Kitchen Dry Ingredient Tracker

ECE 445: Senior Design
Team 43
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1 Introduction

1A. Problem

In today's world, there is no end-to-end maintenance system for kitchen ingredients. It's hard to keep track of ingredients in our kitchen, their availability, and gauge when a necessary grocery run is required. Even though online grocery shopping has gotten very popular, consumers still frequently go to physical grocery stores. The primary grocery shopper in U.S. households made an average of 1.6 shopping trips per week in 2022 [14]. This implies that many consumers usually forget to buy ingredients they need and are forced to go back to the store. The Kitchen Dry Ingredient Tracker is designed to optimize these grocery trips by cutting down on the number of grocery runs a consumer makes. Home cooks can improve their shopping experience through the Kitchen Dry Ingredient Tracker.

1B. Solution

The system is designed to track and communicate with users about their spice necessities. The user can tailor each individual spice to different lower weight threshold measurements. The system uses RFIDs to allow users to place spice containers in any slot while recognizing the spice and its lower weight threshold measurement. The system maintains a dynamic digital grocery list by adding/removing spices based on their individual weights. To allow for a visual representation that a spice has run below the user specified weight limit, the LED light at the container's spot turns red. If a user is outside and close to a grocery store (0.1 miles away), a mobile app notification will be sent to the user's phone to notify them about ingredients on the grocery list and encourage them to stop at the grocery store. An example notification is "You are 0.1 miles away from Target. Time to grab salt and pepper"

1C. Visual Aid

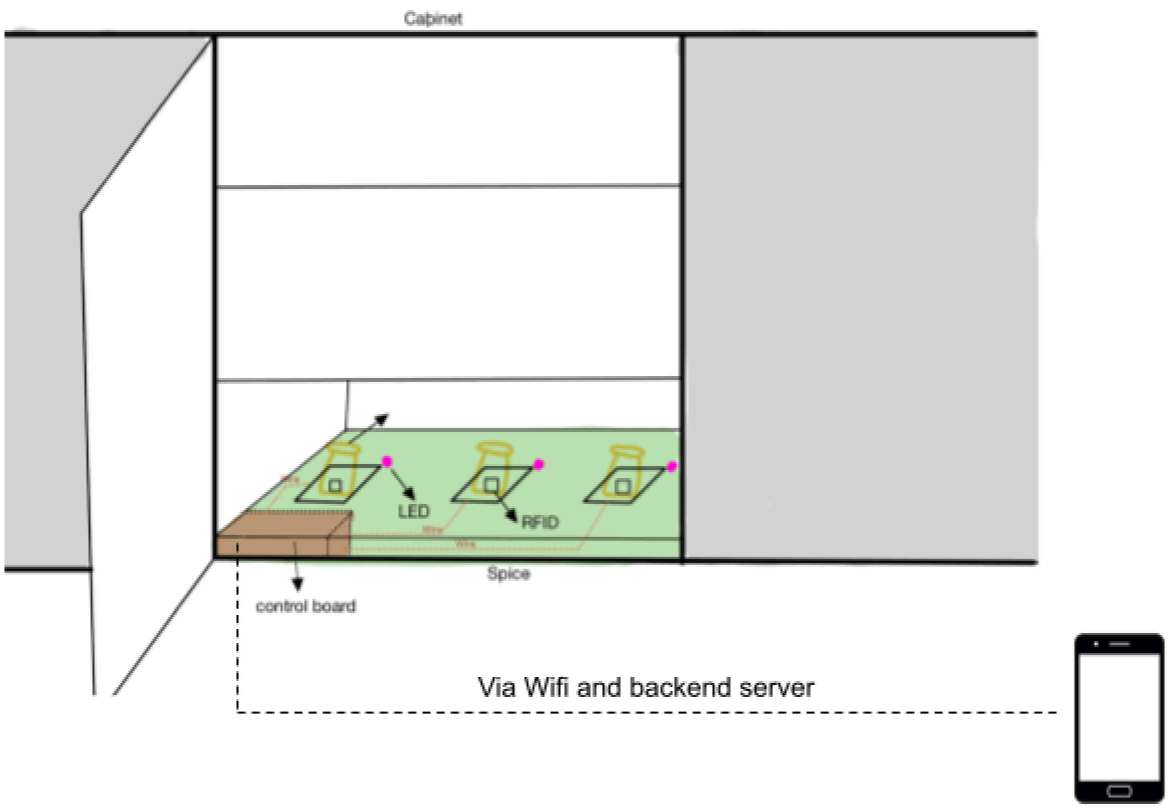

Figure 1: Visual Aid

Our system is capable of tracking numerous spices but for the constraints of the semester, it is designed to track three spices. The product tracks three ingredients, since adding more spice slots is redundant in mechanism. There are also additional constraints for manufacturing this product with more than 3 slots in a timely manner via the mechanical shop. The spices tracked for the demonstration are salt, garlic powder and chili powder.

1D. High-level requirements

1. The MCU will pull weight data captured from the load cells every 15 minutes for the 3 spices tracked. The maximum weight for the spices is 500 grams.
2. The app will have an "Ingredient Dashboard" interface that allows users to specify lower weight thresholds for each spice. These weight thresholds are within the range of 0 - 500 grams and recorded in whole grams.
3. The app will have a "Grocery List" interface where spices are added/removed based on whether their recorded weight is below its lower weight threshold.

4. The product has 1 LED at each of the three spots. The LED will remain red until the load cell reads that the spice weight is above its lower weight threshold.
5. Users can place spice containers in any of the 3 spots. The container's RFID will keep track of the container's position, allowing for the right comparison between the spice's weight and its lower threshold weight.
6. If the user's phone is near a grocery store (0.1 miles away) and there are ingredients in the digital grocery list, the app sends a notification to visit the store and buy those ingredients. An example notification is "You are 0.1 miles away from Target. Time to grab salt and pepper"

2 Design

2A. Block Diagram

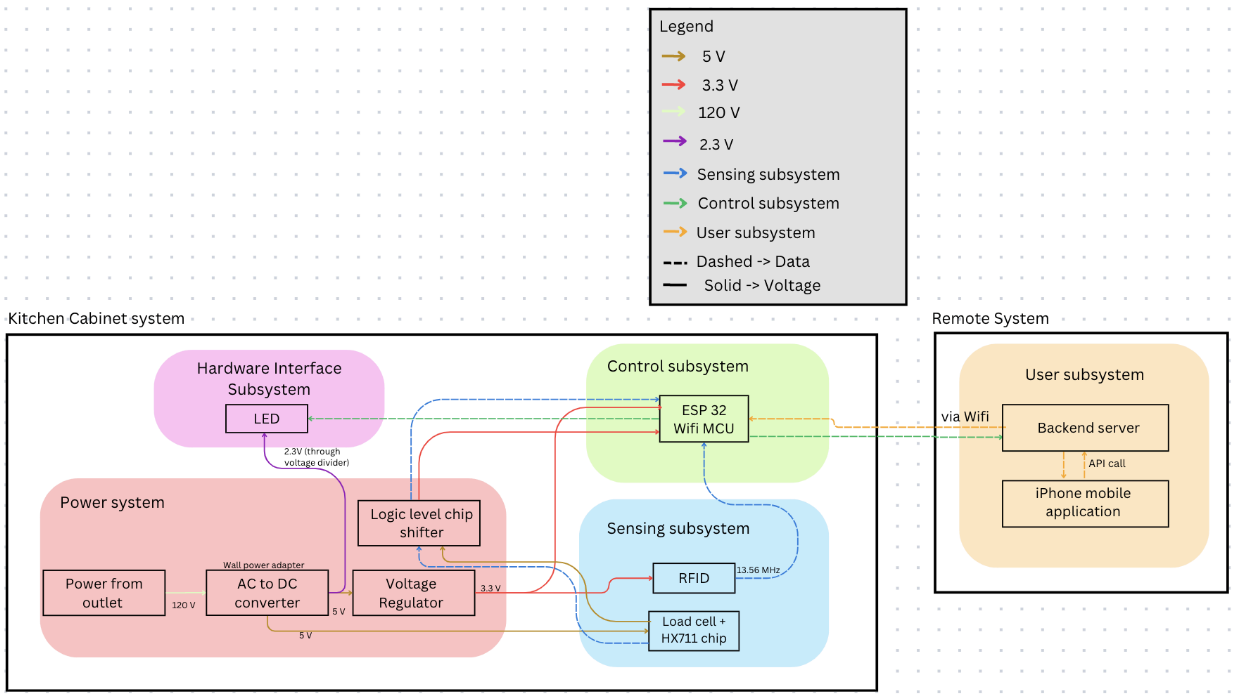

Figure 2: Block Diagram

The system is made up of a power subsystem, control subsystem, sensing subsystem, hardware interface subsystem, and user interface subsystem. The power subsystem powers the device. A wall power adapter converts 120V AC to 5V DC for the RFIDs and load cells. A voltage regulator will be used to step down the 5V to the 3.3V needed by MCU. The system uses resistors to step down the voltage from 3.3V to 2.3V for the LEDs. The sensing subsystem includes the RFIDs and load cells. The container's RFID will keep track of the container's position, thus allowing for the right comparison between the spice's weight and its lower threshold weight. The load cells in conjunction with the HX711 chip measures the weights of the spices. The control subsystem is made up of the

ESP32 MCU. The Wifi protocol of the ESP32 MCU will be used to communicate with the Firebase database to store data. This data is transferred and shown within the app. The user interface subsystem allows the user to interact with the system. The app allows the user to input the spices names and their lower thresholds, see ingredient weights, maintain a grocery list, and receive notifications when they are near a grocery store. The hardware interface subsystem consists of LEDs. These LEDs turn red when the spice weight runs below its lower weight threshold.

2C. Subsystem Overview & Requirements

2C.I Hardware Interface Subsystem

The subsystem consists of an LED which requires 2.3V±0.3V at each spot [10]. Using a two resistor voltage divider, the 5V will be scaled down to 2.3V. The LEDs will provide a visual representation to see which spices have run low. The microcontroller will communicate with the LEDs via wires to display red when a spice is below the user specified lower threshold. The LEDs will be enclosed within a see-through covering to prevent spices and dirt from getting on it.

Requirements:

1. The LEDs turn on and remain red until the load cell reads that the spice weight is above its lower weight threshold
2. The LEDs will remain off when the record weight is between 0 - 482 grams to account for the absence of a spice container as the weight of the spice containers is 481.92 grams

2C.II User Subsystem

The subsystem contains the mobile application which allows the user to interact with the device. On a mobile app, the users will be able to track weights of each kitchen ingredient, view their digital grocery list, and get notifications to grocery stores 0.1 miles away. The "Add New Ingredient" screen, as shown in Figure 3, allows the user to provide the name of spices and the lower weight thresholds for each ingredient. The subsystem will communicate with the microcontroller to gather information about ingredient weights from load cells and compare them to the user's specified lower weight thresholds. The dynamic "Grocery List" synchronizes with the "Ingredient Dashboard" and only displays ingredients that are below the lower weight threshold. The subsystem gathers information from the RFIDs to determine what ingredient is in a particular slot. This information is used to compare against the weight sent by the load cell to the spice's lower weight limit.

Google's Firebase Realtime Database is used to sync the mobile application and MCU. It is a cloud hosted database that allows for devices to receive data on wifi and mobile data [7]. The ESP32 MCU will connect to a user's home wifi network with its built-in wifi protocol. It will then use HTTPS requests to communicate with the Firebase database and update information. The database will communicate with the mobile application using the Firebase JavaScript API.

Every 15 minutes the MCU will pull weight data from the load cells and send the data to Firebase. The 15 minute data frequency rate is sufficient assuming it takes at least 15 minutes to get ready and arrive at the grocery store of the user's choice. The average user takes 40 minutes to shop at a grocery store [5], therefore, the user will have an updated grocery list by the time they arrive/begin shopping at the grocery store.

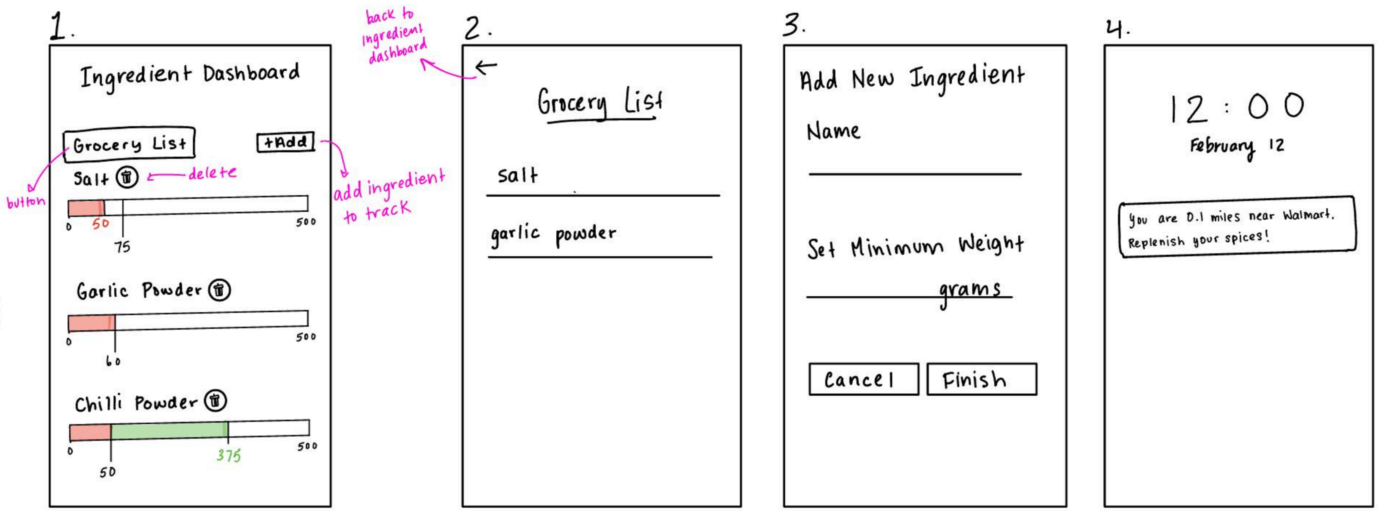

Figure 3: Mock Mobile Application Screen Wireframes

When a user opens the app, the first screen they will see is the "Ingredient Dashboard" (screen 1 in Figure 3). They will then have the ability to add/delete ingredients from the "Ingredient Dashboard" and view the "Grocery List." If they choose to view the "Grocery List," they will be shown the current ingredients that are below their lower weight thresholds (screen 2 in Figure 3). The user can add an ingredient in the "Ingredient Dashboard" using the "+Add" button. The button directs the user to the "Add New Ingredient" screen. The screen will prompt the user to enter a spice name and lower weight threshold. The lower weight value entered must be between 0 - 500 grams and in whole grams.

Requirements:

1. App has two main interfaces: an "Ingredient Dashboard" and a dynamic grocery list.
2. The "Ingredient Dashboard" can track up to 3 ingredients.
3. The app will have an "Ingredient Dashboard" interface that allows users to specify individualized lower weight thresholds for each spice. These weight thresholds are within the range of 0 - 500 grams and recorded in whole grams.
4. Each ingredient on the dashboard visualizes the recorded weight of the spice through a progress bar. The progress bar ranges from 0 - 500 grams with a marker indicating the user specified lower weight threshold.

    a. When the recorded spice weight falls below the lower weight threshold, the filled portion of the progress bar turns red. Otherwise it remains green.
5. Ingredient dashboard receives updates on spices weight every 15 minutes. The "Ingredient Dashboard" data is stored in an online database.
6. Dynamic grocery list synchronizes with "Ingredient Dashboard" and only ingredients that are below the lower weight threshold are displayed

2C.III Sensing Subsystem
The sensing subsystem is made up of the RFIDs and load cells. The sensing subsystem is connected to the control and power subsystems via wires. The system uses RFIDs operating at 13.56MHz [13] to allow users to place spice containers in any slot while recognizing the spice and its lower weight threshold. The spices will be held in plastic airtight containers that weigh 481.94 grams and can hold up to 498.952 grams of spice. The load cells are used to measure the weight of the spices and send the information to the MCU. HX711 chips will be used in conjunction with the load cells to turn the voltage measured across the load cell into 24 bit 2's complement values.

Requirements:
1. Load cells distinguish weights with a resolve of 0.5g (refer to tolerance analysis)
2. Load cells measure the maximum weight of the spices to 500 grams each.
3. Only the 3 valid RFID tags will be read and recognized by the device.
4. The 3 containers with RFIDs can be moved between the 3 spots. The spot's readers allow for the right comparison between the spice's weight and its specific lower threshold weight.

2C.IV Control Subsystem
The control system is made up of the ESP32 MCU. The control subsystem is connected to the power and sensing subsystems using wires. The subsystem connects the user interface subsystem to the sensing subsystem and the hardware interface subsystem. The MCU will use its built-in Wifi protocol to send data from the load cells and RFIDs to the app. It also sends data received from the app to the LEDs. The MCU pulls weight data captured by the load cells every 15 minutes.

Requirements:
1. The output weight from the HX711 chip gets translated through the logic level chip shifter from 5V to 3.3V. This 24 bit 2's complement output value [3] will be converted to decimal values.
2. The data pulled from the HX711 chip to the MCU is transferred to the Firebase database every 15 minutes.

2C.V Power Subsystem
A wall power adapter that converts 120V AC to 5V DC will be used for the load cells, HX711 chip and RFIDs. A voltage regulator will be used to step down the 5V to the 3.3V needed by the MCU. A voltage divider will be used to step down the 5V to the 2.3V needed by the LEDs. A logic level chip shifter will be used between the HX711 chip and the ESP32 to translate the 5V signals to 3.3V signals needed by the ESP32.

Requirements:

1. The LM317 configured as a 5V regulator must be able to provide 3.3V from 5V at 620mA continuous current, with a voltage tolerance no greater than ±0.3V. The voltage tolerance is ±0.3V for the ESP32 as indicated on the datasheet [6].

2D. Tolerance Analysis

Load Cell Tolerance Analysis:

The system needs to measure spices and compare it against the user specified lower weight threshold. The digital grocery list interface adds/removes spices based on whether their recorded weight is below its lower weight threshold.

The weight recorded by the load cell includes the spice container and the spice itself. The container used weighs 481.92 grams. The contents of the container range from 100g to 500g. For this system, a low spice level for a full 500g spice is around 200g. However, some users may want to wait until the spice reaches a lower weight, like 50g, to replenish, while others will replenish early at a higher weight, like 300g.

Therefore, we need a weight sensor that can measure up to 1 kg (~481.92 + 500).

However, a challenge comes with determining the tolerance of the increments of weight the threshold can be set at. Let's assume that the user is tracking cinnamon, which usually comes in 500g containers. The user may not care if the threshold is 200g or 202g. In this instance the user may be satisfied with 10g increments, for example 200g, 210g, 220g, etc. However, if saffron is the tracked spice, then the user may want increments of 1g.

Therefore, the system requires a load cell that can resolve 1g of ingredients, in the worst case. The system will be using a load cell which is rated for 1 kg with a resolve of 0.5g.

Each load cell has a sensor with 4 outgoing wires. These wires are connected to VDD, GND, INA^+, INA^- of the HX711 chip. The HX711 is a 24-Bit Analog-to-Digital Converter (ADC) for weight scales. The HX711 allows for two load cells (Channel A and Channel B). The HX711's "input multiplexer selects either Channel A or B differential input to the low-noise programmable gain amplifier (PGA). Channel A can be programmed with a gain of 128 or 64, corresponding to a full-scale differential input voltage of ±20mV or ±40mV respectively, when a 5V supply is connected to a VDD analog power supply pin. Channel B has a fixed gain of 32" [3].

This is a single point load cell and has 2 circular holes drilled in the middle. This design allows for flexibility and ensures accurate readings even if the weight is unevenly distributed. This design feature is essential "as it removes the effects of human error in placement" [15] of weights onto the load cell. The load cells have four mounting holes in total, two on each side for installation [10]. The HX711 requires 5V for the VDD. Therefore, the load cells will use 5V to maintain a consistent VDD across interacting components.

The output weight from the HX711 is represented as a 24 bit 2s complement value. The output will be sent to the MCU. Since each HX711 operates at 5V and the MCU operates at 3.3V, the design requires a logic level chip shifter to drop the voltage accordingly. The output signal received by the MCU is 0 - 3.3V, where 0V represents the 0 and 3.3V represents 1. The output is shifted out from pin DOUT. When 25~27 positive clock pulses are applied to the Serial clock input (PD_SCK) pin, data is shifted out from the DOUT output pin starting with the MSB bit first. Each PD_SCK pulse shifts out one output bit until all 24 bits are shifted out [3].

The load cell needs to be able to read up to 1kg with a resolve of 0.5g. One level will represent 0.5 grams. Since we have 1000g, the design requires 2000 levels (1000/0.5 = 2000). In order to accurately represent the weight, the chip needs to have at least 11 bits of digital logic ($\log_2 2000 = 11$). Therefore, the HX711 is the right choice as it is a 24-Bit Analog-to-Digital Converter and meets the system's needs.

<u>Linear regulators Tolerance Analysis:</u>

Part	**Worst Case Current Draw @ 3.3V**	**Comment**
ESP32-S3	500mA	Page 56 of the datasheet
LED	120mA	
Total	620 mA	

Table 1: Current Analysis

Variable	**Value**	**Comments**
$\max(T_j)$	125 C	Maximum operating junction temperature of LM317TO-200 package [12]
i_{out}	620 mA	Maximum current draw of components on 3.3V power
vin	5 V	Output of wall power output adapter
vout	3.3 V	Operating voltage of components
θ_{jc}	5 C/W	Junction-to-case thermal resistance of LM317TO-200 package found in datasheet [12]
θ_{ca}	32.9 C/W	The regulator datasheet conveniently specifies θ_{ja} = 37.9 C/W. [12]

T_a	30 C	Let's assume for a warm board

Table 2: Variable Values for Formula Estimating Junction Temperature

The formula below is used to estimate the junction temperature:

$$P_D = iout \times (vin - vout)$$
$$T_{ja} = P_D \times \theta_{ja}$$
$$\Rightarrow T_j - T_a = P_D(\theta_{jc} + \theta_{ca})$$
$$\Rightarrow T_j = P_D(\theta_{jc} + \theta_{ca}) + T_a$$
$$\Rightarrow T_j = i_{out}(vin - vout)(\theta_{jc} + \theta_{ca}) + T_a$$

Formula in regards with system values:

$$T_j = i_{out}(vin - vout)(\theta_{jc} + \theta_{ca}) + T_a = 620mA(5 - 3.3)(5 + 32.9) + 30 = 69.95\,C$$
$$T_j \approx 69.95C < max(T_j)$$

This process of estimating T_j is not meant to be very exact. Since the estimated temperature is 30 degrees below the maximum, the LM317TO-200 package is an appropriate linear regulator to use.

4 Ethics and Safety

The project will comply with the IEEE and ACM Code of Ethics. The safety risks that this device poses are that it has the possibility of being a fire hazard. The electrical parts of the device including their connections will be enclosed within the enclosure. This means that other than the power port, any loose spices will not be able to reach the electrical components and cause a short circuit or electrocute anyone. The LEDs will be enclosed within a see through covering to prevent spices and dirt from getting on it. Thus reduces the risk of a fire hazard. This product does not pose a risk for cross contamination. The spices are placed within plastic airtight containers. Therefore if any containers fall down/move, the spices are safely contained within the container. If any spices fall onto the device, a user can use a wipe to remove the mess.

There are also the possibilities for potential ethical and privacy concerns surrounding the app accompanying the device. The app will require access to the user's location, however the app will not be using the user's information for malicious purposes. This aligns with the ACM Code of Ethics stating, "Computing professionals should only use personal information for legitimate ends and without violating the rights of individuals and groups [...] taking precautions to prevent re-identification of anonymized data or unauthorized data collection [...] and protecting it from unauthorized access and accidental disclosure" [1]. As this app will only be available on Apple devices, the user will have the option to choose their privacy setting in their Apple device settings. The team will follow all safety guidelines, standards, and regulations while completing our project. The team aims to create a device and app that makes kitchen dry ingredient organization easier, while prioritizing safety and the IEEE and ACM Code of Ethics.

5 Citations

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