Functional Specification

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Assignment Evaluation:

Item	Score (0-5)	Weight	Points	Notes
Assignment-Specific Items				
Functional Description		x3		
Theory of Operation		x3		
Expected Usage Case		x3		
Design Constraints		x3		
Writing-Specific Items				
Spelling and Grammar		x2		
Formatting and Citations		x1		
Figures and Graphs		x2		
Technical Writing Style		x3		
Total Score				

5: Excellent 4: Good 3: Acceptable 2: Poor 1: Very Poor 0: Not attempted

General Comments:
Relevant overall comments about the paper will be included here

1.0 Functional Description

The Super Susan is an automated, smart lazy Susan designed to assist users in locating and taking inventory of spices. After loading the Super Susan with spices, the user can request any spice through an on-unit dial interface, and the Super Susan rotates to present the user with the requested spice. The Super Susan also monitors the inventory, and through either the same on-unit interface or a phone app, the user can check the inventory (including both the types and remaining amount of each spice). Inventory information is displayed on an LCD screen or through the phone app.

2.0 Theory of Operation

The user will use a dial to interact with the Super Susan, and to navigate a menu on the LCD screen. When a user selects a spice that they want presented to them, the Super Susan will rotate the spice bottles appropriately via a stepper motor; or when a user requests a remeasure of the inventory, the Super Susan will weigh every spice and update the weight values. An alternate method through which the user can interface with the Super Susan is the phone application, which will be used to read the current inventory or request a remeasure. If wanting to read, the inventory data that is stored on the Super Susan will be sent through WiFi to a server from which the phone application can read the data and present it to the user. This transfer will be facilitated by a WiFi module which will give us an acceptable amount of bandwidth and range to transmit the data through the user's router to the internet.

Whenever the user selects a spice and uses it, the Super Susan will take a new measurement of the remaining spice once the user places the bottle back into place. The Super Susan will rotate the bottle to the measuring station, which will use an undecided weighing method (likely force sensitive resistors) to record the weight of the contents before storing it internally. This way the inventory can be kept up-to-date at all times. In the case when the user would like to add a new spice that is not already identified by the Super Susan, the user will be asked to read the spice bottle's barcode through the barcode scanner to determine the type of spice that it is. Failing this, they will be asked to input the name of the spice they are adding through the phone application or through the dial interface.

The name of the spice which the user has entered will then be written to the bottle's respective NFC tag which will be used for future comparisons. Onboard memory will be used to store information such as a bottle's identifier and its weight to provide a storage location for the inventory second to the near-field communication (NFC) tags. NFC tags are passive circuits which can be written to and read from [1] , and our tags have a storage capacity of approximately 150 bytes. This is enough memory to store basic information such as the name of the spice that the bottle holds. The tag can be read in the future with an NFC reader, displaying the information that has been stored within it.

For weight sensing, a Force Sensitive Resistor (FSR) will most likely be used to measure the weight. This system will be put in place beneath one of the bottle locations and set as a designated weighing zone to which the Super Susan will rotate whenever it needs to measure something.

A functional block diagram has been included in Appendix 1 to supplement the theory of operation.

3.0 Expected Usage Case

The Super Susan is designed to be used by the person who values organization when cooking and speedy acquisition of a particular spice amidst a multitude of various spices. As such, the Super Susan will be used in a kitchen environment as a stationary system, either on a countertop or in a cupboard, provided the user has access to an outlet. Only one user at a time will be expected to use the Super Susan. The nature of our users is quite diverse since the Super Susan is designed to be usable by anyone, with the only requirement being basic technical literacy in order to operate the phone application.

4.0 Design Constraints

The expected use of the Super Susan is in a kitchen, and it will be visible during any time of use. This necessitates aesthetic decisions such as the material it is to be packaged in, choice of power supply, choice of motor control (not too loud) and all of this without ruining the central theme of a lazy Susan that involves the ability to have a level surface to display article of interest to the user in a functional manner. The Super Susan will keep the traditional shape of a mildly thin disk with a circular display area. The choice of a stepper motor or enclosure that is well acoustically dampened so as not to hurt the user's experience is required. Given our expected workload, we must choose weight sensors and correspondingly accurate motors that minimize error and fit our economic constraints.

4.1 Computational Constraints

Though the topic is somewhat controversial, average attention span of an adult may be as low as 8 seconds [2]. In an age of instant gratification and fast responding smart phones, it is just as important to make the Super Susan respond quickly so the user is satisfied with the product. Timewise, the longest latency in the system is communication between the user's smartphone, to the internet, to the Super Susan, and then all of the way back. We aim for performance under 8 seconds for the entire chain of operations between a user's input and the Super Susan processing and servicing the request. The memory required to store the inventory of the Super Susan is estimated to be around the magnitude of a half a megabyte (512B), so even at modest network bandwidth of 1 Mbps, the transfer of data should be manageable within a fraction of a second. The mBaas of choice, Firebase real time database, allows for changes to be recorded and responded to nearly immediately; and making a change from the phone app would result in a similarly small overhead.

4.2 Electronics Constraints

The Super Susan will use a variety of electrical components controlled by a microcontroller from the STM32 family. A stepper motor will be used to achieve accurate rotation of the Super Susan; at this point, we plan to use a bipolar stepper motor. This will require an H-bridge driver, which will interface with the microcontroller through PWM to control the motor speed. The rotation direction will be controlled by toggling the values sent to the pins connected to the H-bridge.

To detect the remaining contents of the containers on the Super Susan, a weight sensor will be used. Currently, the team is investigating the possibility of using a Force Sensitive Resistor (FSR), a high precision load cell, a Velostat FSR of our own making, or a magnet and coil sensor. Though specifics vary slightly, each sensor operates by making a small but appreciable difference in impedance that can be measured with the analog of the microcontroller.

The contents of the Super Susan will be tracked using RFID, and reading and writing modules will be used to identify each spice bottle. Specifically, the Super Susan will use passive NFC tags to store information about the contents of each container, and an NFC reader/writer module will interface with the microcontroller either through I2C or SPI (undecided at this time).

To facilitate the communication with the phone app, a wireless module will be used. This will interface with the microcontroller using SPI.

A dial and several pushbuttons will make up the user interface, and the returned information will be displayed on an LCD or OLED display. Both these displays can communicate with the microcontroller using either SPI or I2C. Additionally, an LED will be used to indicate power on the Super Susan.

4.3 Thermal/Power Constraints

The Super Susan will be plugged into a power supply the entire time it is in operation, so battery life is not a concern. The power consumption will be limited by the power supply, which will likely be a USB-C cable with a maximum current of 5A. Since the Super Susan will carry spices, the operating temperature must not increase to the point that it would damage the spices or require a fan to cool the electronics. Because the volume of the Super Susan base will be somewhat large to provide enough surface area for the containers, we do not anticipate cooling to be a problem. The Super Susan should be able to operate in a range of standard house temperatures, such as 60-85° F.

4.4 Mechanical Constraints

The intended environment of the Super Susan is a kitchen. As for physical constraints, this means the device must be water resistant, stain resistant, and fairly easy to clean. Since circuitry will be sealed inside of a chamber, making the Super Susan water and stain resistant is more a matter of material selection for the enclosure rather than an issue of using a complex sensor system. A durable, stain-resistant plastic like PET (Polyethylene Terephthalate) would be a strong candidate, for it is commonly used in kitchen appliances already. To understand the weight that must be supported, suppose the Super Susan is fully loaded with 24, 8 fl oz. bottles filled sand and gravel:

$$(24\ bottles)(8\ fl\ oz)(29.5735\ mL/oz)(1.92e-3\ mL/m^3 density\ gravel\ w/sand) = 10.90\ kg\ of\ contents$$

Being heavier than most spices, one would expect (10.9kg + 10%), or ~12 kg, to be a fair upper limit to the load that the Super Susan must be able to support across the platform, and turn when the motor is powered. The weight of the Super Susan itself is not as important for two reasons: first, the Super Susan will have rubber coasters to keep it from sliding; and second, a typical countertop can support similar sized or larger appliances made out of heavier materials like metal.

4.5 Economic Constraints

The two areas of cost for the project budget are in components going into the Super Susan and materials needed to develop the product. To constrain the components budget, the team has set the target cost for the Super Susan at $80. Perhaps the average kitchen-goer has no direct need for a smart spice organizer, but chosen price conveys the idea of a luxury and reflects what a user would be willing to afford. To develop product feasibility, the team will need to keep component costs at or below $60 to allow for a profit margin.

The tightest economic constraints of the component budget are centered around technologies that must be purchased. To reduce costs, the team must minimize the amount of purchased hardware and use each module to its maximum potential. If any hardware module can be removed by using a different module more efficiently, this strategy should be taken. The alternate cost reduction strategy is to simulate the complex technologies with our own circuitry. The risk taken is that the time and development costs spent may result in a lower quality product or may potentially outweigh the cost of having bought a module up front. Implementation of a WiFi module, near-field reader/writer, strain gauge and measurement unit, and bar code scanner all fall into this category of hardware.

The other element to project costs is in research and development. In order to prototype the Super Susan, there will be overhead costs to buy supporting development tools such as a size-comparable digital scale, a microcontroller development kit, and spices. Since the majority of weight hardware has tricky to implement circuitry, it may be wise to buy a breakout board to learn how to use, and then emulate that hardware on our own board.

- Expenditures
  - Flexible Costs
    - Flexible in quality (cheap vs nice), xor in necessity (risk reduction)
    - Entails the majority of components
    - Fairly small share of budget
    - General components: LCD screen, buttons, switches, NFC tags, bottles,
    - Developmental: dev kits, prototyping kits (optional)
  - Inflexible Costs
    - Specialized in function
    - Low in volume but high share of budget
    - Material Costs: 3D printed arms, cut plastic body
    - Barcode Scanner: high risk in work around
    - Wifi Module: Impermissible to work around
- Product Cost Analysis
  - Prototype
    - Critical Costs: Wifi Card = $25, Materials =$10, Weight Measurement =$10, Motor=$10, Bottles=$20
    - Projected Unit Cost: $60-80

4.6 Other Constraints

The Super Susan, like any other product, has constraints that come from the expectations of buyers on the market. Besides being a product that does what it says it does, it also must be safe, must be quiet, must stay at or almost at room temperature, must be relatively damage-resistant, must be not too hard clean or maintain, and must be relatively long-lived rather than needing to be replaced or fixed. While the host of unspoken user expectations can be quite a challenge to address, many are being approached as design constraints for the Super Susan including safe operation and ease of use.

The safe use of the Super Susan should encompass having fail-safe mechanisms for the mechanical parts like jamming detection, having alert lights or sounds when the device is about to start rotation; and on the digital side, having encrypted or non-exploitable communication with the network so that user information is protected. The safety constraints must be so that if the motor were to unexpectedly stall, the system would respond within a tenth of a second (0.1s) so that no physical harm could befall the user - this can be implemented using components like thermistors or current sensitive components called PTCs that could alert the Super Susan that the motor has stalled while simultaneously turning it off. Alert lights and timers powered by microcontroller GPIO can be implemented to provide the user ample warning before the Super Susan commences motion. Finally, secure networking can be aided with embedded AES-256 encryption IC's or intelligent algorithms on the microcontroller.

Ease of use is a category difficult to quantify, but for the purpose of development we will likely assess the topic using an array of survey questions. These questions include: time spent before response, difficulty to clean, noise emitted during use, and difficulty connecting to internet. In the prototyping phases we will assess our ease of use by surveying volunteers and getting feedback on how the product behaves intuitively. If the difficulties are minimized, the ratings from the survey will have low numbers. Success in meeting the ease of use constraint will be reflected in having a satisfactory average for each question.

5.0 Sources Cited:

[1] T. Robert (2017, May 29) *NFC Tags Explained* [Online]. Available: http://www.androidauthority.com/nfc-tags-explained-271872/

[2] Time (2015). *You Now Have a Shorter Attention Span Than a Goldfish* [online] Available: http://time.com/3858309/attention-spans-goldfish/

Appendix 1: Functional Block Diagram