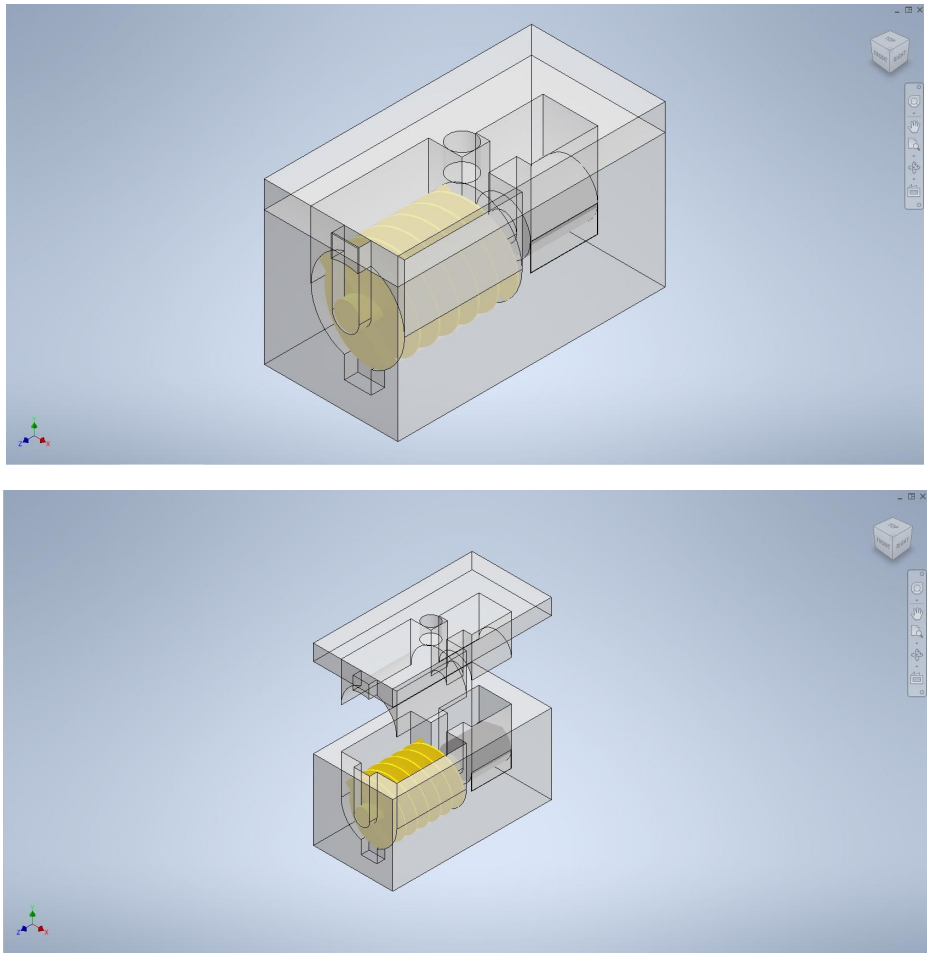


Figure 3: Housing change to include DC motor

As mentioned in the **Changed Coupling System** section, the housings have been changed to include a DC motor. The motor will be attached directly to the spice coil, eliminating the need for an additional drive shaft. However, this does add a level of complexity for the housing. Because there will be electrical components in the housing, it will be necessary to seal the motor portion off from spices. Additionally, the motor will need to either be removed when the housing is cleaned, or completely water-sealed. In the preliminary design above, we can see the separation between the motor and spice coil via a lid on the container. With only six available motors, another order will need to be made in order to meet the requirement of 8 housings.

Minor Changes:

Break Bearing Gear (4-Pieces)

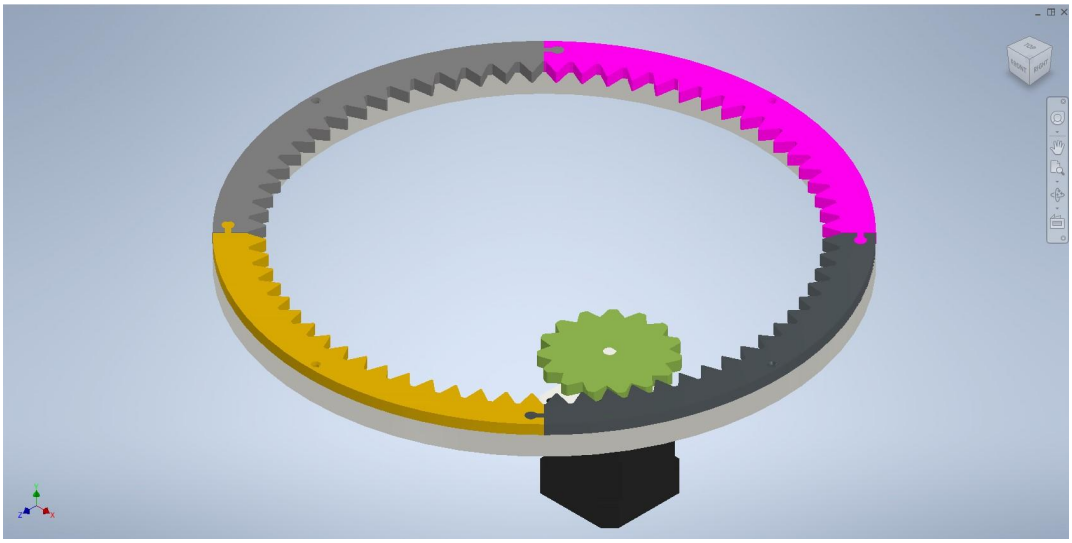


Figure 4: Bearing gear broken into multiple pieces

S.P.I.C.E. utilizes a 10 inch bearing table that the spice housings will be situated on top of. In order to drive the table, a large gear around the circumference will be driven by a smaller gear connected to a stepper motor. Originally, the gear was going to be fabricated in two parts. However, due to limitations of the 3D printer available, the gear will now be printed in four parts.

Updated Budget

Item	Quantity	Cost Per Item	Total Cost
Raspberry Pi Touch Screen	1	$63.99	$63.99
Brown PLA 1.75mm (1kg)	2	$19.99	$39.98
High Torque DC Motor	0	$30.72	$0.00
HDMI to Micro HDMI Adapter	0	$8.99	$0.00
4 Pack L298N Motor Controller	1	$11.59	$11.59
Bearing Table	1	$15.99	$15.99
20 kg Servo Motor	1	$12.99	$12.99
3D Printing Services ($/g)	2500	$0.03	$75.00
Total	$219.54		

Figure 5: Updated Budget Table

The budget has been updated as shown above in order to account for the additional cost of motors and services in the Fisher Engineering Design Center.

Motor Driver Power Change

Switched from a 5V power supply to a 9V power supply

The original 5V power on the motor driver would make the DC motor spin too slow. In order to fix this, the supply was changed to 9V. This voltage resulted in a speed that was too great for the purpose of S.P.I.C.E. However, that can easily be adjusted with the use of resistors.

Database for Recipes

Rather than using a search feature for recipes, S.P.I.C.E. will use a local database uploaded to the Raspberry Pi for its recipes. These recipes will be displayed in a list format that will allow users to easily see what is available to them. S.P.I.C.E. will most likely utilize a local Microsoft SQL database that can query recipes based on what spices are connected.

2.2 System description

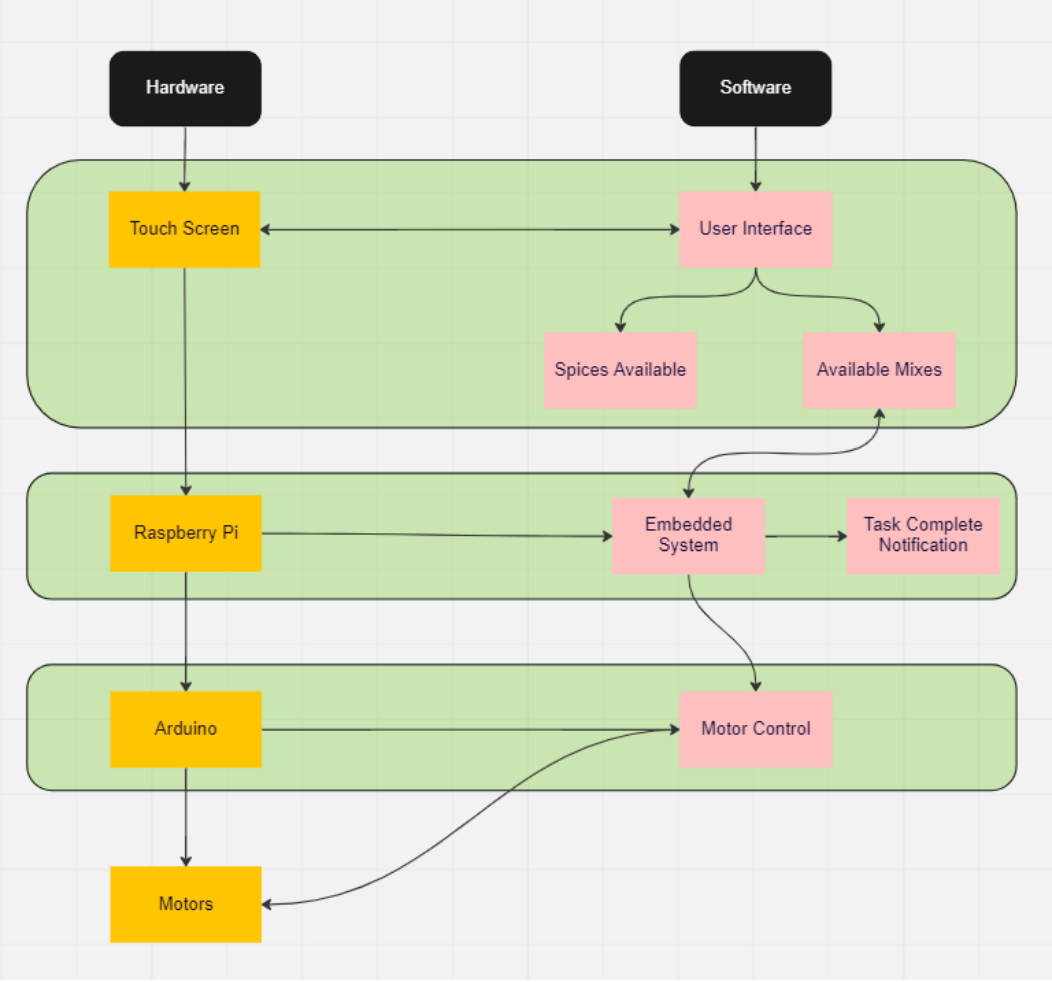


Figure 6: High Level Block Diagram

Touch Screen:

The touch screen acts as the main point of contact for users. It will display the user interface, and allow for users to interact with S.P.I.C.E. This is a key component of the project and will differentiate it from a few of the others from the literature review

Interface Buttons:

An alternative solution to the touch screen interface is physical buttons. This will give tactile feedback to users, making the interface more responsive.

Raspberry Pi:

The Raspberry Pi will be the brains of the device. It will give the user interface functionality on the back-end. The Raspberry Pi will also process human interactions and send the data to the Arduino which then controls the servo motors.

Arduino:

The Arduino will serve as the controller for all the servos and motors throughout the device. It will receive instructions from the Raspberry Pi on which servo motors to activate depending on the user input from the touch screen interface.

Motors:

The orientation motor will control which spice is being dispensed at a given time, while the distribution motors will drive the actual mechanism that accurately dispenses each individual spice for the user. Orientation and distribution are used as identifiers in this case and do not relate to any technical term for a type of motor. These motors will receive instructions exclusively from the Arduino microcontroller.

User Interface:

The User Interface (UI) is a key feature for accessibility and also serves as a point of interaction for users. Along with the touch screen, the UI provides all the necessary functionality needed for the user to record their data into S.P.I.C.E. for desired results. The user will be able to choose between two different options: “Recipes” and “Spices”. The “Recipes” option will be designed specifically for recipes on the web. Once a recipe is selected by the user, the UI will then display a summary of the recipes to be dispensed after parsing is complete. The user can then confirm that those are the correct spices, and then the system will dispense the spices as instructed. The “Spices” option accommodates users who just want to dispense custom quantities of spices, which is entirely independent of recipes. Upon selection, the UI will prompt the user to select the spices they intend to dispense. After the user selects their spices, they will be able to input the amount in teaspoons of each spice they want to dispense from the machine. An updated diagram of the UI is shown below:

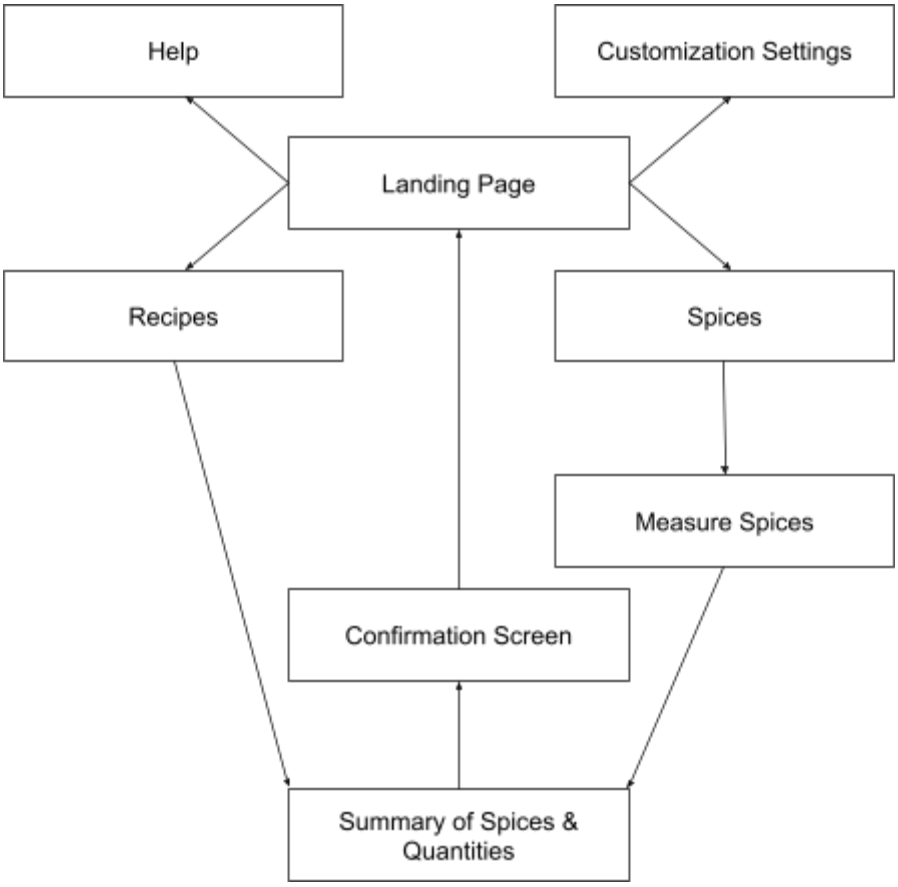


Figure 7: Updated S.P.I.C.E. User Interface

This project can be broken into two major elements: the hardware and the software. Ideally, this project can be executed with as little as: a motor controller, motors, well designed spice containers, and a previously mentioned carousel mechanism.

The goal is to utilize a raspberry pi to handle human interactions through the touch screen module. Then, translate those interactions into necessary instructions for the Arduino to interpret and relay to the corresponding motors.

2.3 Complete module-wise specifications

Circuit Diagram for Raspberry Pi, Arduino, and motor

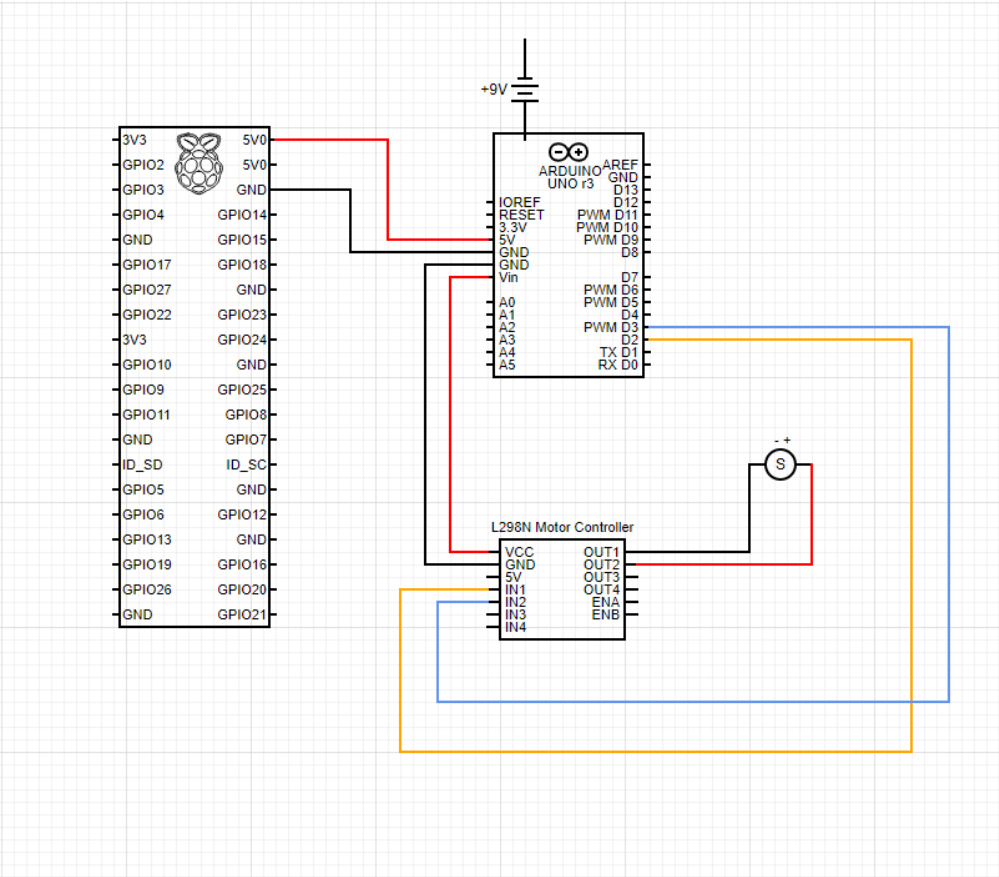


Figure 8: Circuit Diagram for Raspberry Pi, Arduino, motor connections

Interfaces and pin-outs

- The team decided to use a 7 inch 1024x600 touch screen to support the user interface. The touch screen will be powered through an HDMI to micro-HDMI cable and will operate under 5V.

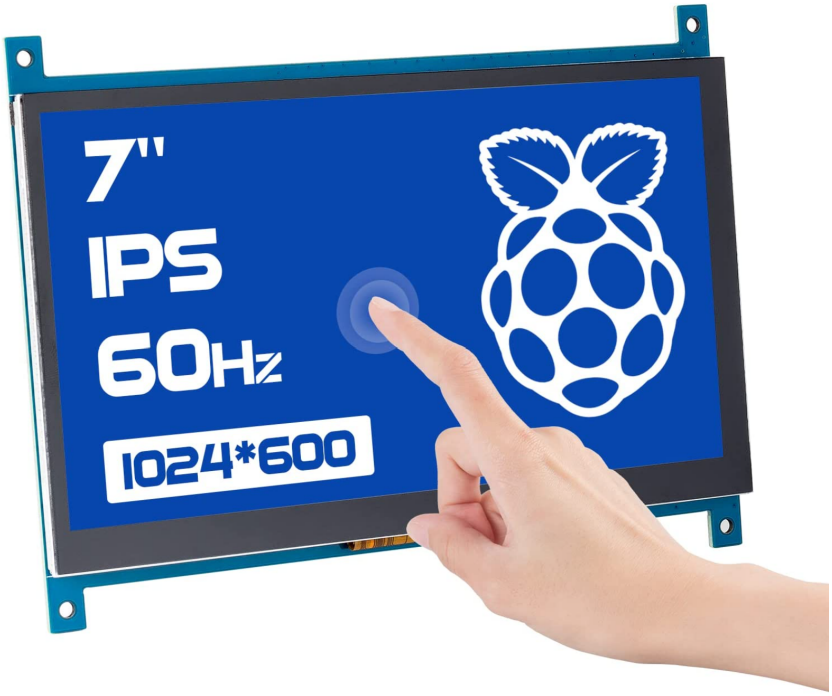


Figure 9: Touch Screen Component

UI Design:

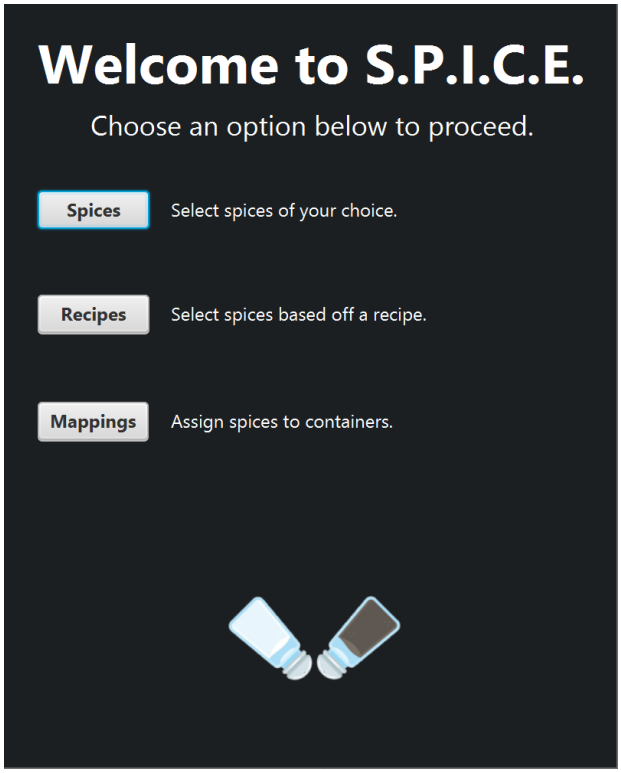


Figure 10: Landing Page

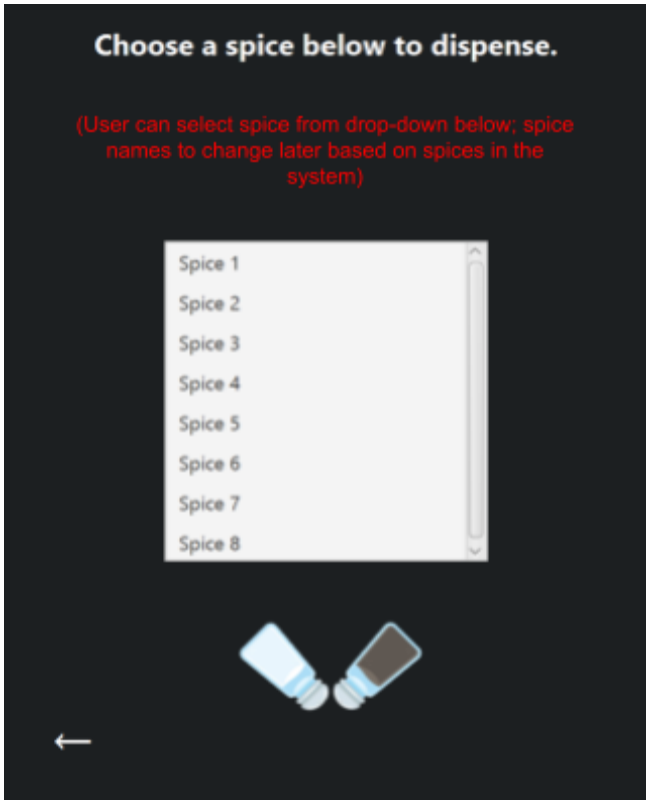


Figure 11: Spice Page

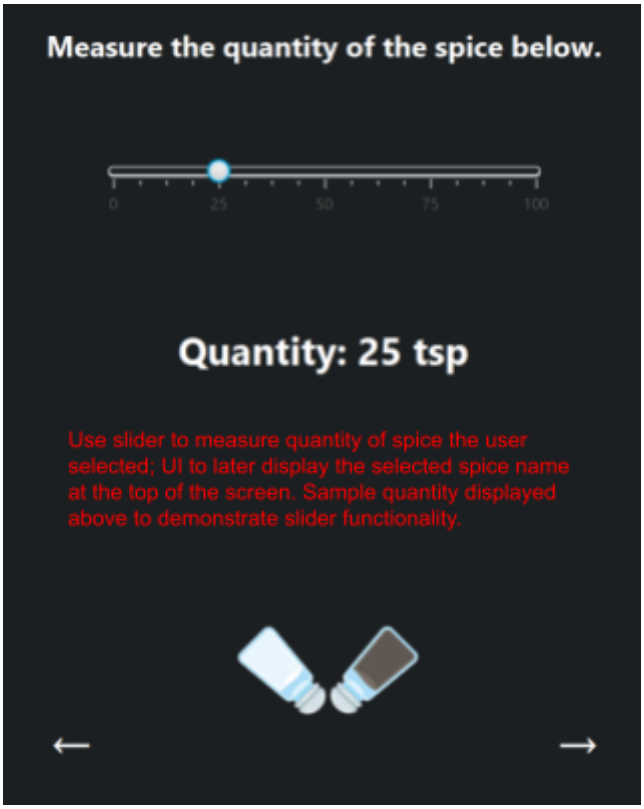


Figure 12: Measurement Page

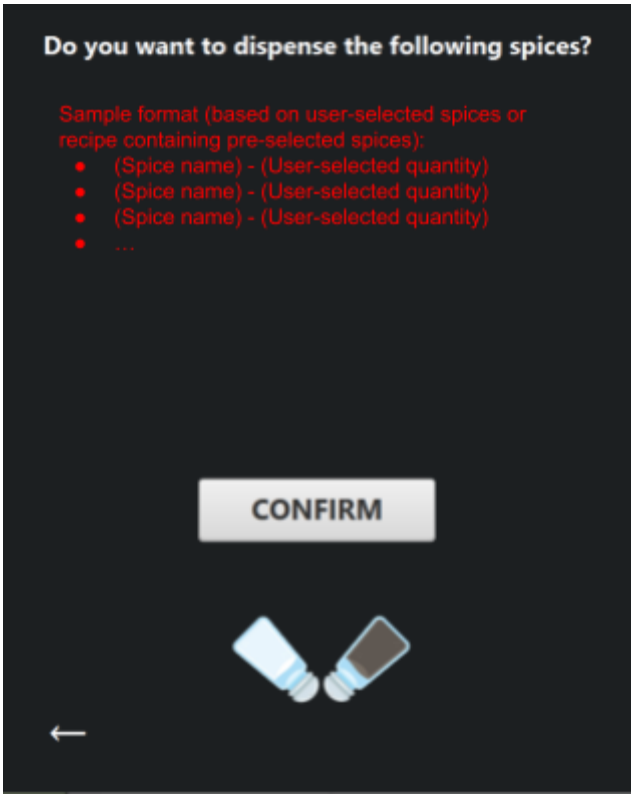


Figure 13: Confirmation Page

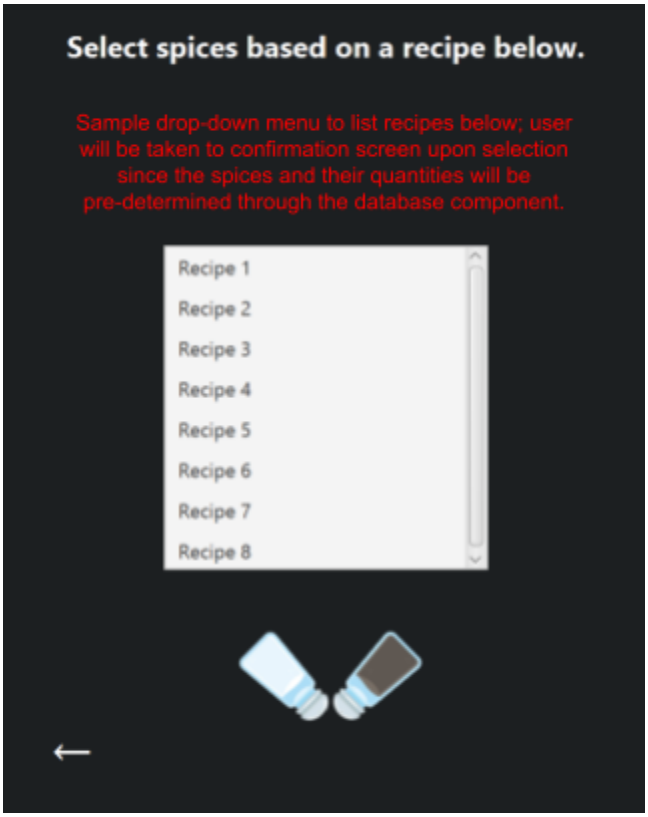


Figure 14: Recipe Page

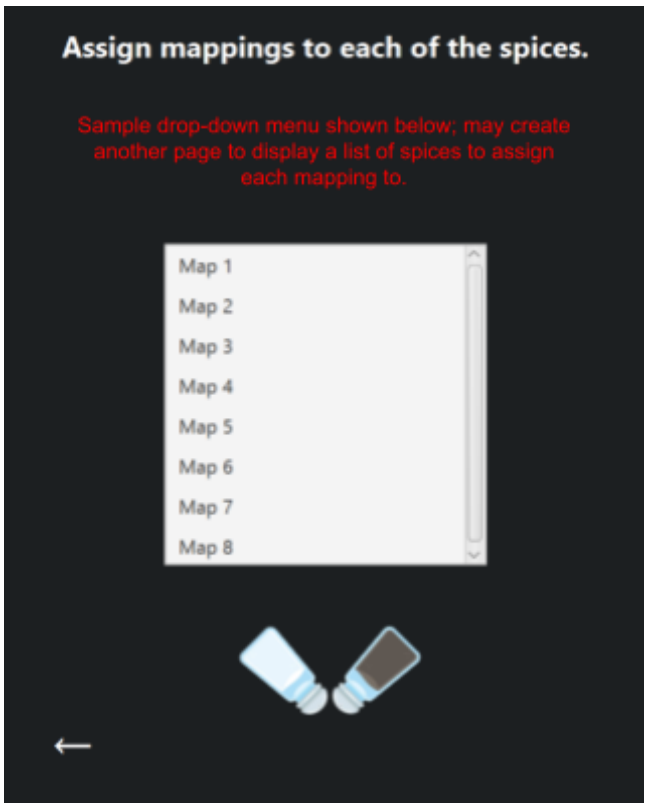


Figure 15: Mapping Page

Parts:

- Raspberry Pi Touch Screen (Quantity: 1)
- 1 kg Brown PLA 1.75 mm (Quantity: 1)
- High Torque DC Motor (Quantity: 2)
- Fiesta Brand Spice Containers (Quantity: 8)
- Bearing Table (Quantity: 1)
- 20 kg Servo Motor (Quantity: 1)
- 4 Pack L298N Motor Controller (Quantity: 1)

3 Project management

3.1 Updated implementation schedule

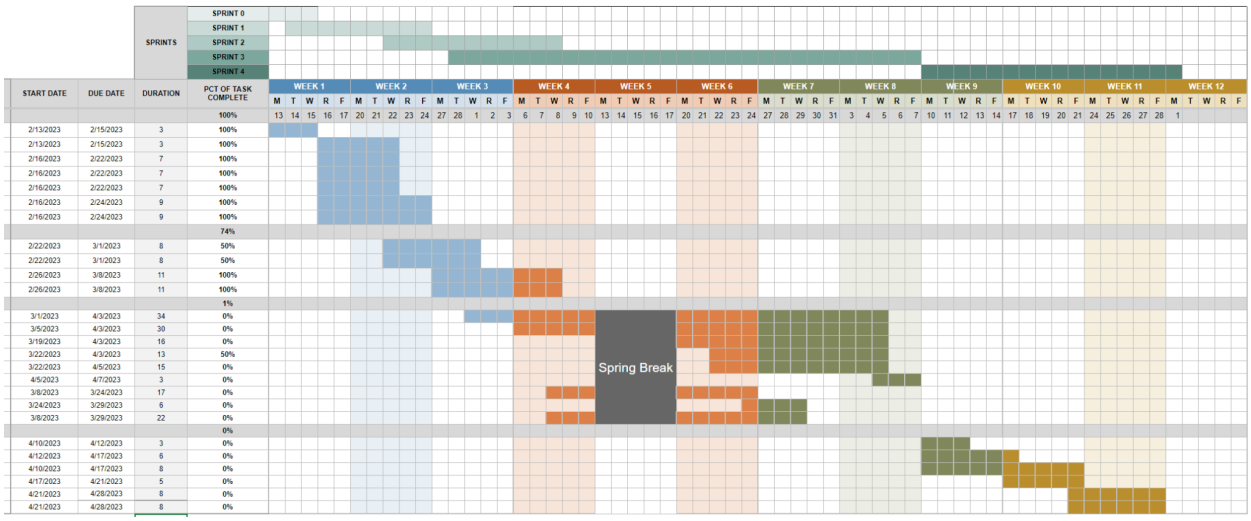


Figure 16: Updated Gantt Chart

Due to some design changes and fabrication limitations, Sprint 3 has been extended to April 7th and Sprint 4 has been shortened to three weeks. This should give the team adequate time to fabricate all parts, and connect them to the hardware components. Even though the overall time for validation has been reduced, time efficient testing should leave enough time for any last minute changes.

The team has continued to hold regular weekly meetings every Friday. These meetings have included project updates and discussion on individual roadblocks as intended. The addition of a meeting time outside of lecture gives the team flexibility with scheduling while maintaining a constant workflow. The tasks and the team's burndown chart have been updated accordingly in the Google Sheets Gantt chart shown above. This gives each team member the ability to track their progress individually and update the team during Friday meetings. Outside of class, the team's meetings have been held over their CSCE 483 Discord server. Documentation for all meetings was recorded in personal notebooks, the team google document, and Discord instant messages. Maintaining documentation in three places has been successful in ensuring that no design, idea, or personal thought was left out of discussion.

3.2 Updated validation and testing procedures

The validation process for S.P.I.C.E. will consist of multiple stages throughout the duration of development. This method is essential for successful development in the sense that waiting until the project is "finished" to perform testing could cost time if a major issue or bug is discovered as it would be difficult to pinpoint the exact location of the bug due to there being many components to examine. This method is organized in such a way that there are multiple factors to consider when designing this product based on the objectives and constraints the team set forth for this project. Such factors include accuracy, environment, and usability/accessibility.

The first round of tests will consist of ensuring that the UI meets the team's standards and constraints, as well as testing the hardware and mechanics of the system. Upon completion of the UI, it will be tested for accessibility and usability by recording the average time it would take to input data into the system as well as testing the functionality of each of the buttons and ensuring that they do what they are supposed

to. The hardware testing process will include tests to ensure that the base components themselves are working properly (motor, touchscreen, Raspberry Pi). This aspect is important to consider, or else there wouldn't be a working product since S.P.I.C.E. relies heavily on hardware to operate.

Durability will be another factor to perform tests on. In other terms, the team will perform tests on the product in the environment it is designed to operate in, which is a kitchen. These tests will be based on temperature and if the system doesn't physically malfunction at a normal kitchen temperature (65-75°F). The validation process in this category will consist of observing the behavior of the motors in the system. Since one of the main aspects of S.P.I.C.E. is for it to be a household kitchen product, durability is an important factor to take into consideration when validating the design of the product.

Accuracy is another important feature to test. This will require the hardware to be synchronized with the UI and touch screen. Tests will be performed on the system by taking various measurements of spices through user input and comparing the measurements generated by S.P.I.C.E. with handmade measurements in teaspoons. The margin of error between the two measurements must be no greater or no less than a tenth of a teaspoon. This is a critical aspect to validate, especially for the quality of food and recipes.

Finally, there will be a round of testing with the fully integrated system. While the components of the system would be individually validated beforehand, it is still crucial to test S.P.I.C.E. to its fullest potential to ensure that it is a product that satisfies the team's goals and solves the main problem identified by the team. More specifically, S.P.I.C.E. should function in a way that it makes cooking enjoyable for people who are living alone and those with motor disabilities. This means that it should be usable, accessible, operational, and accurate. These four main qualities will be accounted for when executing the final rounds of testing.

3.3 Updated division of labor and responsibilities

Role	Member(s)
Project Manager	Carlos Zapata III
Mechanical Design	
● Component Modeling ● Material Acquisition ● Hardware Placement	● Caleb Herrera, Carlos Zapata III ● Carlos Zapata III ● Caleb Herrera
Software Design	
● UI Designer ● Microcontroller Specialist ● Hardware Networking	● JP Bartsch ● Kile Zimmermann ● JP Bartsch, Kile Zimmermann
Validation Lead	JP Bartsch

With previous management experience in both academic and extracurricular activities, Carlos Zapata has been chosen to be project manager. The responsibilities of this position will include maintaining organization items such as: Gantt charts and burndown charts, as well as scheduling meetings. Additionally, Carlos will be assisting lead CAD designer Caleb Herrera with the design and fabrication of the mechanical components of S.P.I.C.E.

Caleb will be responsible for managing progress on hardware related tasks. He also has previous outside experience with Computer-aided Design (CAD) and arduino/raspberry pi style projects, so he will be contributing heavily to any microcontroller systems and 3D modeling when necessary.

JP has experience with front-end development and database systems and will manage the progress of the software design as well as designing a possible database to store all the recipes and designing a user interface. He will also be in charge of testing the product and integrating the touch screen with the software. This will include working on an easy-to-use interface that minimizes button-pressing as much as possible for convenience.

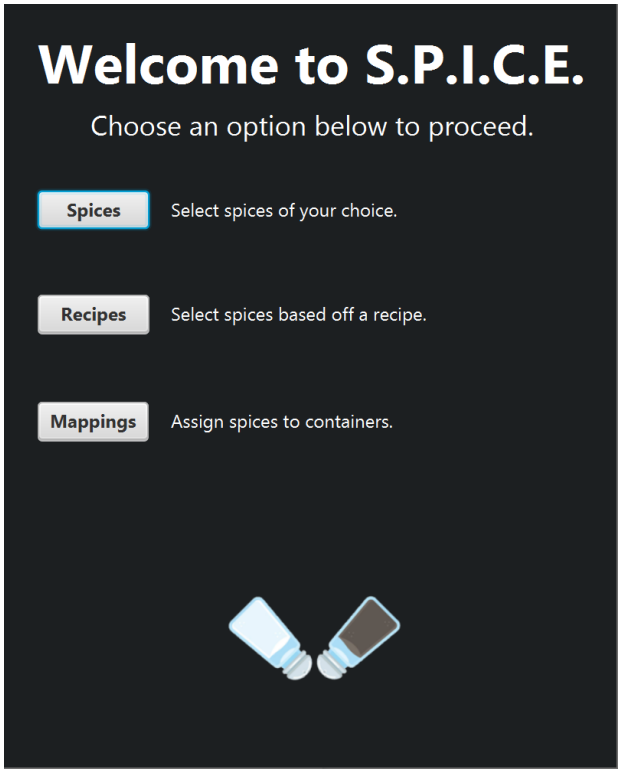
Kile has past experience utilizing Raspberry Pis for projects and has an interest in embedded systems. He will primarily contribute to the microcontroller systems aspect of the project alongside Caleb. Another key responsibility of this position is interpreting schematic diagrams for various circuit components that will be used throughout the project to ensure they are being used correctly and optimally.

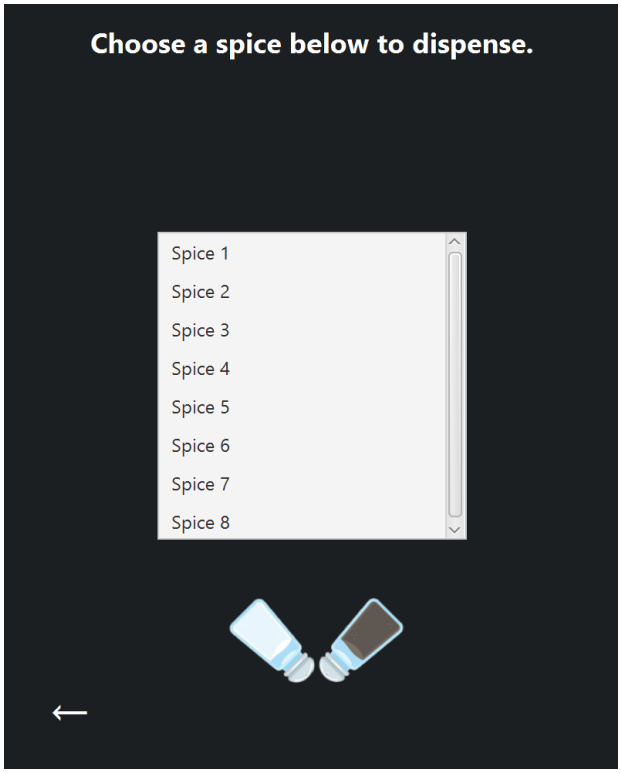
WORK BREAKDOWN STRUCTURE	TASK TITLE	TASK OWNER	AMOUNT OF WORK IN HOURS			SPRINT	START DATE	DUE DATE	DURATION	PCT OF TASK COMPLETE
			ESTIMATE	COMPLETED	REMAINING					
1	Proposal		67	67	0					100%
1.1	Project Proposal	ALL	18	18	0	0	2/13/2023	2/15/2023	3	100%
1.1.1	Presentation	ALL	8	8	0	0	2/13/2023	2/15/2023	3	100%
1.2	General Design of Parts	ALL	10	10	0	1	2/16/2023	2/22/2023	7	100%
1.3	Gather Parts	Carlos	3	3	0	1	2/16/2023	2/22/2023	7	100%
1.4	Draft Design of Mechanical Components	Caleb, Carlos	12	12	0	1	2/16/2023	2/22/2023	7	100%
1.5	Draft Design of UI	JP	8	8	0	1	2/16/2023	2/24/2023	9	100%
1.6	Draft Design of Microcontroller	Kile, Caleb	8	8	0	1	2/16/2023	2/24/2023	9	100%
2	Design		46	34	12					74%
2.1	Finalize Motor Mechanism	Caleb,Carlos	12	6	6	2	2/22/2023	3/1/2023	8	50%
2.2	Finalize Sliding Shaft	Caleb,Carlos	12	6	6	2	2/22/2023	3/1/2023	8	50%
2.3	Begin working on UI	JP, Carlos	22	22	0	2	2/26/2023	3/8/2023	11	100%
2.4	Begin work on Arduino	Kile, Caleb	22	22	0	2	2/26/2023	3/8/2023	11	100%
3	Fabrication		220.8	3	217.8					1%
3.1	Fabricate Rotating Base	Caleb, Carlos	13.8	0	13.8	3	3/1/2023	4/3/2023	34	0%
3.1.2	Fabricate Housings (Motor Bases)		116	0	116	3	3/5/2023	4/3/2023	30	0%
3.1.3	Fabricate Corkscrew Dispensers		18	0	18	3	3/19/2023	4/3/2023	16	0%
3.2.1	Design Pin Connection		6	3	3	3	3/22/2023	4/3/2023	13	50%
3.2.2	Fabricate Pin Connection		14	0	14	3	3/22/2023	4/5/2023	15	0%
3.1.4	Attach Motors	V	8	0	8	3	4/5/2023	4/7/2023	3	0%
3.3.1	Finalize UI	JP	3	0	3	3	3/8/2023	3/24/2023	17	0%
3.3.2	Integrate Touch Screen	JP, Kile	12	0	12	3	3/24/2023	3/29/2023	6	0%
3.4	Finalize Arduino Functionality	Kile	30	0	30	3	3/8/2023	3/29/2023	22	0%
4	Validation		127	0	127					0%
4.1	First Round Validation	All	16	0	16	4	4/10/2023	4/12/2023	3	0%
4.2	Fix Mechanical Issues	Caleb, Carlos	20	0	20	4	4/12/2023	4/17/2023	6	0%
4.3	Add Spice Mix functionality	JP, Kile	16	0	16	4	4/10/2023	4/17/2023	8	0%
4.4	Second Round Validation	All	15	0	15	4	4/17/2023	4/21/2023	5	0%
4.5	Final Fixes	All	30	0	30	4	4/21/2023	4/28/2023	8	0%
4.6	Final Round Validation/Updates	All	30	0	30	4	4/21/2023	4/28/2023	8	0%

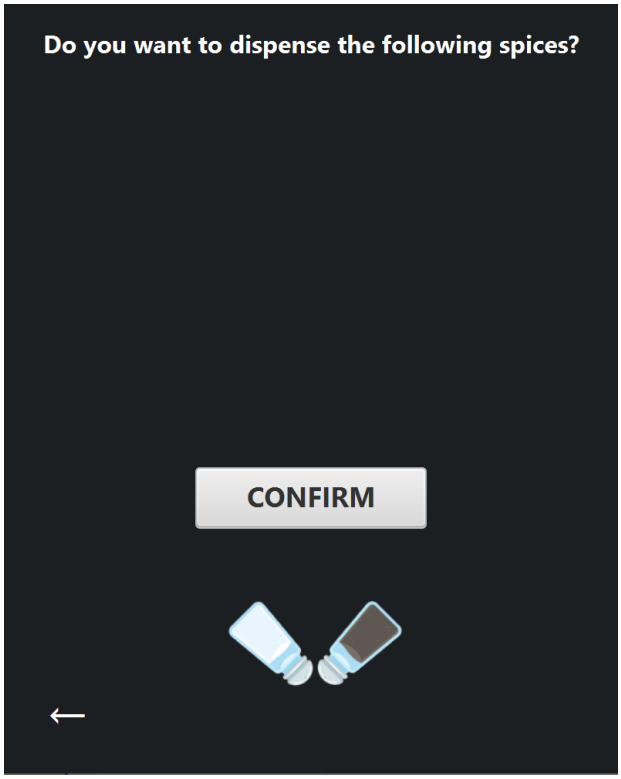
Figure 17: Updated Schedule of Tasks

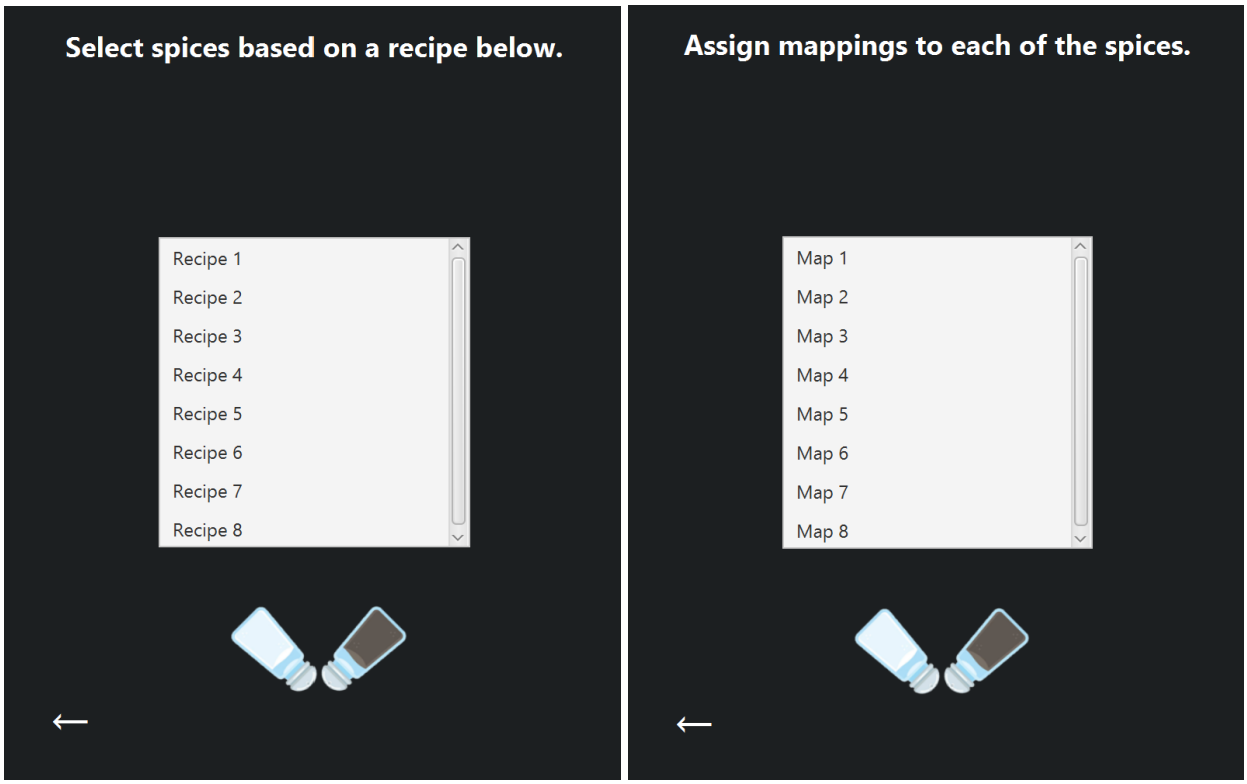
4 Preliminary results

Screenshots of UI:









Motor Videos:

5V Power Supply

- https://youtube.com/shorts/9ELkheffbps?feature=share

9V Power Supply

- https://youtube.com/shorts/5m6c0ll1cwY?feature=share

5 References

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