ECE445 Senior Design Laboratory

Automated Tea Maker Project Proposal

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Contents

Introduction

Problem

Dry tea leaves are a great cost effective alternative to buying tea bags. They offer higher quality and allow a large assortment of flavors to choose from. However, storing leaves and measuring out precise amounts can become quite tedious. They must be kept within specific temperature and humidity ranges to avoid any degradation of the leaf over time. With multiple types of tea leaves out there, many users would benefit from being able to easily create their own blends. New tea drinkers would be able to experiment and see what flavor combinations best suit their taste profile. Traditional methods of storing tea leaves include containers, tins, and ceramic jars. These provide no real time feedback as to the whether or not the conditions for that specific leaf are being met. Users may be unknowingly losing out on money as the aroma and quality of the leaves diminishes. Also, blending different flavors requires precise measurements to get the most out of the final result. An all-in-on storage and dispensing unit currently does not allow users to automate the monitoring and dispensing process simultaneously.

Solution

Our proposed solution is to offer users an integrated product that allows them to get the most out of their tea experience. They would be able to store dry tea leaves inside separate vertical units. Each unit will house temperature and humidity sensors to monitor the quality of each unit. This information will be relayed back to a series of LEDs attached to the device. Different colors will provide users with insight into the conditions in which the leaves are being stored in. This will also be communicated to a simple app that users would be able to use. They would be able to see these conditions in the app and be notified when levels get low. IR sensors would help with this as the levels within the vertical units decrease over time and eventually go below the sensors. The app would also alert users when their blend was ready to be measured out. The second benefit would be allowing users to input different combinations and amounts of each flavor into the app. Once they are ready to dispense the blend, they place their mesh spoon in a weighing tray where the product will fall. A series of motors will measure out the correct proportion of the blend and drop it into this weighing area, directly into the spoon. Once the weight sensors under the tray notify the dispensing process to stop, users would simply be able to remove the spoon and steep their hot water. This solution will automate the entire process of storing and measuring out tea leaves. Users will be able to easily experiment with different blends and get the most out of their tea-drinking experience. The final enclosure would roughly be 6 inches by 8 inches by 8 inches.

Visual Aid

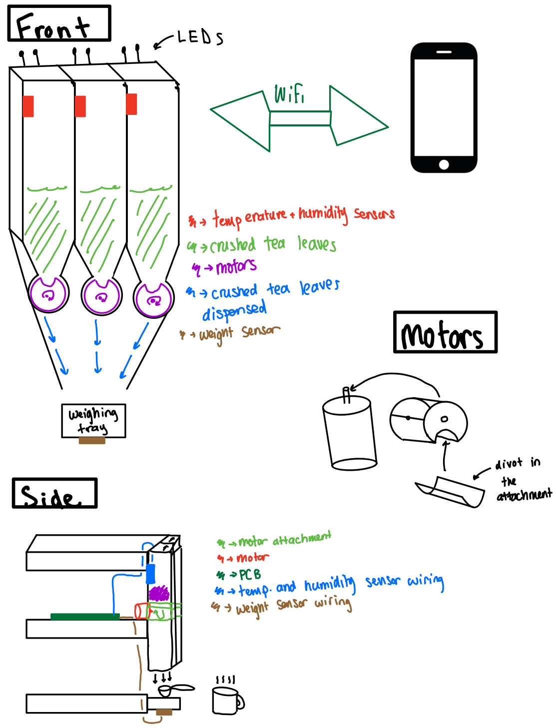

Figure 1: Rough sketch of proposed design

The proposed solution is to have a unit that stores the tea leaves and is connected to a series of motors. The motors will require an additional attachment to allow leaves to fall into a small divot as they rotate. The backside of the unit will house our PCB, electronic components, wiring, and power source. The communication between the app and micro controller will take place through WiFi. Finally, the blend will fall into a spoon where it will be measured in real-time. Users can then prepare their cup of tea.

High-Level Requirements List

- The dispensing component should be able to dispense precise amounts of blend combinations, as specified through the app. The result should measure out to within ±0.5 grams of the intended weight according to how much tea will be prepared.
- Temperature and humidity sensors within the vertical storage units should be able to accurately measure conditions and update users. This should convey temperature readings with an accuracy of ±1% and humidity readings with an accuracy of ±5% for relative humidity. These results need to be conveyed back to the app as well as LEDs attached to the storage units.
- Users must be able to utilize a simple app to trigger the dispensing process as well as check the conditions of each storage unit. Updates to and from the microcontroller must have minimal latency. Users should be able to request different amounts of dry leaves and store combinations

for future use. There should also be an emergency stop options where users can halt the current dispensing process.

Design

Block Diagram

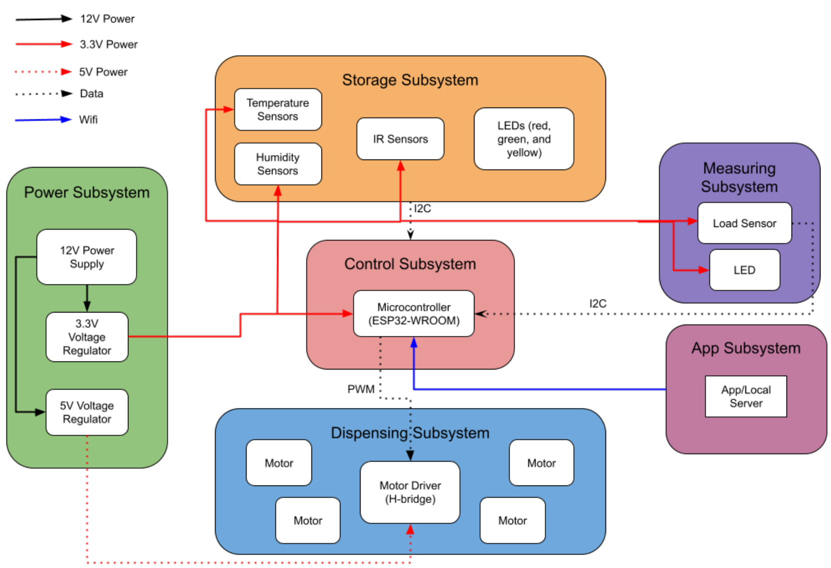

Figure 2: Proposed block diagram

Subsystem Overview

Power Subsystem

The power subsystem will be responsible for taking a centralized 12V source and converting it to necessary voltages for other subsystems in the design. Specifically, lower voltages of 5V and 3.3V are required. Both of these will be the result of voltage regulator circuits that convert the 12V input to the desired output. The 5V line will need to help power the motor driver within the dispensing subsystem. A series of stepper motors will help dispense precise amounts of tea leaves. The 3.3V line will power the rest of the subsystems. The storage subsystem will contain a series of sensors that require a fairly small amount of power. The load sensor contained under the tray that sits within the measuring subsystem will also require 3.3V. Most importantly, our microcontroller (ESP32 WROOM), is the final component that will need to be powered by this line. This will be responsible for performing all operations and directing different subsystems.

Control Subsystem

The control subsystem will include our microcontroller, the ESP32 WROOM. This specific MCU supports WiFi/Bluetooth functionality which is crucial for the user interface of our design. The MCU will help monitor storage conditions, trigger and verify the measuring process, and control motors accordingly. Real-time feedback will be relayed to a local app/website where users can begin the dispensing and choose blends. They can also check the temperature, humidity, and stock levels of the leaves being stored. The motor driver requires PWM/GPIO signals from the control subsystem as well. Finally, LEDs located on the measuring and storage subsystems will need to be lit up whenever conditions fall outside a predetermined threshold and when the dispensing process is complete. Sensor readings will need to be converted from analog to digital signals before feeding into the microcontroller.

App Subsystem

The app subsystem will host a local server that can be accessed through WiFi. Users will be able to monitor and dispense different blends. They will be presented with an interface that shows the temperature, humidity, and amount in each tea leaf storage unit. This will be able to communicate, over WiFi, with the microcontroller. The ESP32 WROOM is capable of hosting its own simple server or connecting to an existing network. We will need to develop our own protocol (most likely leveraging HTTP GET/SET) to run through a series of different states. The frontend can be implemented using Javascript/CSS while the backend can utilize C++ or Python. We will consider various languages and see which interfaces best with the MCU. The app will also need to be able to efficiently convey different instructions to the microcontroller. Finally, users can expect alerts when levels within the storage containers fall below a threshold. Also, they will be notified when the blend is done being dispensed and ready to steep.

Storage Subsystem

The storage subsystem will house the actual leaves in separate vertical storage units. We will work alongside the machine shop to create an enclosure that can easily fit in an everyday kitchen. The units will need temperature, humidity, and IR sensors placed within them to help monitor conditions. The leaves will sit atop a series of motors with customized divots in them to scoop small amounts. The top of the storage subsystem will be covered in lids that can be removed. The backside of this enclosure will leave room for our PCB and electrical components. LEDs on top will light up different colors depending on the conditions and whether or not they fall outside the healthy range. Overall, this subsystem will work closely with the microcontroller to notify users of important information regarding their stored tea leaves. IR sensors will be pointed into the units and trigger once the tea leaf level falls below it.

Dispensing Subsystem

The dispensing subsystem will contain a series of stepper motors and be located below the storage area. The leaves will sit on top of these motors that will have custom divots in them to scoop ingredients. The size of these divots will depend on how granular the leaves end up being. A motor controller will need to process PWM signals and output the correct voltage/current to each motor according to what the microcontroller tells it. This will most likely be some sort of H-bridge circuit. The precision of our product depends heavily on whether or not these motors can reliably rotate and not get jammed up. They will eventually stop rotating as the dispensing process yields the correct weight of the blend requested. As the motors scoop a small amount of each leaf, they will fall through a funnel and drop into the measuring subsystem. This component will rely on gravity to make sure that the full amount of the measured leaves make it through. Motors will turn one by one to avoid any current complications.

Measuring Subsystem

The measuring subsystem will be the final destination for the tea leaves once they are dispensed. Users will be able to place a spoon here that they will use to steep their tea. The spoon will need to be calibrated since the tray that it sits on will be on top of a load sensor. We are considering having a button on this subsystem that users can press to ”zero” out of the scale. The load sensor will need to accurately and quickly relay updated measurements to the microcontroller. This is what will lead to the most precise measurements. Once the desired amount has been reached, there will be an LED that lights up here notifying users that their blend is ready for a cup of hot water.

Subsystem Requirements

Power Subsystem

Requirement	Verification
Must be able to supply 5±0.5V to the dispenser subsystem	Use a multimeter to measure across ground and the output of the 5V voltage regulator. Ensure that the readings fall within the desired threshold.
Must be able to supply 3.3±0.5V to the sensors, LEDs, and microcontroller	Use a multimeter to measure across ground and the output of the 3.3V voltage regulator. Ensure that the readings fall within the desired threshold.

Control Subsystem

Requirement	Verification
Must be able to receive signals from temperature, humidity, and IR sensors and convert from analog to digital signals.	We can unit test sensors separately and together while reading input and outputting values through software. We should use a baseline to ensure that the readings match what is expected from the environment. For these readings, we will use commercial products (thermometer and humidity meter).
Must be able to send PWM signals to the motor driver that will control various stepper motors in the dispensing unit.	Unit test the dispensing unit with controls coming from the microcontroller. We can use an oscilloscope to verify that packets sent over follow the correct protocol and vary as we change the signals.
Must be able to obtain readings from load sensors efficiently and stop sending signals to the motor controller to stop the dispensing process. Readings should be produced with an accuracy of ±0.5 g from the intended amount requested.	We can request specific amounts and combinations and verify that readings are accurate by printing load sensor readings through software. Also, we can check by running the dispensing process and making sure that PWM signals are no longer sent to the motor controller once the desired amount has been measured out.

App Subsystem

Requirement	Verification
Must be able to efficiently send and receive instructions from the microcontroller with minimal latency of less than 1 second.	We can unit test different components of our design and check that updates within the app appear as close to real-time as possible. This will include changing temperature, humidity, and IR conditions to trigger an alert and checking that the update came through quickly enough. Also, notifying the microcontroller when to begin dispensing a blend must be quick. This can be done by incorporating timestamps into packets sent between the app and microcontroller and checking that their differences fall below the threshold.

Storage Subsystem

Requirement	Verification
Must be able to send accurate signals from temperature, humidity, and IR to the microcontroller according to their respective data sheets. Temperature and humidity readings are expected to be 72-77F and 30%-50% for optimal storage	We can unit test each sensor and make sure that the readings registered by the microcontroller are reasonable relative to the environment.
Must be able to alert users, through an LED, when readings fall outside a specified threshold.	We can slightly alter the environment that the sensors are in as well as thresholds and visual verify that alert LEDs are triggered the moment readings fall outside the safe range.

Dispensing Subsystem

Requirement	Verification
Must be able to receive signals from the motor controller and rotate stepper motors a full 360 degrees while also allowing control over varying step sizes.	We can test the motors individuals and together and vary rotation speed, step size, and rotation time to ensure that they behave as expected according to data sheets.
Must be able to stop when notified by the microcontroller that the dispensing process has been completed. There should be minimal latency with 0 extra rotations.	We can hardcode values within the code to test that the motors stop rotating when notified. There should be no delay between when the process should stop and when the motors stop.

Measuring Subsystem

Requirement	Verification
Must be able to accurately make readings using a load sensor from 0-500 grams.	We can test the load sensors with varying weights and verify that readings displayed through software and the microcontroller match the expected results.
Must be able to register fine changes in measurements and allow users to calibrate a steeping spoon to "zero" out the scale.	We will add small amounts of tea leaf manually to the scale and verify that the readings are able to update accurately. Also, we will use a customer "zeroing" routine to make sure that the values also take into account the weight of the spoon.

Tolerance Analysis

A main component of our design is accurately measuring the desired weights of different tea blends. One requirement of our control subsystem is to have this accuracy within 0.5 grams of the intended amount the user requests. We plan on working with the machine shop to create custom attachments for the motors in the dispensing subsystem. These attachments will go on the ends of the motor and appear as divots in the shape of a half circle. The radius and length of this divot will depend on the amount of a single tea leaf we want a single rotation of a motor to dispense.

The measurements will depend on the density of the dry tea leaves we use. Since this will vary depending on the type of leaf, we decided to have the tolerance be quite high initially. As we progress with the design, we may work at refining this. Overall, the goal is to have a single rotation measure out 0.5 grams of that tea leaf. The leaves will be a bit more crushed to make it easier to scoop. The following calculations represent how we plan on shaping the motor attachment to attain this goal. We will assume that the average density of the tea leaf we will work with will be between 0.2 g/cm^2 and 0.4 g/cm^2.

$$\text{Density of dry tea leaves} = 0.2\ g/cm^2 \text{ to } 0.4\ g/cm^2$$

$$\text{Volume upper bound (smaller density)} = \frac{\text{Mass}}{\text{Density}} = \frac{0.5 \text{ g}}{0.2 \text{ g/cm}^3} = 2.5 \text{ cm}^3$$

$$\text{Volume lower bound (larger density)} = \frac{\text{Mass}}{\text{Density}} = \frac{0.5 \text{ g}}{0.4 \text{ g/cm}^3} = 1.25 \text{ cm}^3$$

The cross-section of the motor attachment's divot will be in the shape of a half-circle with radius r and length L. The following shows the volume of dry tea leaves the divot can hold with these dimensions:

$$\text{Volume} = \text{Half-circle cross-section area} \times \text{Length}$$

$$\text{Half-circle area} = \frac{1}{2}\pi r^2$$

$$\text{Volume of divot} = \frac{1}{2}\pi r^2 \times L$$

The range for the product of r^2 and L is as follows:

$$2.5 = \frac{1}{2}\pi r^2 \times L$$

$$r^2 \times L = \frac{2.5 \times 2}{\pi} \approx 1.59$$

$$1.25 = \frac{1}{2}\pi r^2 \times L$$

$$r^2 \times L = \frac{1.25 \times 2}{\pi} \approx 0.795$$

Depending on what we choose for the radius r and length of the divot L, we can get close to a single rotation measuring out 0.5 grams of dry tea leaves. The range for the product shown above will be from 0.795 to 1.59 since the range of tea leaf densities is from 0.2 g/cm^2 to 0.4 g/cm^2.

Let's assume we take the radius of the divot to be 1cm. The calculation for the length of the divot will be the following for a density of 0.2 g/cm^2:

$$1^2 \times L = 1.59 \quad \Rightarrow \quad L \approx 1.59\,\text{cm}$$

And the following for a density of 0.4 g/cm^2:

$$1^2 \times L = 0.795 \quad \Rightarrow \quad L \approx 0.795\,\text{cm}$$

This means we can take a length between 0.795 cm and 1.59 cm. A tolerance of 0.5 grams is required because not all of the divot will actually be filled with dry tea leaves. Since they are solid, there will be gaps in the scoop which can lead to the rotation giving out less than 0.5 grams. Moving forward, we will assume that roughly between 60% and 80% of the divots can be filled with dry tea leaves. This means that a single rotation can potentially scoop out 0.3 grams to 0.4 grams. For multiple rotations, this can amount to a large amount of error. We will need to consider this by either making the divot larger than it needs to fill 0.5 grams, or crushing up the leaves to make them finer. A proposed solution is to make the divot fit closer to 1 gram so that it is less of an issue when only 60% to 80% ends up being occupied.

Ethics and Safety

To ensure there aren't any safety concerns in the design of the Automatic Tea Maker we have identified a few scenarios where the device can potentially cause minor harm. One of the potential safety concerns may be that the motors in the enclosure might not be fully enclosed and can potentially come in contact with the user. To prevent this scenario we will make sure all the moving parts of the system are as inaccessible for the user as possible and make sure no motor is exposed. Next, we will make sure no component in the system gets dangerously hot by managing voltage, motor speed, dissipating the heat or having warning alerts to ensure safety.

Overall we will make sure our design abides with all the IEEE code of ethics to ensure that we help improve the lives of our users without harming anyone else in the process[1]. We will ensure that the design is safe for use in various environments and run focus groups to see how the customer is using our product. We will also provide our contact information on the machine so that customers can give us their feedback on the product so that we can keep on improving our design.

References

[1] IEEE - IEEE Code of Ethics, www.ieee.org/about/corporate/governance/p7-8.html. Accessed 20 Sept. 2024.

[2] This is an example citation: [2] "How to Store Loose Leaf Tea." Té Company, tecompanytea.com/blogs/tea-atelier/how-to-store-loose-leaf-tea. Accessed 19 Sept. 2024.