Component Analysis

Year: 2017 **Semester:** Fall **Team:** 15 **Project:** Super Susan
Creation Date: September 1, 2017 **Last Modified:** September 8, 2017

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Assignment Evaluation:

Item	Score (0-5)	Weight	Points	Notes
Assignment-Specific Items				
Analysis of Component 1		x2		
Analysis of Component 2		x2		
Analysis of Component 3		x2		
Bill of Materials		x6		
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 Component Analysis:

Several major components are needed to construct the Super Susan. The microcontroller must have the capabilities to interface with all 5 major components, as well as other smaller parts including a rotary dial and LEDs; and the microcontroller must have sufficient memory and processing power. A stepper motor will provide the rotation for the Super Susan turntable, and a display will communicate important information to the user. NFC tags and an NFC reader will enable the Super Susan to keep track of the items on the turntable, and a weight sensor will detect the remaining amount of each item. A wireless module will provide internet connection for the Super Susan and enable a phone app to show the inventory as it modified to the user. Together, these components will enable the Super Susan to track the items stored on it, measure the amount remaining of each item, and communicate this information to the user and deliver spices.

1.1 Analysis of Component 1: Stepper Motor

A stepper motor is the chosen method for turning the Super Susan because of the accuracy with which it can turn a particular distance. This is an important criteria for the design because the turntable must stop exactly when the requested spice is at the presentation location. Stepper motors can be either unipolar or bipolar, and we decided to use a bipolar stepper motor because they typically have higher torque [1].

The first potential stepper motor identified was a permanent magnet 5-V stepper motor by Seeed Technology [2]. Since it is a permanent magnet motor, it is expected that this motor has a higher torque than a comparable variable-reluctance motor [3]. This motor is inexpensive ($4.59) and has 2048 steps per revolution, which would enable accurate turning. However, the holding torque is only 5.5 oz-in, which could potentially be too low. Additional calculations (see below) were performed to verify the amount of torque required to turn the Super Susan.

Assuming that the weight is uniformly distributed so that the turntable can be treated as a solid disk, the values and calculations are as follows:

$$r = turntable\ radius = 7\ [in] = 0.1778\ [m]$$

$$m = mass\ of\ filled\ spice\ bottle = 8\ [oz]$$

$$n = number\ of\ spice\ bottles = 24$$

$$M = total\ mass = n * m = 24 * 8\ [oz] = 192\ [oz] = 5.44\ [kg]$$

To account for the weight of the turntable itself, the total mass is rounded up to $M = 6\ [kg]$.

The moment of inertia is then calculated:

$$I = \frac{1}{2}Mr^2 = \frac{1}{2} * 6\ [kg] * 0.1778^2\ [m^2] = \mathbf{0.095\ [kg * m^2]}$$

Torque is defined as $\tau = I\alpha$, where $\alpha = angular\ acceleration = \frac{\Delta\omega}{\Delta t}$.

Approximating $\omega = 1\ revolution\ per\ 10\ seconds = \frac{2\pi}{10}\left[\frac{rad}{sec}\right] = \boldsymbol{\frac{\pi}{5}}\ \left[\boldsymbol{\frac{rad}{sec}}\right]$.

Since we want gradual acceleration, we will take the time to accelerate $\Delta t = 2\ [sec]$.

$$\alpha = \frac{\frac{\pi}{5}\left[\frac{rad}{sec}\right]}{2\ [sec]} = \frac{\pi}{10}\left[\frac{rad}{sec^2}\right]$$

$$\tau = I\alpha = 0.095\ [kg * m^2] * \frac{\pi}{10}\left[\frac{rad}{sec^2}\right] = 0.0298\ [Nm] = \mathbf{4.22\ [oz\text{-}in]}$$

To further ensure that the motor provides sufficient torque, we will require that the torque be at minimum twice the calculated, or **8.5 oz-in**.

This torque requirement eliminated the Seeed Technology motor, so we investigated another more powerful motor. The Adafruit Hybrid Stepper Motor [4] has a holding torque of 28 oz-in, which would be more than sufficient according to our calculations. It is a hybrid motor, which gives it the precision of variable-reluctance motors in addition to the torque of permanent magnet motors [3]. It has a higher voltage rating of 12 V, but the USB-C power supply we plan to use will be able to provide this. The current rating is 350 mA, which will help to stay below our power supply current limit. This motor is more expensive than the previous, at a cost of $14, but it is still very affordable.

For variety, we also considered the SparkFun Hybrid Stepper Motor [5]. This is a slightly larger motor (frame size 23), and it has a higher current rating of 2 A. While this allows for greater torque (125 oz-in), drawing 2 A could be problematic for our power supply. It is also considerably more expensive at $23.95. With all these considerations in mind, this motor was discarded from the options, and the Adafruit Hybrid Stepper Motor was chosen.

Criteria	**Seeed Technology Stepper**	**Adafruit Hybrid Stepper**	**SparkFun Hybrid Stepper**
Type	Permanent Magnet	Hybrid	Hybrid
Unipolar/bipolar	Bipolar	Bipolar	Bipolar
Torque-Holding	5.5 oz-in	28 oz-in	125 oz-in
Steps per revolution	2048	200	200
Voltage Rating	5V	12 V	3.2 V
Current Rating	N/A	350 mA	2 A
NEMA frame size	N/A	17	$23.00
Price	$4.59	$14.00	$23.95
		CHOSEN	

Table 1: Stepper Motor Decision Table

1.2 Analysis of Component 2: Display

To display the names of spices, as well as provide an interface for the user to communicate with the Super Susan, a display will be used. For this component, we examined both LCD screens as well as OLED screens. The LCD screen would be a familiar approach since all team members have worked with them in previous classes, but the OLED display could potentially have a nicer display. Both character and pixel LCDs were considered. Due to the number of spices present on the Super Susan, we need to be able to display at least 4 lines of information, and each line must be able to accommodate 16-20 characters. Graphics and RGB color are not necessary, though RGB color would make the entire product seem more sophisticated to consumers.

The first screen considered was the Hitachi HD447780 LCD [6]. It is a 20x4 character array, which would be sufficient for our needs. The price at $17.95 is reasonable, and the only limiting aspect of this display is that it is a character display. This could work for the Super Susan, but having a more flexible display would allow more customization.

Another very similar display we considered was the Hitachi RGB LCD screen [7]. This is the same LCD display as the previous option, except that this version has an RGB backlight with black text. This would add aesthetic appeal to the project, but the RGB LCD costs $24.95. We determined that since color is not a vital part of our design, paying for the color display would not be worth the cost.

We also considered a 20x4 White OLED screen [8]. This is comparable to the LCD screens above in terms of size and display capabilities. However, the OLED technology costs considerably more, and the unit is priced at $35.00. Since having an OLED display would not be significantly improving our design, we discarded this option.

The final display considered was the Newhaven Display [9]. This is an LCD pixel display, which allows for flexible displays. With 122 x 32 pixels, the display can fit four lines of text, and font sizes are adjustable. The screen is slightly smaller than the other display screens, but since the required amount of text can fit on it, the size is not a problem. Additionally, this display has the added benefit of only costing $12.50. Since this is the display that best meets our design criteria as well as budget constraints, we decided to use it.

Criteria	**Hitachi HD447780 LCD**	**Hitachi RGB LCD**	**20x4 White OLED**	**Newhaven Display**
Display Type	LCD character - 20x4	LCD character - 20x4	OLED - character	LCD - pixel
Display Size	70 mm x 26 mm	70 mm x 26 mm	70.00 mm x 25.20 mm	60.55 mm x 18.50 mm
Physical Size	97 mm x 60 mm	97 mm x 60 mm	98.00 mm x 60.00 mm x 10.00 mm	83.5 mm x 27.8 mm
Color	Blue with white text	Color backlight, black text	Black with white characters (also blue, green, yellow)	Blue with white text
Number of Lines/Pixels	4 lines	4 lines	4 lines	122 x 32 pixels
Interface	SPI - 6 lines	SPI - 6 lines	SPI	Parallel, 8-bit
Price	$17.95	$24.95	$35	$12.50
				CHOSEN

Table 2: Display Decision Table

1.3 Analysis of Component 3: NFC Reader

Each bottle on the Super Susan will be tagged with an NFC tag, and a single NFC reader will read the tags until the desired bottle is found. To save on costs, only one spot will have an NFC reader; this location will also serve as the weigh station and the presentation station. The NFC reader does not need to have writing capabilities because the tags will come preloaded with identifiers, and the user will select the spice name from a predetermined list.

Since NFC is a subset of RFID, an RFID reader will also be able to read the NFC tags, provided that it uses the same frequency and the ISO 14443 protocol [10]. We considered three different reader/transponder modules, the PN512, PN538, and TRF7864A.

The first module, the PN512, has many advantages, particularly that it directly supports NFC with its protocol [11]. All three modules support the ISO 14443 protocol, so they should all work for NFC, but the PN512 is specifically designed for NFC applications. Additionally, it has flexible interface options - I2C, SPI, and UART. For the price of $6.39, it is a very good option. The disadvantage, which it shares with the other two modules, is that it only comes in QFN packaging. While this will make it more complicated to use, we should still be able to use it.

The next module, the PN538, is a widely-used module [12]. It is similar to the PN512, but it works for many other protocol standards in addition to NFC. For our purposes, we are not concerned with these. It is almost twice as expensive as the PN512, at $11.48; since it has no obvious advantages over the PN512, it does not seem like the best choice.

We also considered the TRF7864A module [13]. It is very reasonably priced at $6.03, and it supports the ISO 14443 protocol. It would work for NFC applications, but it is limited to an SPI interface. Because of this limitation, as well as the fact that the PN512 has the most documentation for NFC applications, we chose the PN512 over the other two.

Criteria	**PN512**	**PN532**	**TRF7864A**
Frequency	13.56 MHz	13.56 MHz	13.56 MHz
Relevant Protocol	NFC, ISO 14443	ISO 14443	ISO 14443
Interface	I2C, SPI, UART	I2C, SPI, UART	SPI
Required Voltage	2.2 - 3.6 V	2.7 - 5.5 V	2.7 - 5.5 V
Package	32-VFQFN	40-VFQFN	32-VFQFN
Cost	$6.39	$11.48	$6.03
	CHOSEN		

Table 3: NFC Reader Decision Table

1.4 Analysis of Component 4: Wifi module

The primary function of the wireless sensor is to collect and relay inventory data along with volume measurements to the database, from which it can be modified and viewed by the phone app as necessary. The sensor of choice for this is the cheap but relevant ESP8266 [14] from NodeMCU. The choice of this over the other competing options such as the Silicon Labs WF121-A-V2 [15] and the RTL8710 [16] from Seed electronics was because of the following factors. They included bluetooth (which we did not need, price reflects this), did not support a/b/g/n or supported ac (which is unnecessary for our application) and did not have nearly enough supporting documentation or successful documented projects available for us to look into. Price due to popularity is also very low [17]. Differences between top competing options is very minor.

Criteria	**LUA ESP8266**	**SL WF121-A-V2**	**Seed RTL8710**
IEEE 802.11	a/b/g/n	b/g/n	a/b/g/n
Price	8.2	15.9	4
Frequency	2.4Ghz	2.4Ghz	2.4Ghz
Dimensions	4 x 4 x 2 inches	15.4 x 26.2 x 2.0 mm	0.8 x 0.4 x 0 inches
Documentation	Very Good	Passable	Passable
	CHOSEN		

Table 4: Wifi Module Decision Table

1.5 Analysis of Component 5: Weighing Station

The task of measuring weight electrically is most typically done using materials that change resistance under compression. The technology used to accomplish this can vary, and the ease of implementation, level of precision, and device cost are likewise varied with these differences. The main components to choose from then become a choice of technology: a load cell (also called a strain gauge), a force sensitive resistor, or a custom made Velostat sensor.

Our consideration of the these options was centered around size, accuracy, and precision. The largest drawback of load cells is that they are large, both laterally (taking up room that would be occupied by circuit boards) and vertically (potentially forcing the Super Susan to need to be taller). However, their precision is much greater than the alternative options making them a good choice for a higher end product. The round FSRs marketed on Adafruit were another option for us, but the accuracy of these devices is not very high, and the precision from FSR to FSR could vary by as much as 10% [18]. This complication could make any necessary duplication of hardware an infeasible option. Unlike the other sensors, the benefit of the FSR is that it can sustain a voltage level that is compatable with ordinary analog ports, so no additional load amplifier is required (saving about $8 in costs). To save costs, we could create custom sensors out of Velostat, but the risk of losing all precision and accuracy outweighs the potential cost benefit. Velostat, unlike either option however, is very flexible metaphorically and literally. A velostat sensor could be shaped into flatter geometeries and be applied to curved surfaces, which is not allowable with the other sensors.

Chosen was the load cell, the AuBreey Digital Load Cell Weight Sensor 1KG - AREEY470. Having found a load cell that is as cheap as its less accurate and less precise competitors is automatically an attractive option; Having found the same load cell tuned to our desired weight range and that comes with an $8 load amplifier included for free maked this decision an obvious choice.

Tag	Load Cell	Round FSR	Velostat
Name	AuBreey Digital Load Cell Weight Sensor 1KG - AREEY470	Round Force-Sensitive Resistor (FSR) - Interlink 402	Pressure-Sensitive-Resistive Sheet (VELOSTAT/LINQSTAT)
Technology	Load Cell	Force Sensitive Resistor	Resistive Material
Range	1 kg	~10.2 kg	unsure
Size (Weighing Area)	1/4 inch square	1/2 diameter circle	adjustable
Size(Height)	0.25 "	0.02 "	0.004"
Is Accurate to 1g	Yes	No	No
Accuracy Varies Unit-Unit	No	Yes	Yes
Requires Amplifier	Yes	No	Yes
Price	$7 + amp included	$7	$4, 11"x11"
	CHOSEN		

Table 5: Weight Sensor Decision Table

1.6 Analysis of Component 6: Microcontroller

The comparison for microcontrollers was greatly filtered by our teams set of criteria. The microcontroller we were to chose must be an active part with a processor core that is widely industry recognized. Considering this, obvious choices that stood out included Texas Instruments families like the MSP430 and MSP432, the STM32 family including its various ARM core processors, and Microchip's PIC family, known for their low cost and ubiquity. Understanding the possibility of needing analog to digital conversion, the availability of fair quality analog ports were taken into consideration. Though almost all micros have some variety of ADC unit, 10 bit precision seemed like a fair baseline requirement, if analog is to be needed. In consideration of the many spice bottles and input signals that will be present, a minimum of 50 pins was estimated for the Super Susan. To match this need and simplify soldering, we sought QFP packages because we could get high signal counts and retain having pins.

Having acknowledged the broader criteria of the microcontrollers on the market, there were still many options to consider. The finer criteria came from more project specific needs. To address the needs of communicating via wifi, handling a more complex display screen, and juggling data from sensors and motors, a microprocessor of higher caliber processing power seemed necessary. Though many subtleties in architecture differentiate performance, for the purpose of comparing micro controllers, clock speed is a fair estimation; our chosen set included only options with better than 40 MHz clock speed. Memory, in terms of RAM and flash memory seemed less important than clock speed, but 16 KB of flash and 4 KB of RAM held as minimum values. Final considerations were centered around the practicality of prototyping. Having a microcontroller that has a development board accelerates the process of testing and learning the microcontroller, while having a microcontroller that is fairly inexpensive means being able to afford extra in the event were one to burn.

The final decision rested on the STM32F410 because of its reasonable price, high clock speed, and availability of development board. Sacrificing the additional pins that the PIC32MX330 would afford, the chosen is in STM family, which is more familiar to the course staff, and has more memory at its disposal, allowing more comfort room for programming.

Part Number	*STM32F302 R8T6*	*STM32F410 RBT6*	*STM32F103 R6T6A*	*STM32F303 R8T6*	*PIC32MX35 0F128H*	*PIC32MX33 0F064L*	*MSP432P40 1RIPZ*
Has Dev Board	yes	yes	no, but similar	no, but similar	no, but similar	no, but similar	yes
Manufactur er	STMicroele ctronics	STMicroele ctronics	STMicroele ctronics	STMicroele ctronics	Microchip Technology	Microchip Technology	Texas Instrument s
Price	4.35	4.40	5.44	4.67	3.97	4.06	8.29
Series	STM32 F3	STM32 F4	STM32 F1	STM32 F3	PIC® 32MX	PIC® 32MX	MSP432™
Speed	72MHz	100MHz	72MHz	72MHz	80MHz	80MHz	48MHz
# I/O	51	50	51	51	53	85	84
Memory Size	64KB	128KB	32KB	64KB	128KB	64KB	256KB
RAM Size	16KB	32KB	10KB	12KB	32KB	16KB	64KB
Data Converters	A/D 15x12b	A/D 16x12b	A/D 16x12b	A/D 15x12b	A/D 28x10b	A/D 28x10b	A/D 26x14b
Package / Case	64-LQFP	64-LQFP	64-LQFP	64-LQFP	64-TQFP	100-TQFP	100-LQFP
		CHOSEN					

Table 6: Microcontroller Decision Table

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