ECE 445

SENIOR DESIGN LABORATORY

DESIGN DOCUMENT

Tea Blend Distributor

Team #14

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1 Introduction

1.1 Problem

Recently, coffee makers have become popular among coffee lovers as emerging home appliances. Even people who do not know much about coffee are able to use coffee machines to get a cup of coffee that meets their taste requirements conveniently and quickly. Tea is also a popular beverage over the world. However, the procedure of brewing tea is very complicated. It is not an easy task for people to obtain a good cup of tea.

1.2 Solution

To solve the problem stated above, we want to design a tea brewing machine whose usage is part of similar to the coffee machine. In general, this tea brewer can make the proper tea according to the preferences input by the user. All the brewing process is automatic, and users only need to wait for a while to get a good cup of brewed tea. It allows tea lovers to save the energy needed to brew tea and will enable people new to tea to have a chance to try it.

1.3 Visual Aid

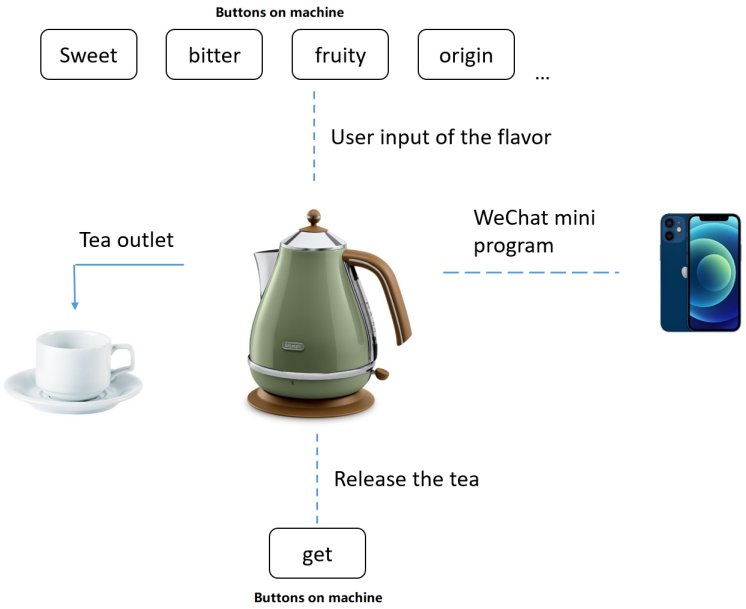

Figure 1. Visual Aid of Tea Blend Distributor

Figure 1 shows the way to use the Tea Blend Distributor schematically. In sum, users can input requirements, including bitterness, sourness, sweetness, and floral aroma, to the machine. Then the device will automatically make the corresponding tea. Two methods are available for users to input their requirements. The first method is to press the buttons

on the machine, selected from “Sweet”, “Bitter”, “Fruity”, “Origin”, etc. Another one is using WeChat Mini Program to make an order. Once Tea Blend Distributor receives users’ taste requirements, it will tell users to wait for a while. After waiting, the Tea Blend Distributor will alert users by pushing messages on WeChat or the Blinking indicator. Users can put the “Get” button on the machine to release the tea.

1.4 High-level requirements list

- WeChat Mini Program should allow users to input their requirements and transmit data to the machine through the server. Besides, the user input from WeChat Mini Program includes the type of tea, the flavor requirements, and the strenth of the tea and ingredients.
- Tea and Supplement Dispensers should accurately distribute set amount of ingredients into the container. For example, tea leaves and small flowers like osmanthus should be dispensed in units of one gram and large flowers like roses should be dispensed in units of a single flower.
- Server should transmit user input from WeChat Mini Program to Local Control Subsystem.
- Tea Brewing System should maintain the water temperature at $85°\mathrm{C}$ and the tea brewing time at least 2 minutes.

2 Design

2.1 Block Diagram

The block diagram of Tea Blend Distributor is shown in Figure.2.

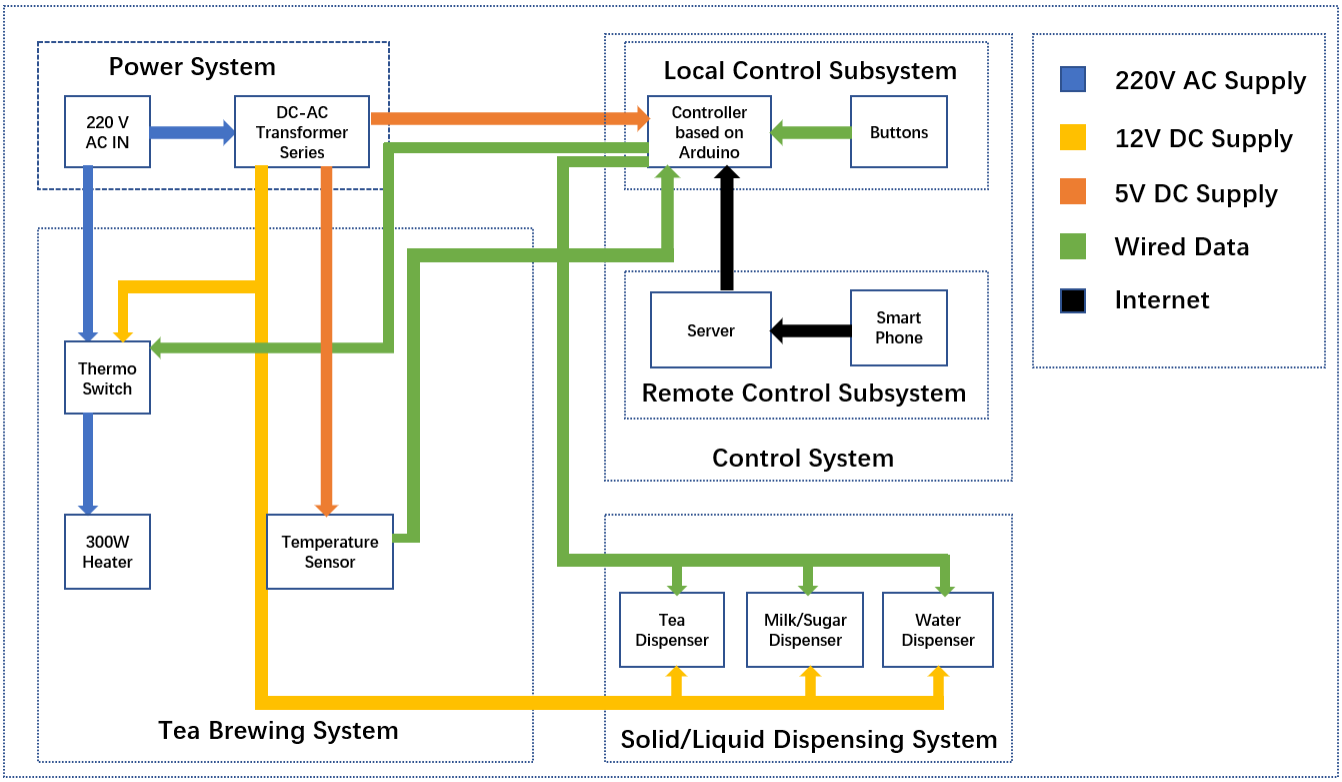

Figure 2. Block Diagram of Tea Blend Distributor

2.2 Physical Design

The physical diagram of our design is shown in Figure 3. It mainly shows the mechanical components in our machine.

The physical diagram of our design is shown in Figure 3. It mainly shows the mechanical components of our machine. There are seven containers, and we might adjust the specifications and quantities depending on further requirements. Components 1 and 2 are liquid containers, one for water and one for milk. Both are connected with pipe-like objects (shown in red), acting as liquid dispensers by applying proper electrical signals. Components 3 and 4 are containers for green and black tea, component 5 contains sugar, and components 9 and 10 are filled with different kinds of flowers. All of them have solid dispensers beneath, which can output a certain amount of items according to the requirements. Components 6 and 8 are vessels for heating, and component 7 is the heating jacket. The wall of the minor vessel is mesh. Sugars and teas would fall in it and contract with the liquid, but they will not float outside the mesh. Water and milk are injected into

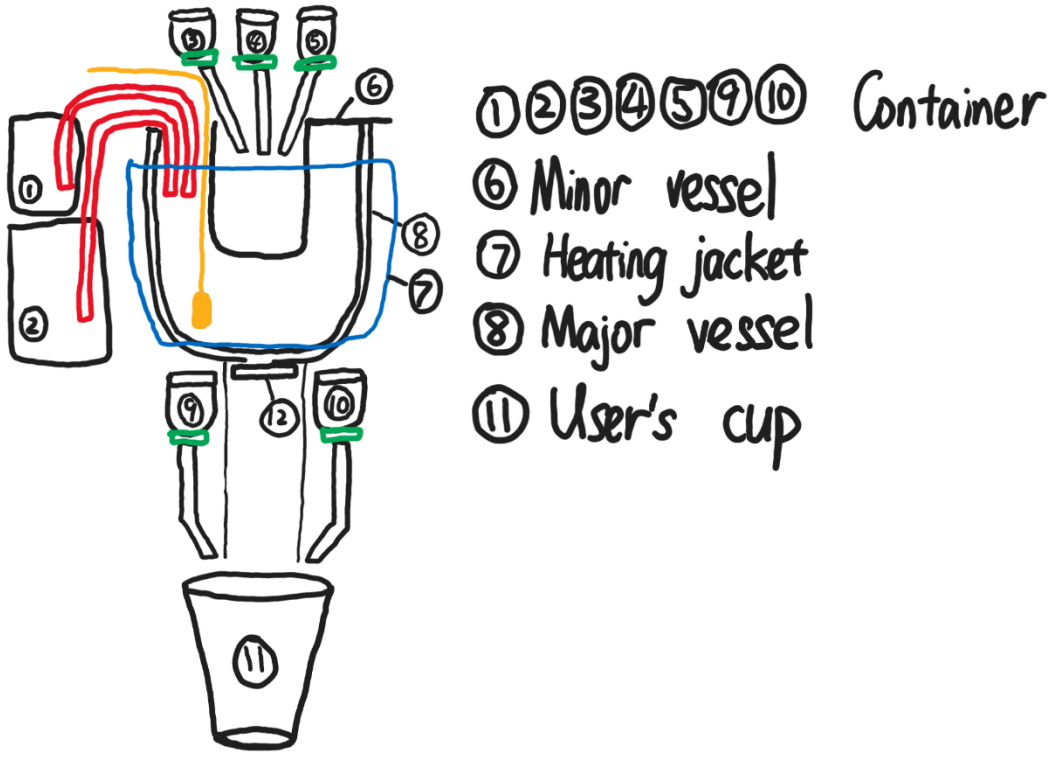

Figure 3. Physical Diagram of Tea Blend Distributor

the larger vessel. With of help of a temperature sensor (shown in yellow), the heating jacket will keep the water temperature around 85 degrees Celsius, which is the optimal temperature for making tea. After that, component 12 will open, and tea will be poured into the user's cup. Finally, flowers will also be added to the cup.

2.3 Subsystem Overview

2.3.1 Power System

The Power System is used for supplying power to all other systems, which contains a 220V AC input, DC-AC transformer series, two 5V outputs, and a 12V output. The 220V AC input comes from a socket, the two 5V outputs will be connected to Temperature Sensor in Tea Brewing System and Controller based on Arduino in the Local Control Subsystem of the Control System as a power supply. The 12V output will be connected to the Tea Dispenser, Milk/Sugar Dispenser, and Water Dispenser of the Solid/Liquid Dispensing System as a power supply. The 12V output will also be connected to the Thermo Switch of the Tea Brewing System as a power supply.

2.3.2 Control System

The Control System is used for controlling the remaining parts of this machine, consisting of the Local Control Subsystem and the Remote Control Subsystem.

The Local Control Subsystem is the core part of the Tea Blend Distributor, which receives user input and internal signals and sends out control signals. This system contains a Controller based on Arduino and buttons. It has a 5V DC input, an Internet data input, a wired data input, and four wired data outputs. The 5V DC input, which is the power supply, is given by the Power System. The Internet data input will be connected from the Server in the Remote Control Subsystem of the Control System, transferring user input. The Wired Data input will be connected from the Temperature Sensor of the Tea Brewing System as temperature input. The first Wired Data Output will be connected to the Thermo Switch of the Tea Brewing System as temperature input, and the other three will be connected to the Tea Dispenser, Milk/Sugar Dispenser, and Water Dispenser of the Solid/Liquid Dispensing System as order input.

The Remote Control Subsystem, containing a server and a smart device, which is used for getting user input by smart devices, has only an Internet data output which will be connected to Controller based on Arduino as user input.

2.3.3 Solid/Liquid Dispensing System

The Solid/Liquid Dispensing System is used to dispense material. It consists of several tea dispensers, a sugar dispenser, a milk dispenser, and a water dispenser. They are linked with containers that restore the necessary materials to make a cup of tea. Each dispenser has a wired data input and a 12V power input. The wired data inputs will be connected from the Controller based on Arduino of Local Control System. The power inputs will be connected from the DC-AC Transformer Series of the Power System. In general, when working, the dispensers can receive wired data inputs from the Local Control Subsystem and do corresponding responses by dispensing a precise amount of items into the vessel. For liquid dispensers, they can pour the required volume of corresponding liquid into the major vessel. In the test, the fluid flow rate is essentially a constant. So the amount of liquid output can be fixed by controlling the running time of the dispensers, and the Local Control Subsystem gives this signal. For solid dispensers, they can drop a settled amount of materials into the minor vessel. The dispenser device receives a single electrical signal, causing the container to drop a fixed amount of items. This quantity is the smallest unit of dispensing. For tea, the smallest unit is 1g; and for sugar, it is one piece. The number of received signals determines the total amount and will be an integer multiple of the smallest unit.

2.3.4 Tea Brewing System

The Tea Brewing System is used for heating and brewing water and other materials to make a cup of tea. It contains Thermo Switch, 300W Heater, and Temperature Sensor. This system has a wired data input, a wired data output, a 5V DC input, a 12V DC input, and a 220V AC input. The 220V AC input will be connected from the 220V AC inputs of the Power System, and the DC inputs will be connected from the proper DC outputs of the DC-AC Transformer Series of the Power System. The wired data input will be connected from the Controller based on Arduino, receiving temperature settings for the

Thermo Switch, and the wired data output will be connected to the Controller based on Arduino, sending the temperature information to the Controller based on Arduino.

2.4 Requirements and Verification

Table 1. R&V of Power System

Requirements	Verifications
(1) The Power System should use a DC-AC transformer series, which transfers 220V AC input to provide 220V AC power supply, 12V$\pm$0.2V DC power supply and 5V$\pm$0.2V DC power supply. (2) The Power System should be able to work correctly even if the current and voltage are too high sometimes.	(1) Measure the circuit voltages at these transformer series respectively by the multimeter in the lab. The results should be 220V AC, 12V$\pm$0.2V DC and 5V$\pm$0.2V DC, which conforms to the requirements. (2) First, configure the machine to make tea, and the Power System's wires and components should not heat up and continue to work, which conforms to the requirements.

Table 2. R&V of Control System

Requirements	Verifications
(1) The Remote Control Subsystem should handle user inputs from smartphones and send the inputs to the Local Control Subsystem, and the Local Control Subsystem should get inputs when users push buttons. (2) When the Local Control Subsystem receives a taste requirement profile from buttons or a smartphone, it can control the Solid/Liquid Dispensing System to work. (3) The Local Control Subsystem can alert the Tea Brewing System and set the tea to a calculated temperature (85°C in most cases).	(1.1) When the requirement profile is set on the smartphone, the server should show a new record about this new order, which shows the server and smartphones are connected. (1.2) Once the server gets a new requirement or the buttons are pushed, the Controller based on Arduino can detect a control signal from the server, which verifies the Controller based on Arduino can detect signals correctly.

Table 2 (continued). R&V of Control System

Requirements	Verifications
(1) The Remote Control Subsystem should handle user inputs from smartphones and send the inputs to the Local Control Subsystem, and the Local Control Subsystem should get inputs when users push buttons. (2) When the Local Control Subsystem receive a taste requirement profile from buttons or a smartphone, it can control the Solid/Liquid Dispensing System to work. (3) The Local Control Subsystem can alert the Tea Brewing System and set the tea to a calculated temperature (85°C in most cases).	(2.1) When the Controller based on Arduino receive a control signal, it will send a control signal to the Solid/Liquid Dispensing System, and this could be verified by detecting this signal on the sensors or motors in the Solid/Liquid Dispensing System. (2.2) After the Solid/Liquid Dispensing System is built, it should start to make tea when a requirement is set using the buttons or on a smartphone. This means the interaction between the Control System and the Solid/Liquid Dispensing System is functioning properly. (3) The Thermo Switch in the Tea Brewing System can detect this alerting signal sent from the Local Control Subsystem, showing that the Control System and the Tea Brewing System are connected. Once the Tea Brewing System is built, the temperature of the tea measured by the thermometer should be the same as the setting one (85 degrees Celsius in most cases).

Table 3. R&V of Solid/Liquid Dispensing System

Requirements	Verifications
(1) The liquid dispenser, including the milk dispenser and water dispenser, could pour an appropriate amount of liquid into the major vessel according to the signal. (2) The solid dispenser, including the tea dispenser and sugar dispenser, could drop an appropriate amount of tea or sugar into the minor vessel according to the signal.	(1) First, configure the machine to output pure water or milk and then use the measuring cylinder to collect the liquid. The volume of collected liquid conforms to the received signal. (2) First, configure the machine to output only tea leaves or sugar and then use the beaker to collect them. The weight of dropped tea and sugar measured by the scale conforms to the received signal.

Table 4. R&V of Tea Brewing System

Requirements	Verifications
(1) The 300W Heater should be started to heat the mixture of tea, water, sugar, and milk When receiving signals from Local Control Subsystem. (2) The Thermo Switch should react properly to the water temperature When receiving signals from Local Control Subsystem. (3) The temperature sensor should be sensitive enough to report the actual temperature to Local Control System.	(1) First, insert a thermometer in the water and then configure the machine to brew tea. The tea will be heated, and the temperature shown by the thermometer should be stable at $85°\mathrm{C}$ eventually.

2.5 Tolerance Analysis

2.5.1 Power System

To ensure all parts work normally, the Power System should use a DC-AC transformer series, which can transfer 220V AC input to 12V$\pm$0.2V DC power supply and 5V$\pm$0.2V DC power supply. For 12V$\pm$0.2V DC power supply and 5V$\pm$0.2V DC power supply, we used the circuit shown in Figure 4 to measure its voltage.

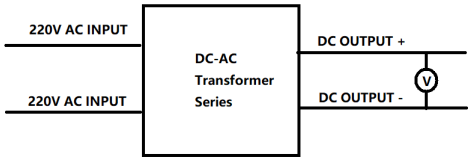

Figure 4. Circuit Used to Measure Output Voltage of DC-AC Transformer

By measuring, the output voltage of all DC-AC transformers we bought falls in the range of 12V$\pm$0.2V and 5V$\pm$0.2V. The experiment procedure would be measuring the input voltage of all parts and check if these values fall in the range required.

2.5.2 Solid/Liquid Dispensing System

The actual output of solid and liquid dispensing systems should be within a range of quantities. In detail, using the smallest units as instances, in the tea dispensing systems, when the required tea is 1g, the dropping mass should be $1\mathrm{g} \pm 0.05\mathrm{g}$. For the water dispensing systems, the needed water for a single injection is 120ml, so the output of real water should be $110\mathrm{ml} \pm 10\mathrm{ml}$. Simple experiments can be designed for these tolerance verifications. Before the actual use of these devices, we would connect their output pipe with a plastic cup. The solid/liquid items would be transported into the cup, and a balance would be used for measuring the weight. This experiment procedure would be

repeated 10 times for a single dispenser. The devices will not be put into use until passing the tests.

2.5.3 Tea Brewing System

To get the maximum flavour of the mixed tea, the tea brewing system must control the temperature of tea to be $85°\mathrm{C} \pm 1°\mathrm{C}$. By consulting the seller of our temperature probe, we got that the probe can measure temperature from -50$°\mathrm{C}$ to 120$°\mathrm{C}$. So it can properly measure the temperature of the tea. The Local Control Subsystem will collect the differential, integral and current values of temperature. With this information, the Local Control Subsystem can control the power supply of the heater, in a PID-based way. The circuit is shown in Figure 5.

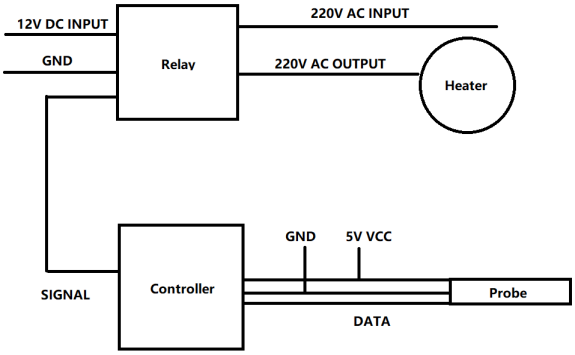

Figure 5. Circuit Used to Control the Temperature of Tea

The experiment procedure would be starting to heat the tea until the temperature of tea is stable, then insert a thermometer into the tea, and then observe the temperature the thermometer shows.

3 Cost and Schedule

3.1 Cost Analysis

3.1.1 Labor

Table 5. Labor Costs

Name	Hourly Rate	Hours	Total	Total*2.5
Zhenzuo Si	$20	200	$4000	$10000
Zhiyuan Wang	$20	200	$4000	$10000
Ruiqi Ye	$20	200	$4000	$10000
Anyu Ying	$20	200	$4000	$10000
Total				$40000

3.1.2 Parts

Table 6. Component Costs

Description	Quantity	Cost/unit	Total
Material for 3D Printing	2	$13.59	$27.18
3.3V DC power module	1	$0.59	$0.59
5V DC power module	1	$1.03	$1.03
12V DC power module	1	$1.61	$1.61
STM32F407VET6 development board	1	$23.43	$23.43
Heating jacket	1	$3.08	$3.08
Temperature probe	1	$1.73	$1.73
Relay	1	$1.17	$1.17
5m silicon tube	1	$0.56	$0.56
2500ml plastic kettle	2	$1.36	$2.72
Heated glass vessel	1	$10.07	$10.07
Total			$73.8

3.1.3 Sum

Table 7. Sum Cost (Labor & Parts)

Section	Total
Labor	$40000
Parts	$73.8
Grand Total	$40073.8

3.2 Schedule

Table 8. Schedule

Week	Task	Responsibility
3/13/2023	Customize heating jacket for the tea brewing system	Zhenzuo Si
	Draw the rough physical diagram and analyze the structure	Zhiyuan Wang
	Make tea and test together, and record the result	Ruiqi Ye
	Make tea and test together, and record the result	Anyu Ying
3/20/2023	Build the circuit of heating system	Zhenzuo Si
	Build 3D printer, design the structure of water dispenser	Zhiyuan Wang
	Make a prototype of the Wechat program	Ruiqi Ye
	help to build the heating system	Anyu Ying
3/27/2023	Programming and testing the heating system	Zhenzuo Si
	Construct, test and adjust the water dispenser	Zhiyuan Wang
	Make the user interface of the Wechat mini program	Ruiqi Ye
	Help to build the dispensing system	Anyu Ying
4/3/2023	Design the Interface between Control System and Dispenser	Zhenzuo Si
	Design the solid dispenser	Zhiyuan Wang
	Finish the main interface and start the subinterface	Ruiqi Ye
	Design the connection of the heating system and the dispensing system	Anyu Ying

Table 8 (continued). Schedule

Week	Task	Responsibility
4/10/2023	Testing and Debugging the Dispenser	Zhenzuo Si
	Construct, test and adjust the dispenser	Zhiyuan Wang
	Designing subinterfaces	Ruiqi Ye
	Build the connection between the heating system and the dispensing system	Anyu Ying
4/17/2023	Programming the server-machine communicating interface	Zhenzuo Si
	Complete all mechanical dispenser parts	Zhiyuan Wang
	Designing subinterfaces	Ruiqi Ye
	Build the connection of the heating system and the dispensing system	Anyu Ying
4/24/2023	Programming the back end of Wechat Mini Program	Zhenzuo Si
	Design and construct the physical part of the project	Zhiyuan Wang
	Connect the front end to the back end	Ruiqi Ye
	Fix any problems in the previous parts	Anyu Ying
5/1/2023	Make all parts together and test	Zhenzuo Si
	Design and construct the physical part of the project	Zhiyuan Wang
	Achieve connection between the server and the machine	Ruiqi Ye
	Collect data on the heating system, which will be used in the next week	Anyu Ying
5/8/2023	Test and debug	Zhenzuo Si
	Complete whole mechanical parts of the project	Zhiyuan Wang
	Make sure the machine correctly corporate with the cellphone	Ruiqi Ye
	Train neural network to have intelligent control of the heating system	Anyu Ying

Table 8 (continued). Schedule

Week	Task	Responsibility
5/15/2023	Test the stability of the system and fix any problems	Zhenzuo Si
	Test the function stability and fix any problems	Zhiyuan Wang
	Finish remaining bugs	Ruiqi Ye
	Test the stability of the system and fix any problems met	Anyu Ying
5/22/2023	Continue to fix problems/design algorithms to recommend options for users	Zhenzuo Si
	Test the function stability and fix any problems	Zhiyuan Wang
	Preparing final stuffs	Ruiqi Ye
	Continue to fix problems/design algorithms to recommend options for users	Anyu Ying

4 Ethics and Safety

4.1 Ethics

We have checked the IEEE Code of Ethics and confirmed that we and our product would never violate these rules. Based on the 1 IEEE Code of Ethics [1], we will put the safety and health of users will always be put first during development. The detailed safety considerations are listed in next part. All materials used in our products are also environmentally friendly. Referring to the #5 and #6 IEEE Code of Ethics [1], all the designs and data will be authentic in our reports and presentations, and we would accept criticism and comments with an open mind.
In our project, we commit to treat people equally. In our designing process, we will treat each of our members fairly and carefully understand and help each member. For users, we will provide different kinds of options so every user can find his/her satisfactory needs. These follow the requirements of #7 and #9 IEEE Code of Ethics [1], which ask us to give fairly treatment and respect to others and not to injure others.All of us have read the IEEE Code of Ethics carefully and committed to follow it, which satisfying the 10 IEEE Code of Ethics "to support colleagues..." [1].

4.2 Safety Considerations

The safety hazard factors are mainly reflected in the use process, which could be divided into four parts. The first is the issue of material safety. The output of our product is tea, which customers would drink. To ensure the health of users, the materials inside our machines contacting with the output tea will be food grade. The second is that part of the machine will be heated internally during the operation. Depending on the choice of different modes, the temperature will reach about 50 to 100 $^{\circ}\mathrm{C}$. The misuse of our machine might have the risk of scalding. To solve this problem, a caution label will be applied to the product surface, and the heating section will be separated from the product housing by a sufficient distance. Third, since we use tea leaves and flowers to brew tea, the issue of allergy is considered. In the user selection screen, we will warn users about allergy problems. So, users with pollen allergies or gastrointestinal problems could select appropriate combination of tea leaves and flowers. Fourth, we use electricity as our power supply and use mechanical structures to control some parts of the system. For these parts, safety is ensured. As illustrated in the design block diagram, the electrical and mechanical parts including the power system and the solid/liquid dispensing system which might be dangerous are isolated from the users, so the users will not be hurt by electricity or the mechanical structure. Therefore, the safety of users will always be protected.
In our designing process, we will use 220V power supply for our system and use mechanical and electrical device in the lab to build our heating and dispensing systems. In this process, we can protect our safety, since we have participated in the lab safety training and are familiar with the mechanical and electrical device which will be used in our design. We will always remind each of us to follow the safety instructions. Additionally, we will always check the heating and dispensing systems are operating as we designed,

so no unexpected hazard will happen.

5 References

[1]"IEEE Code of Ethics." www.ieee.org/about/corporate/governance/p7-8.html. Accessed 19 Mar. 2023.