Perfect Pour Over Coffee

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CONCEPT OF OPERATIONS

REVISION – Draft
25 January 2018

CONCEPT OF OPERATIONS
FOR
Perfect Pour Over Coffee

TEAM <14>

APPROVED BY:

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Mark Golla Date

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T/A Date

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1. Executive Summary

The company sponsor is looking to automate the pour over coffee process to curate the perfect cup of coffee every time. The proposed solution is to make a coffee maker that utilizes computer vision and machine learning algorithms to not only automate the method but also to adjust timings and temperatures based on user feedback for future pours. A camera is used to monitor the saturation of the coffee grounds as the heated water is poured to prevent oversaturation of the grounds. After each pour, user feedback is gathered to reinforce a different machine learning algorithm to adjust water temperature and ground saturation limits. This algorithm will, over each iteration, narrow in on the perfect settings catered to each user. As a result, the user will consistently have their perfect cup of coffee without the hassle of doing it themselves. The benefit of this product over existing technologies is that the machine adjusts its settings so that each user will be able to have a cup of coffee that is catered to their choosing.

2. Introduction

Pour over coffee is a common method used to brew coffee by pouring heated water over the grounds until saturation, and intermittently adding more as the water filters through. Water is reintroduced at various intervals to keep the grounds at a certain saturation value. The advantage of this over a traditional drip coffee is increased control over water temperature and the rate at which water is added to the grounds. The issues with pour over coffee pertain to human errors and inconsistencies with pouring methods. Our system aims to eliminate these issues within the pour over method and create the perfect cup of coffee catered to each user.

2.1. Background

The traditional method lacks the ability to consistently track temperature and control water saturation levels. Our system focuses on automating the pour over coffee process by utilizing machine learning and built-in sensors to regulate temperature and water saturation levels. Rather than having the user focus on heating and drizzling water over the grounds for personalized coffee, the user can concentrate on choosing what type of roast they prefer with the app. Our system will then curate the brew for that user based on their feedback from the previous. This reduces the amount of time a user will have to spend on using the pour over method and eliminates any of the skills involved. Also, the system will brew the same perfect cup of coffee every time since there will be no human interference involved during the brew itself. A friend or family member would be able to brew their loved one's perfect coffee without worrying about messing it up.

2.2. Overview

The three different types of roasts our system will cater to are light, medium, and dark roast. Our system will have preset temperatures and water saturation levels catered to each type of roast prior to the user. After the first usage of the system, the user will be able to relay feedback on the app to determine whether they enjoyed their coffee or not. This information will be stored in the database and depending on the evaluation given, the system will adjust the temperature and water saturation levels. Machine learning will be used to adjust these measurements and compare it to previous data to curate the perfect brew for the next time.

2.3. Referenced Documents and Standards

- FDA - CFR Title 21
- FCC Title 47- Part 15
- https://www.seriouseats.com/make-better-pourover-coffee-how-pourover-works-temperature-timing
- https://resource.bunn.com/library/pdf/coffee_basics_brochure_scae_english.pdf
- https://www.ctahr.hawaii.edu/oc/freepubs/pdf/EN-3.pdf
- https://realpython.com/python-ai-neural-network/
- https://home.howstuffworks.com/coffee-maker.htm#:~:text=On%20the%20left%2Dhand%20side%20of%20the%20base%20of%20the,aluminum%20tube%20heat%20the%20water.
- https://www.barniescoffee.com/blogs/blog/the-difference-between-pour-over-and-drip-brew-coffee

3. Operating Concept

3.1. Scope

The system aims to brew personalized cups of coffee for every individual user by modulating the temperature and water saturation level according to the coffee's roast type and user preferences. It will learn and adjust those two parameters every time the machine brews to ensure the next cup is a step closer to being catered perfectly to the user.

3.2. Operational Description and Constraints

The system is designed to be added to the typical consumer's kitchen ecosystem. Each user will create a user profile, which will be constructed using default brewing parameters. To start a brew, the user will add water to the reservoir, place their preferred grounds onto the filter, and enter the quantity of coffee along with their roast selection into the user interface. The brewing sequence will start, and the progress will be displayed. At the end of the sequence the user will be alerted by both the machine and the app that their coffee is ready. Afterwards, they can then dispose the grounds, rinse the filter, and rate their coffee.

The operational constraints are as follows:

- Must be connected to a smartphone for usage of the app
- Designed for indoor use only
- The device, except for the carafe and filter, must not be immersed in water
- The device should only be brewed with coffee grounds
- The camera lens must be clean and unobstructed for proper performance

3.3. System Description

The system can be described in three separate subsystems: hardware (sensors and brew control), database and machine learning, and lastly the android app.

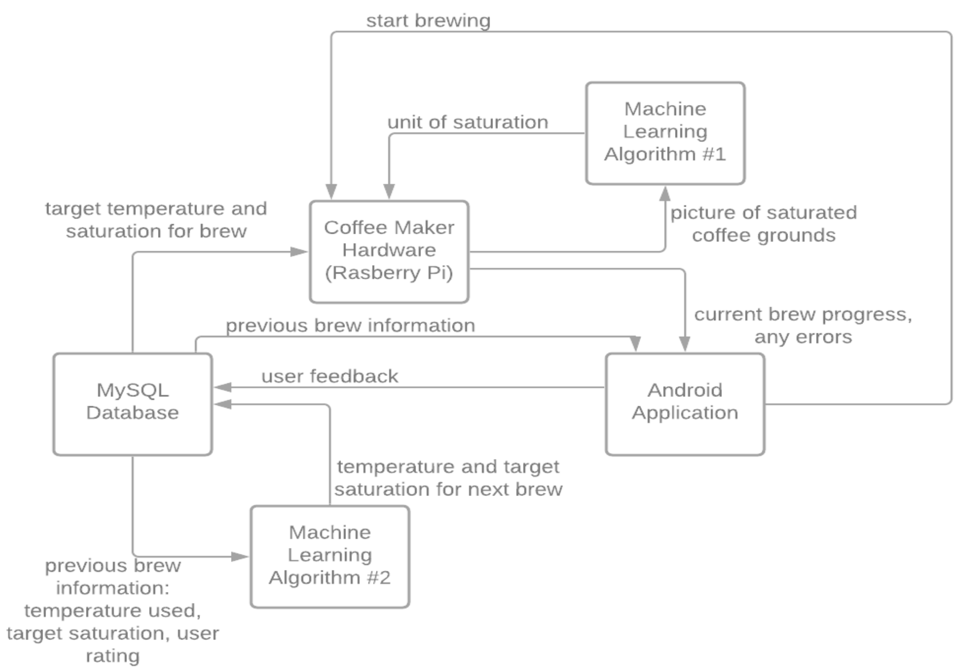

Figure 1: Software System Breakdown Model

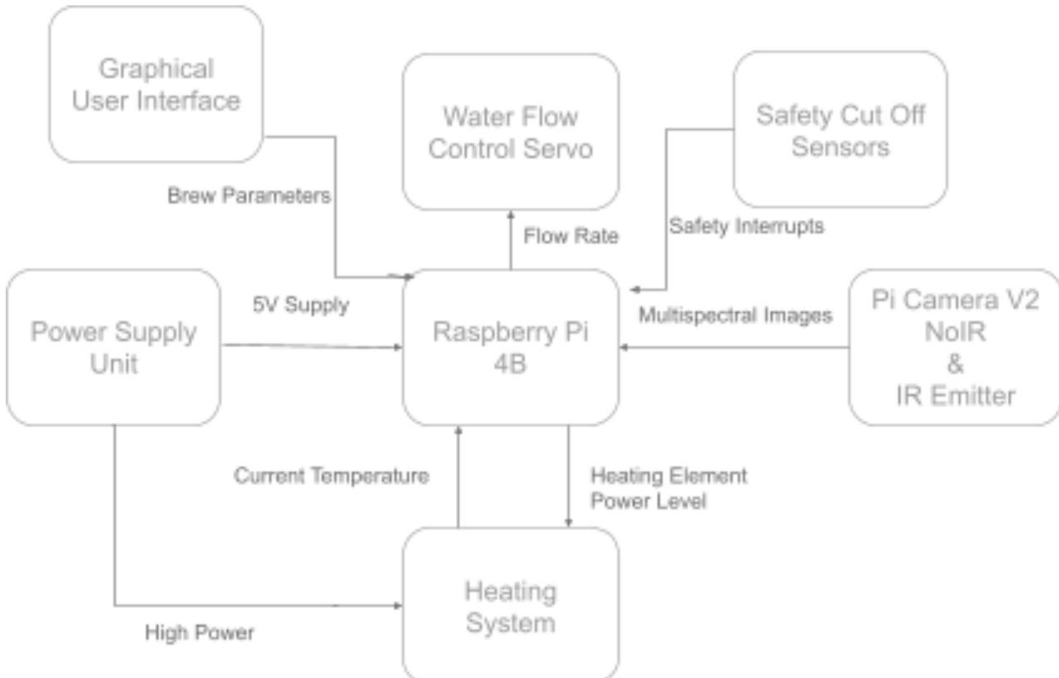

Figure 2: Hardware Control System Breakdown Model

Hardware User Interface: The user will be able to select a user profile under which their settings will be saved, then enter their desired roast type and brew amount. The user will interact with a minimalist interface of an OLED display and set of directional buttons. The interface will also present basic information during the brewing process such as progress.

Control System and Sensor Array: The brains of the device will be a Raspberry Pi 4B which will interface with the locally stored brew database, receive user input from the user interface, and run the brewing script which will involve the control of the water heating and dispersion system while collecting feedback from the sensors. To aid the primary function of the device, a temperature sensor for water temperature and multispectral camera to track saturation will be employed. The multispectral camera will communicate with a machine learning algorithm to translate the captured image of the grounds to a saturation value. Other sensors designed for user safety such as thermal runaway detection and carafe detection will be added.

Brewing Hardware: The heart of the brewing action is performed by the water heating and dispersion system. The water must be heated quickly and accurately to around boiling point and be well distributed across the grounds in controlled intervals. The heating system will use a resistive heating element, common to automated coffee makers, to heat the water before it flows into the grounds' chamber. The flow of water will be controlled by a sprinkler system that will actuate open and closed to maintain the target saturation value provided by the database. By tracking the rate of water distribution, the quantity dispensed will also be tracked.

Database: The MySQL database will contain the light, medium, and dark roast's corresponding temperature and water saturation value along with all the user's feedback after each brew. This data will be updated based on the machine learning algorithms and the evaluation from the user.

Machine Learning: The machine learning subsystem will consist of two algorithms. During the brew process, the classification algorithm determines how saturated the ground beans are based on image processing. Prior, the classification algorithm will be trained by images of saturated ground beans at varying amounts to determine the initial brew temperature and water saturation level. To generate the perfect cup of coffee, the regression algorithm will take the user's feedback and predict the temperature and water saturation levels for the same user's next brew.

Android App: The android application will be created in Java and use the smartphone's Wi-Fi capabilities to connect to the raspberry pi along with the database. The application will retrieve user data from the database to display history of previous pours and provide information on their device's maintenance. The application will also be able to start the brewing process on the coffee maker by sending a signal to the raspberry pi to begin the whole process. The raspberry pi will also send data back to the application to update it on its progress which will be shown to the user. This will also allow the user to receive a notification when their coffee has been poured.

3.4. Modes of Operations

There are two ways to operate the coffee maker. One will be through the built-in display that will have the basic controls for the coffee maker. This includes the ability to start the brewing process and provide feedback on each cup of coffee. For more advanced features and insight, there is an android application. The application will also allow the user to start the coffee maker and provide feedback but will also give the user historical information on their previous pours, a help guide with frequently asked questions, and maintenance information.

3.5. Users

Coffee enthusiasts are the main target user. The product is made for those who are looking for a more personalized coffee experience. This coffee machine will adjust its brewing settings based on the user's preferences and over time learn to brew the perfect cup of coffee for the user. This product also benefits those branching into using the pour over method for the first time without the hassle of learning how to drizzle or heat the water. Lastly, this product will also be beneficial to those who cannot manually do the pour over method themselves. The device itself will require minimal effort to set up as it only needs to be connected to a power source and the brew will be automated by the app. Little to no experience is required to operate the device.

3.6. Support

Support will be provided through an in app page that will include frequently asked questions, common issues and how to deal with them, as well as maintenance for the device to keep it running smoothly. If these options are not sufficient for the user, a contact email for our development team will be available for additional support. An online pdf manual will be provided in the app and on the website and a paper manual will be included with the product that will go over initial setup instructions and proper maintenance. The app will also have an initial setup guide when it is first opened that will show the user how to set up the device and get it ready for its first use.

4. Scenarios

4.1. Coffee Enthusiasts

More experienced coffee drinkers are most sensitive to slight changes in tastes of coffee and that varies drastically from person to person. For people looking to get a more personalized pour over coffee experience will truly benefit from this product. The coffee maker will learn each individual user's coffee preferences and adjust its timings and temperatures accordingly to create the perfect cup of coffee for each user.

4.2. Office Environments

In a large-scale corporate office, there are all different types of coffee drinkers. This machine allows all the users to have their own profiles that would adjust the coffee pouring to suit their taste. One machine in an office space can handle many users as long they connect their device to the coffee maker. Afterwards, the coffee maker will work the same as if only one person is using it. The data that it gathers will be specific to each user to ensure that everyone is getting their perfect cup of coffee every morning.

4.3. Handicapped or Disabled

This coffee maker would automate the pour over method for those who are incapable or have disabilities that prevent them from making coffee this way. This also allows those users to be able to have the perfect cup of coffee as free-handling may be difficult or dangerous due to the weight and temperature of a kettle.

5. Analysis

5.1. Summary of Proposed Improvements

The standard coffee brewing system isn’t very smart; it performs the simple task of pouring hot water over coffee grounds without regard for the subtleties of how hot the water is or how quickly it's introduced. For those who want more control over their brewing experience, the pour-over is the method of choice. This method relies on the user manually heating and pouring boiling water over the grounds in short intervals to ensure that the grounds are evenly wet and never oversaturated. However, this method leads to inconsistencies in the brewing experience with small characteristics from changing water temperature to pour speed affect the quality of the brew. Through the automation of this process, every facet of the brewing process can be fine-tuned and made repeatable. While other solutions for pour over coffee exist on the market, this device will provide unparalleled performance thanks to its unique sensor array featuring optical saturation monitoring and ability to learn and adapt user preferences over time.

5.2. Disadvantages and Limitations

While perfectly usable offline, the device performs best when it has a wireless connection. In the absence of this, it will no longer be able to perform firmware updates or connect with the app for viewing the history of previous pours or receiving notifications when the brewing process is complete. The user would also not be able to see troubleshooting information or maintenance information.

Some other coffee solutions allow for other beverage programs such as tea or hot chocolate. The device will only be designed for the brewing of hot coffee from coffee grounds as the algorithms will not be trained to deal with anything else.

5.3. Alternatives

The proposed method of saturation tracking for the grounds is a camera system that translates multispectral images to saturation values. While this system should work in theory, it may need to be assisted by more traditional moisture sensors to reach the required accuracy.

In most traditional automated coffee systems, water is boiled in small quantities and the boiling action propels the water through the tube and onto the grounds. Meanwhile, pour over coffee typically relies on using a kettle to boil all the water at once allowing for precise control of the water's temperature by timing how long it's been off boil. Currently the coffee machine relies on the traditional automated system, if there are difficulties with temperature control the system may change to a more kettle-like heating design.

5.4. Impact

The system will have a washable, reusable stainless steel coffee filter. This should positively impact the environment by eliminating the waste that comes with the use of paper filters. The app will also advise within the user guide that coffee grounds can be disposed of as compost rather than contributing to a landfill.

Perfect Pour Over Coffee

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FUNCTIONAL SYSTEM REQUIREMENTS

REVISION – Draft
23 February 2022

FUNCTIONAL SYSTEM REQUIREMENTS
FOR
Perfect Pour Over Coffee

PREPARED BY:

Author Date

APPROVED BY:

Mark Golla Date

John Lusher, P.E. Date

T/A Date

Change Record

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1. Introduction

1.1. Purpose and Scope

The Perfect Pour Over Coffee System is created to add automation and a high degree of precision to the brewing of pour over coffee in order to eliminate the error that occurs in a conventional brew. The device will be able to track the temperature of the water for brewing and add it in controlled intervals to keep the coffee grounds in the ideal saturation area. The device will also be able to change its brewing parameters based on the roast type of the grounds and user feedback on previous brews.

The sensor array for the device will include a water temperature sensor, multispectral camera, and a CO_2 sensor. The water temperature sensor will ensure that the water being poured onto the grounds matches the recipe and the camera and CO_2 sensor will work in tandem to determine the saturation of the grounds and whether it's time to add another shower of water. The true saturation value is determined by a machine learning algorithm with the camera and CO_2 sensor acting as inputs

The device will use a database to store brewing parameters which can also be called recipes. These recipes will be updated after each brew in accordance with user feedback to try and tweak the recipe towards a better cup. The user will use an android app both to brew and provide feedback.

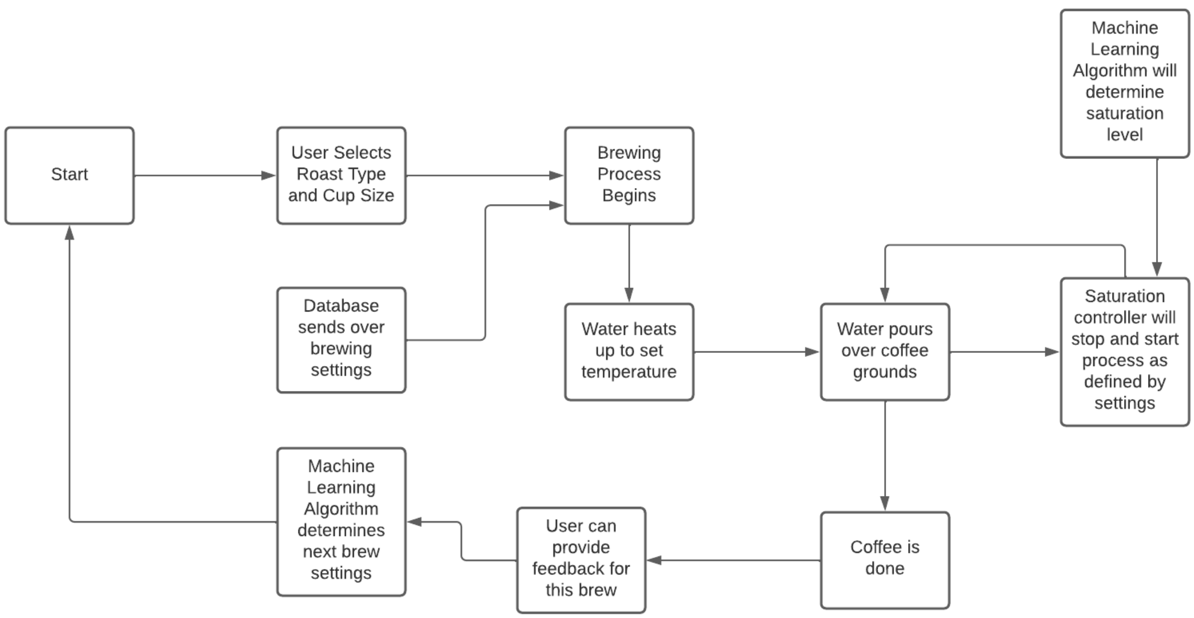

Figure 1: User Flowchart

1.2. Responsibility and Change Authority

The team leader, Mark Golla, will be responsible for ensuring that the requirements are met. Mark will also have the authority to make the changes along with our sponsor, Stavros Kalafatis.

Table 1: Team Member Responsibilities

	Subsystem	Responsibilities
Mark Golla	Hardware	Development of brewing hardware and control systems with associated sensors.
Cindy Ho	Database/ML	Creation of a database to house user data, preferences, brew history, and other relevant data Training of a machine learning algorithm to determine saturation status of the grounds based on sensor input
Zeeshan Virani	Android Application	Development of an android application to control the device including a full UI, use guide, and user feedback system

2. Applicable and Reference Documents

2.1. Applicable Documents

The following documents, of the exact issue and revision shown, form a part of this specification to the extent specified herein:

Table 2: Applicable Documents

Document Number	Revision/Release Date	Document Title
Title 21	01/06/2022	FDA - CFR Title 21
UL 1082	09/29/2016	Standard for electric coffee makers and brewing-type appliances
IEEE 802.15.1	2005	WPAN / Bluetooth Communication Standards

2.2. Reference Documents

The following documents are reference documents utilized in the development of this specification. These documents do not form a part of this specification and are not controlled by their reference herein.

Table 3: Reference Documents

Document Title	Address
Raspberry Pi 3B Documentation	https://www.raspberrypi.com/documentation/computers/raspberry-pi.html
Raspberry Pi Camera v2 Documentation	https://www.raspberrypi.com/documentation/accessories/camera.html
DS18B20	https://datasheets.maximintegrated.com/en/ds/DS18B20.pdf

2.3. Order of Precedence

In the event of a conflict between the text of this specification and an applicable document cited herein, the text of this specification takes precedence without any exceptions.

All specifications, standards, exhibits, drawings or other documents that are invoked as “applicable” in this specification are incorporated as cited. All documents that are referred to within an applicable report are considered to be for guidance and information only, except ICDs that have their relevant documents considered to be incorporated as cited.

3. Requirements

3.1. System Definition

The Perfect Pour Over Coffee system is a coffee brewing machine which heats and pours water over coffee grounds to produce coffee. The device will use a machine learning powered array of sensors to track the brewing process and ensure that the brew meets certain parameters such as water temperature and ground saturation. The device will be controlled using an android smartphone application which will allow the user to select the amount and type of coffee before brewing as well as rate the result afterwards. The resultant rating is used to change or reinforce the parameters for future brews.

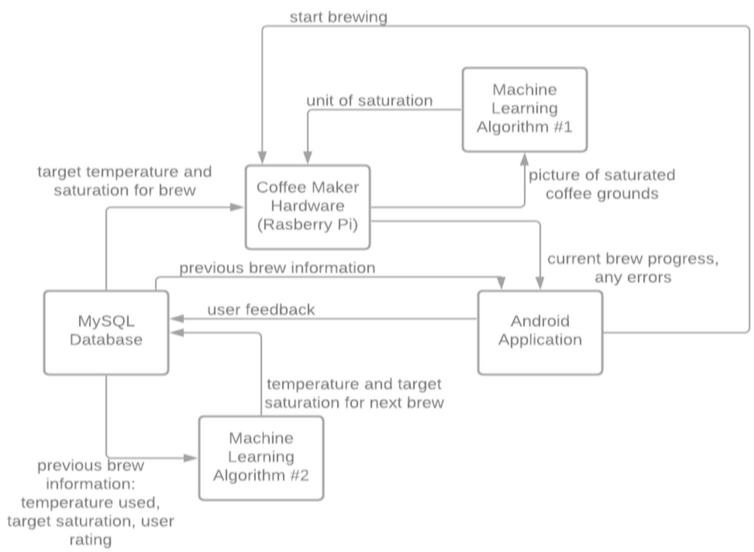

Figure 2. Software Conceptual Breakdown

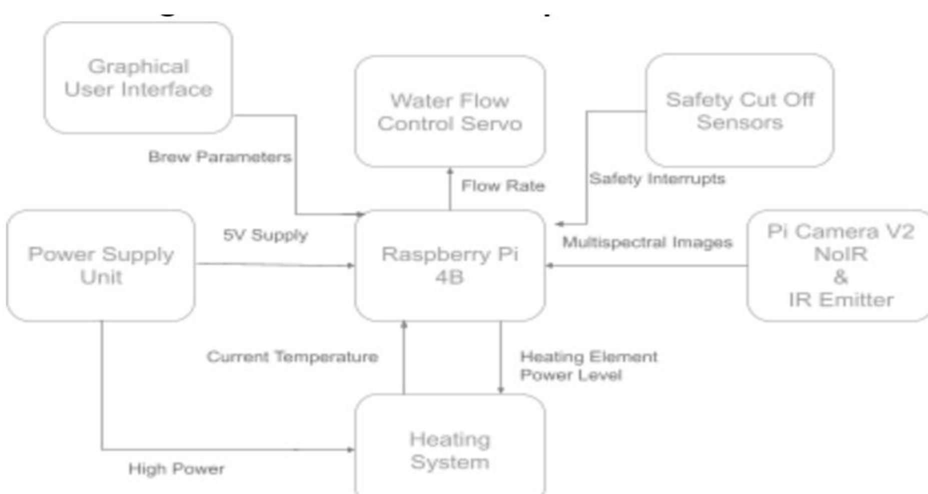

Figure 3. Hardware Conceptual Breakdown

Brewing Hardware: The brewing hardware will first heat its reservoir of water until it reaches the brewing parameter and work to maintain this temperature throughout the brewing process. The water will be dispersed using a sprinkler system above the grounds and will continue adding water periodically through a valve actuation depending on the sensor array's reading of the grounds' status.

Sensor Array: A temperature sensor will be implemented into the water reservoir to track the temperature of the water before its poured into the grounds. The temperature read will determine how much power is supplied to the heating element. To monitor the grounds and determine whether more water should be added, a combination of a CO2 sensor and a multispectral camera will be placed above the grounds. The values read from these sensors will be fed to a machine learning algorithm to determine a saturation value and whether the grounds can absorb any more water.

Power: A converter will be implemented to convert 120 VAC to 5 VDC at no more than 2.5 amps for use with the pi, sensor array, and water distribution valve. A 120 VAC line also will be modulated according to the pi in order to provide controlled power to the heating element

Machine Learning Algorithm #1: First, a training dataset will be created for the algorithm. The dataset will consist of images of ground beans at various levels of saturation for the four types of roasts. Since the images will be taken by a multispectral imaging camera, there will be an image for each wavelength. The algorithm will then take the average red pixel value since the blue and green won't pick up the NIR. These averages correlate to the water content of the grounds since water has different absorbency in NIR than coffee grounds. The algorithm itself will be created in Python and contain libraries from TensorFlow. The end result will be a linear regression model to predict the saturation level. Once the algorithm has been trained with the initial dataset, there will be at least two more testing datasets to validate the model. After the model is verified, it will be implemented, and the desired saturation levels will be saved into the database.

Android Application: This subsystem will handle the user interface and interaction with the hardware. The user will be able to select their coffee roast type and the quantity to dispense then be able to start the brewing process. The user also will have access to brewing history and the ability to rate previous brews. The rating process will be used to determine the parameters for the next brewing session. The app will also provide some basic hardware information as well as how to maintain the device and troubleshoot any issues they may encounter. The application will connect to the Raspberry Pi and a MySQL Database.

Machine Learning Algorithm #2: This Python algorithm will be responsible for adjusting the temperature according to each user's preferences. When negative feedback is received, the script will determine whether it increases or decreases the temperature. On the other hand, the script will maintain the temperature if positive feedback is received. If there is a new user, the chosen temperature will then be picked based upon the average temperature that corresponds with the positive feedback.

MySQL Database: The database will handle storing and managing all the data. The data includes login information, brewing sessions, and user settings. The database will provide this data to the android application as well as one machine learning algorithm that will compute brewing parameters for a user's next brew.

3.2. Characteristics

3.2.1. Functional / Performance Requirements

3.2.1.1. Application Data Size

The Android application will not exceed 15 megabytes of storage.

Rationale: This will allow users to be able to quickly download the application and will not be a burden to most people's storage capacity.

3.2.1.2. Maximum Brew Quantity

The amount of coffee that can be brewed at one time will not exceed 24 oz

Rationale: 24 oz is the size of the carafe and the user shouldn't be able to brew more than it can hold

3.2.1.3. Smartphone App Communication Range

The smartphone being used to control brewing should be within 30 ft of the device

Rationale: 30 ft is the functional range for bluetooth

3.2.2. Physical Characteristics

The volume envelope of the Perfect Pour Over Coffee System will be less than or equal to 48x48x48 inches. It will also need to accommodate a carafe that is 11 in tall and 6 inches in diameter beneath the brewing hardware.

Rationale: The device is expected to be reasonably small to fit onto a kitchen counter alongside other appliances and house a carafe within it

3.2.3. Electrical Characteristics

3.2.3.1. Inputs

a. The presence or absence of any combination of the input signals in accordance with ICD specifications applied in any sequence shall not damage the Perfect Pour Over Coffee System, reduce its life expectancy, or cause any malfunction, either when the unit is powered or when it is not.

b. No sequence of command shall damage the Perfect Pour Over Coffee System, reduce its life expectancy, or cause any malfunction.

Rationale: By design, should limit the chance of damage or malfunction by user error.

3.2.3.2. Power Consumption

a. The maximum peak power of the system shall not exceed 1500 watts.

Rationale: Most kettles are 1500 watts. This is because although wall outlets are usually rated for 15 amps, appliances shouldn't pull this full current since the breaker is likely to trip.

3.2.3.3. Input Voltage Level

The input voltage level for the system will be 120 VAC. This voltage will be converted to 5V DC for the Pi, sensor array, and water flow servo. The 120V will be applied to the heating element with a current limiting resistor and pulse width modulation.

Rationale: The device is expected to be in a kitchen and will need to be powered by a conventional 120 V wall socket. The control circuitry runs on 5V, but the heating element will need more power to quickly heat water, which is more easily achieved at 120 V.

3.2.3.4. Outputs

3.2.3.4.1 Data Output

The Raspberry Pi will output brewing process status directly to the user's android smartphone.

Rationale: The user is able to monitor at what point of the brewing process their coffee is in as well as be able to see if any issues occur.

3.2.3.4.2 Diagnostic Output

The Perfect Pour Over Coffee System will have a LAN port located on the pi which can be used to ssh in and run basic diagnostics or reinstall the brewing software

Rationale: Provides the ability to access the hardware directly for debugging manually and a way to update the software

3.2.4. Environmental Requirements

The Perfect Pour Over Coffee System will be designed for indoor use only and will be designed to operate in standard indoor climate conditions of 50 to 90 degrees fahrenheit and humidity of 0 to 50%. While the device will be designed to handle moisture from brewing condensation and cleaning, it may not be submerged.

Rationale: The device is meant for a kitchen environment but is not required to be waterproof.

3.2.5. Fault Detection

The Perfect Pour Over Coffee System will arrest overheating scenarios through the use of a thermal fuse. Once the unit reaches the unsafe operating temperature threshold of 150C, the switch will flip, disabling the unit. A 13 amp electrical fuse will also be added to protect the user and device in the event of water leakage, grounding fault, or other electrical abnormality.

The device will also protect against user error by ensuring there is a carafe present to receive the coffee as well as a sensor to detect that there is water remaining in the reservoir. Should a user error occur, they will be alerted through the app as well as the blinking of the power indicator light.

4. Support Requirements

4.1 Smartphone with Bluetooth Capabilities

The advanced features of this device, including the ability to adjust settings based on user input, will require the customer to be able to use an Android smartphone with bluetooth capabilities to connect to the device.

4.1 Maintenance

The user will be required to clean and maintain the device using instructions from the user manual featured in the android smartphone application.

4.1 Troubleshooting and Warranty

For issues that are beyond user control, the user is able to email the customer support team for assistance. If the issue is beyond repair virtually, the user may send the device back for repairs under the included manufacturer warranty coverage.

Appendix A: Acronyms and Abbreviations

BIT	Built-In Test
I2C	Inter-Integrated Circuit
CSI	Camera Serial Interface
GPIO	General-Purpose Input/Output
VAC	Volts (Alternating Current)
VDC	Volts (Direct Current)
V	Volts
A	Amps
LAN	Local Area Network
ML	Machine Learning
Pi	Raspberry Pi
CO_2	Carbon Dioxide
NIR	Near-Infrared

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INTERFACE CONTROL DOCUMENT

REVISION – Draft
23 February 2022

INTERFACE CONTROL DOCUMENT
FOR
Perfect Pour Over Coffee

PREPARED BY:

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Author Date

APPROVED BY:

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Mark Golla Date

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John Lusher II, P.E. Date

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T/A Date

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1. Overview

The following document will cover specific details on each of the subsystems of the Perfect Pour Over Coffee System and their interactions. The primary subsystem being the hardware itself. The second subsystem being the android application used for controlling the hardware. The third subsystem is the database and machine learning algorithms used to manipulate the data and settings needed for the hardware subsystem to function.

2. References and Definitions

2.1. References

Table 1: Reference Documents

Document Title	Address
Raspberry Pi 3B Documentation	https://www.raspberrypi.com/documentation/computers/raspberry-pi.html
Raspberry Pi Camera v2 Documentation	https://www.raspberrypi.com/documentation/accessories/camera.html
DS18B20	https://datasheets.maximintegrated.com/en/ds/DS18B20.pdf

2.2. Definitions

I2C	Inter-Integrated Circuit
CSI	Camera Serial Interface
GPIO	General-Purpose Input/Output
VAC	Volts (Alternating Current)
VDC	Volts (Direct Current)
V	Volts
A	Amps
CPU	Central Processing Unit
RAM	Random Access Memory

3. Physical Interface

3.1. Weight

The Pour Over Coffee System will weigh up to 15 lbs including the raspberry pi, sensor array, power system, carafe, and housing.

3.2. Dimensions

The volume envelope of the Perfect Pour Over Coffee System will be less than or equal to 48x48x48 inches. This size is to allow for the device to fit in most consumer kitchens while allowing plenty of space to house the carafe which is 11 inches tall and 6 inches in diameter beneath the brewing hardware

3.3. Mounting Locations

3.3.1 Mounting of Coffee Grounds Sensors

The multispectral camera and CO2 sensor will need to be mounted above where the grounds are held to take measurements. The camera will need to be placed behind a clear antifog window to avoid damage due to steam or splashing of water.

3.3.2 Mounting of Water Temperature Sensor

The temperature sensor will be mounted in the inner wall of the reservoir in order to take the most accurate temperature readings and far enough away from the heating element that erroneously high readings are avoided.

3.3.3 Mounting of Fault Sensors

A thermal fuse will be mounted next to the heating element to ensure it doesn't reach critical temperatures and the carafe detection sensor will be mounted into the base where the carafe will sit to easily ensure it's present.

3.3.4 Mounting of Raspberry Pi and Power System

The pi and power system will be housed within the main body of the device to reduce the risk of water infiltration. Ports exiting the device will need to include a instrument cable connector for 120 VAC, an opening for the LAN port, and a set of vent slits for the fan to exhaust heat through. Mounting will need to accommodate wires connecting the pi/power system shared enclosure to the sensor array as well as the user interface. The enclosure must not interfere with the use of Bluetooth.

4. Thermal Interface

4.1. Raspberry Pi and Power System

The raspberry pi will need basic air circulation to keep from overheating or thermal throttling during use. Heatsinks will be mounted on the cpu and ram for better heat dissipation and ventilation slits will be located near the device for passive cooling. The conversion from 120 VAC to 5 VDC is expected to cause considerable heat buildup, so a small case fan will be added to exhaust heat from the device.

4.2. Water Heating System

The water heating system will need to be thermally isolated from the rest of the device to avoid damaging components or making a hazard for the user. This will be accomplished through use of an insulator around the heating coil, and standoffs to minimize the contact between any heated components and the rest of the device.

5. Electrical Interface

5.1. Input Power

120 VAC from a standard wall receptacle will be used to power the device. This power must be rectified and stepped down to 5 VDC at a maximum of 2.5 amps for use with the pi as well as the sensor array. The whole device should draw less than 1500 watts to minimize the time it takes to heat the water while reducing the chance of popping a breaker.

5.2. Microcomputer

Raspberry Pi 3B will be the computer that controls the operation of the device and handles the data transfer between itself and the android app, monitoring of sensor values, and control of brewing hardware. It will also host the brewing database locally. It has a 1.2GHz CPU and 1GB of RAM. It also has Bluetooth and Wi-Fi capabilities built in. The pi runs off of 5V and has a maximum current draw of about 2.5 A

6. Communications / Device Interface Protocols

6.1. Wireless Communications (Bluetooth)

All wireless communication will be done over Bluetooth with the pi host device and an android smartphone. This protocol will operate in specification with IEEE 802.15.

6.2. Raspberry Pi IO

The raspberry pi will use 3.3V logic across its GPIO pins in order to communicate with the sensor array. The use of these pins will also allow for I2C inter device communication for controlling systems such as the lighting for multispectral imaging or the power system for the heating element. The camera for the multispectral imaging will connect to the pi through its CSI port

Execution Plan

End Date	Cindy	Mark	Zeeshan	Status	Completed Date
03/02/2022	- Develop database - Construct sample data - Create a mock system to gain familiarity	- Order Initial Parts -Finish IR Camera/ Emitter system to begin ML data collection	- Full application UI prototyped	In Progress	
3/02/2022	Midterm Presentation			In Progress	
03/09/2022	- Verify dataset has sufficient amount - Create base python script that adjusts temperature	-Finish water sprinkler system	- Home page functional. Ability to select roast types, cup sizes and begin brewing process	Not Started	
03/23/2022	- Create a base machine learning algorithm	-Finish heating system - Finish calibration of sprinkler system	- History page functional. Displays a list of user's previous brews. - Settings page functional. Users are able to modify the appearance and adjust profile and notification settings.	Not Started	
03/30/2022	- Run tests on prediction to create neural network	-Finish calibration of heating system to make stable temperatures	- Entire GUI Tested. Users can move throughout the app without bugs and are able to virtually start the brewing process.	Not Started	
3/30/2022	Status Update Presentation			Not Started	

04/06/2022	- Run unit tests and check edge cases	- Finish power system	- App is able to connect to the database and retrieve sample data.	Not Started	
04/13/2022	- Connect ML with Database - Run final tests	-Write python script to follow values given by database	- App is able to connect to the Raspberry Pi and turn on an LED	Not Started	
04/20/2022	- Revise any issues with neural network and algorithm	-Testing of a full brew cycle -Install and test fault devices	- Final testing completed - App fully functional	Not Started	
04/30/2022	Final Presentation, Demo, and Report			Not Started	

Validation Plan

Test Name	Success Criteria	Methodology	Status	Responsible Engineer(s)
Application Size	Overall application size is under 15 mb.	View file size to validate.	Untested	Zeeshan Virani
Functional User Interface	User is able to navigate throughout all pages within the application without bugs, crashes, or need for outside intervention.	Open the application and handle it as an end user.	Untested	Zeeshan Virani
Android Application Storage	The Android application of the system shall not exceed 15 megabytes of storage.	Monitor frontend design images and functions size.	Untested	Zeeshan Virani
Application Connection With Raspberry Pi	The Raspberry Pi turns on an LED when a connection is established between the android application and itself.	Visually Verify connection has been established.	Untested	Zeeshan Virani
Database Connection With Application	The application is able to send and receive data from the database.	Send data to the database and then query to see if that data has been stored.	Untested	Zeeshan Virani
Brew Temperature Prediction	The machine learning algorithm is able to receive feedback from the user and can adjust the temperature up or down if the feedback is negative.	Data will have linear relationship between user feedback ratings and temperature to each user. If user has positive feedback, the temperature will stay constant. If user has negative feedback on too hot or too cold, the temperature will adjust in the direction that generates a positive outcome for the user.	Untested	Cindy Ho
Database Storage Amount	The datasbase shall not exceed 65,535 bytes or 8.61 GB (Raspberry Pi maximum storage).	Return error output if user tries to exceed allocated storage space.	Untested	Cindy Ho
Database Storage Savings	The database is able to save user feedback ratings, temperature, and water saturation requirements.	Running the training data and checking if the database saves all of the data with no null responses.	Untested	Cindy Ho
Water Saturation Prediction Accuracy	The machine learning determines percentage of ground bean saturation within +/- 5% range.	Run initial training data and two subsequent train data tests through (train/test splits). Have a confusion matrix to compare results.	Untested	Cindy Ho
Input Voltage (Peripherals)	The input voltage level for the converter used for the Raspberry Pi, Sensor Array, and Water Distribution Valve will convert 120VAC to 5	Use multimeter and a test load to validate input and output voltage levels.	Untested	Mark Golla

	VDC at no more than 2.5 Amps.			
Mass	Mass of all hardware shall not exceed 15 lbs.	Measure entire system utilizing a scale.	Untested	Mark Golla
Volume	Thesize of the full system shall not exceed 48x48x48 inches.	Measure dimensions of system	Untested	Mark Golla
Basic Sensor Readings	Test the temperature sensor against a known working thermometer at 200 F and ensure CO2 value increases when breath or co2 from a duster is introduced	Test the CO2 and temperature sensors by connecting to the pi and writing scripts to recieve thier values	Untested	Mark Golla
Multispectral Camera	Successful capture of an image at each NIR wavelength and its compilation into a multidimensional image within less than one second.	The camera should be able to cycle through wavelengths and capture a full image of a white background as well as coffee grounds every second for 2 minutes. The images should be consistant and the light intensity should not saturate the camera	Untested	Mark Golla
Water Heating System	The temperature of water in the reservoir should be able to be held at a constant temperature anywhere in the range of 190 degrees F to 210 degrees F for 30 seconds without fluctuating more than 2 degrees	The temperature values will be swept in increments of one from 190 to 210 degrees and held at each step for 30 seconds	Untested	Mark Golla
Fault System	The system should not start brewing or stop actively brewing if there is a fault present	Each fault condition will be implemented individually and in parallel both while the system is running or about to be run and observe whether it attempts to brew	Untested	
Brew Quantity	The amount of water dispensed should be within 10% of what was requested.	Run the hardware with pre defined quantities and measure the amount of water dispensed to verify the dispensing mechanism	Untested	Mark Golla
Full System Demo	A user of the system can select brew type and cup size according to their needs and make a cup of coffee.	The system is able to complete when the camera reads the grounds to have reached the required saturation levels, the temperature sensor reads all of the temperature for water maintained, and CO2 levels are matched according to specifications.	Untested	Everyone