

# Technical Report

## The way to brew a perfect cup of filter coffee with IoT

1906868 Woohyeon JO

### Abstract

It is hard to brew a perfect filtered coffee with our two hands due to so many variables that need to be controlled. In other words, if we can control all the variables our hands can't do, then we can brew a cup of coffee with ideal flavour. Many of us enjoy filtered coffee. We oversee the waterfall difference between the tip of the kettle and the grinded coffee beans. This difference makes significant changes on the coffee flavour and we decided to add some sensors to reduce differences. We had added 4 things that are scale, flowmeter, Thermometer and heating element.

The scale is a basic and important sensor for the filter coffee to help the machine brew an exact amount of coffee. The flowmeter makes the water flow constant and it reduces the fall difference a lot. Also the flowmeter can calculate the water flow rate so that the user can observe as a data and modify the brewing receipt. Thermometer is a sensor that detects temperature but it also gets the target temperature from the user and sends it to the heating element. The heating element is an autonomous device which is similar to a kettle that boils water and maintains the temperature of water in the machine to reduce the difference in temperature when the machine brews a cup of coffee.

To brew a perfect coffee, a smartphone app is really important because the server collects all the data from sensors and the app shows all the data from the server. This means the user can observe all the datas when the machine starts to brew until completed. Also the app can see the temperature and water flow graph data so that the user can modify the recipe easily. This is a brief summary of brewing perfect filtered coffee.

### Application domain and problem

A cup of coffee, some people don't drink it for their health reasons, but many of us are having it for plenty of reasons. There are some purposes such as to spend their fresh morning time, to enhance and prolong their workout performance or to stay up late and avoid feeling sleepy with a cup of coffee. However, some of them just enjoy drinking a cup of coffee without any purposes. I am also the one who enjoys the flavour and aroma of coffee itself. Many of us who enjoy coffee itself are also interested in brewing their own filter coffee.

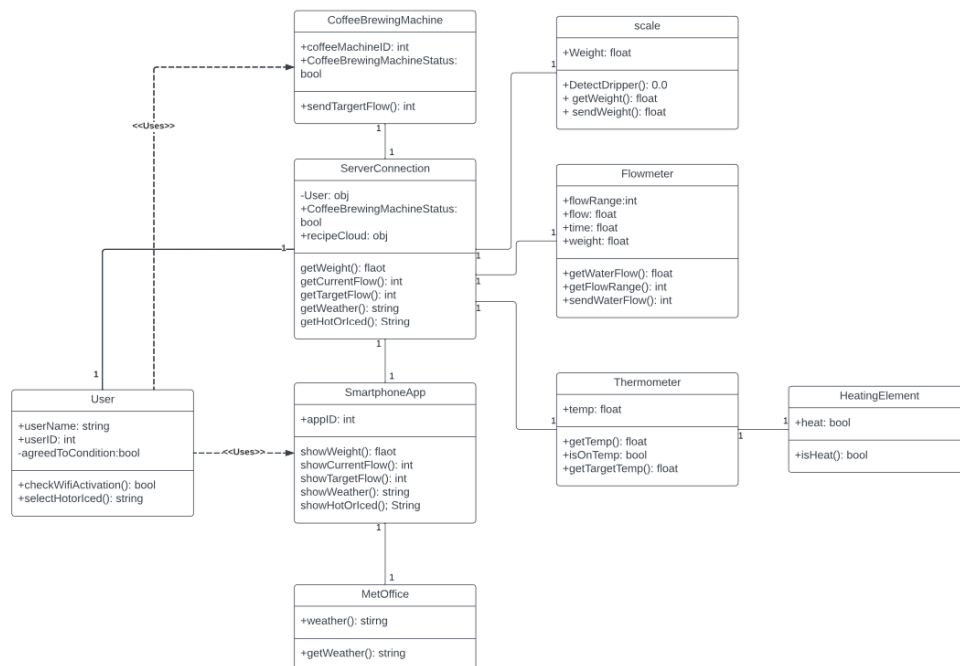
When we start brewing filter coffee for the first time, there should be uncountable errors with their coffee flavour. We definitely followed the world champion coffee recipe and expected flavoursome and aromatic coffee with a balance of sweetness and acidity. However, the fact is that it doesn't taste like the one we ate at a cafe or even much worse than that.

We thought about the problems and limitations of brewing filter coffee also known as hand drip coffee. Filtered coffee is one of the most sensitive brew techniques that reveals characteristics of the coffee bean we brewed. This feature can be a positive aspect if we can extract the good part of the bean, but if not, it can also be negative. Small changes in sensitive brewing methods can make big changes on the flavour in either good or bad ways. The brewing machine with IoT will invite us to drink a cup of coffee with ideal flavour without wasting expensive coffee beans.

As we said earlier, the biggest concern of people who like to brew filter coffee is that the cup of coffee we brewed is not the same one that we expected. It is common sense for those who love coffee to consider the grinding size and the temperature as important points in filter coffee. However, flow rates and the water level we dropped from a pot also can make significant changes on coffee flavour. These two features are relatively overlooked compared to grinding size or temperature because our hand can't control these two variables perfectly. The brewing machine with IoT will make coffee life more enjoyable and comfortable than hand drip by controlling the flow rate, water level and the temperature on the smartphone app. Also the user can observe the controlled variables via a graph shown on the smartphone app after the brewing is completed.

There is a machine called "pour steady" some cafes are currently using for their filter brewed coffee. This coffee machine quickly produces a constant flavour of coffee by pouring over the same amount of water at the selected time. Also this machine allows the user to change the amount of water and the time on their website. However, it is not suitable for our purpose, which is a cup of coffee with ideal flavour, it makes high standard cups of filter coffee constantly though. We will make a new device with IoT based sensors and a smartphone app based on this "pour steady" hardware.

## **System Architecture**



This figure is the class diagram of the coffee brewing machine. We added 4 things that are scale, flowmeter, thermometer and heating element to make a perfect cup of filtered coffee with IoT. All sensors and autonomous devices are interacting with the main server with internet wifi and the autonomous device can get the data from sensors via server. The app recommends the recipe based on the weather data. The weather data is given from the UK Met Office. After getting the data, the app shows one of 4 phrases that are quite similar to today's weather such as rainy and chilly day.

## Definition of Context Widgets

As we read before, there are four things that are interacting with each other to make a good cup of filter coffee.

First, the scale class is a sensor that detects and scales the weight. It is a very important sensor for coffee brewing because it can detect whether the dripper and drip server is on the device or not. If the scale sensor detects any object on the brewing machine, the scale tare the scale immediately which means make the scale to zero whatever the object is on the machine so that the machine can brew the coffee from 0 gram. Also the scale sensor continuously sends data to the server so that the user can see the current scale during their brewing process.

Second, the flowmeter is a sensor and it can also be an autonomous device that detects the water flow and makes the flow or stream constantly. The main purpose of using the flowmeter is to calculate the water flow so that the user can manage the flow range level at any time via

continuously interacting with the server. Moreover, the flowmeter helps the brew machine with steady flavour by providing more constant water flow.

Third, the thermometer and the heating element both are used regarding the heating water. Thermometer is a sensor that detects the temperature of water in the brew machine. When it gets the water temperature, it sends a temperature to the server and continuously interacts with the server if there is a change in the temperature until the coffee brewing machine is turned off. There is one more thing that the thermometer is doing is that it gets the target temperature from the user and sends it to the heating element which is an autonomous device that boils the water in the machine same as a electric kettle.

Fourth, the server connection class collects plenty of data from the sensors. Also the server has a cloud of brewing recipes that can be downloaded to a smartphone app. The server always interacts with the 3 sensors , brewing machine and smartphone app so that the user can get the current data without delay.

Finally, the smartphoneApp class is an app that the user uses. The app gets all data from the server and organises and shows the data to the user. Also the user manages the brewing machine using the app. In this case, the app sends the data to the server and the machine gets the data from the server by interacting with each other.

These are the brief flow of the brewing machine and the application works and some explanations of each class and context widgets.

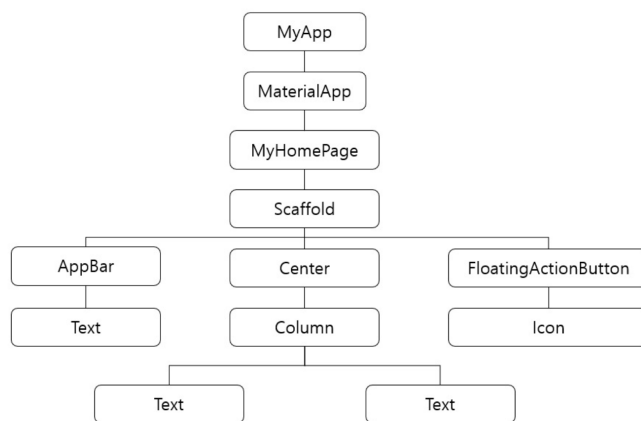
### **Smart phone app functionality**

To brew a perfect filter coffee, a smartphone app is essential to control variables connected to the brewing machine. When we open the app, the app shows the phrase about the weather such as "Rainy and chilly day". At the bottom there are two buttons that are HOT or ICED so that the user chooses one of them based on the weather phrase. In addition, the app should show the 'stop preparing' button because after we open the app, the machine is preparing for brewing coffee immediately. When the temperature of water is about 90°C, 'stop preparing' is changed into 'ready to brew'.

When the user chooses one of Hot or Iced, the smartphone app recommends the brewing recipe based on the water and hot or iced. After the user chooses the recommended brewing recipe, the app shows the beans weight to be prepared and grinding size. After brewing a cup of coffee, the app shows the user a graph of temperature and water flow rates so that the user can observe and modify the recipe easily and intuitively.

This is the basic status of the app when the user is trying to brew a cup of filter coffee. Briefly speaking, there are three main parts in every frame that are top, mid, and bottom. The app shows the main keyword or informative word as a subject at the top. At the bottom the app shows the status of what the brewing machine is doing such as heating the water or ready to brew. In the

middle part, the app shows a graph or picture or lets the user choose hot or iced as a main part.



This figure is a widget tree that I used as a basic app design which is divided into top, mid and bottom.

### W3 Thing Description for each 'thing'

The main four things in the brewing machine we designed are scale, flowmeter, heating element and thermometer. The scale is used when we calculate the water flow rates with the time on the smartphone. Also it is used to detect whether the dripper and the server is on the brewing machine or not. Moreover it also shows the current amount of coffee in a cup that is currently brewing. The flowmeter helps the brewing machine to get a constant stream so that the brewing machine extracts the grinded coffee beans equally. Also the flowmeter can control the amount of water to drop that we set on the recipe. The flowmeter interacts with the scale so that we can compare and detect whether it is working well or not and it makes the machine possible to brew a coffee even though one of them is broken. The heating element is just heating the water and it interacts with the thermometer so that the heating element heats the water until the temperature the user has set. Each description for these 4 things will be followed in the next part. The four pictures below are the thing models specified in JSON which are scale(upper left), flowmeter(upper right), Thermometer(down left) and Heating element(down right).

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## Thing functionality

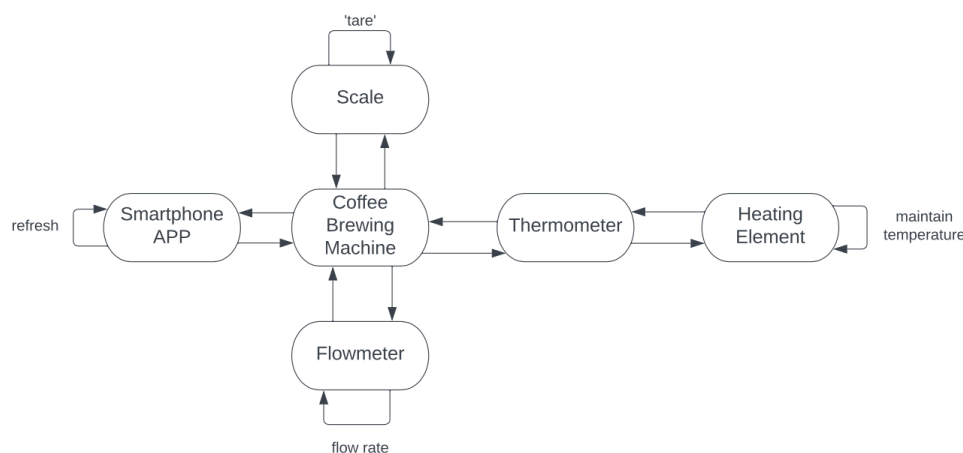
The scale which is built in the bottom of the brewing machine is the first functionality of our design. The scale is turned on or off when the smartphone app is opened or not. When we open the smartphone app, the brewing machine turns on and the scale turns on at the same time. The most important action in a scale is the ‘tare’. Tare the scale means zero out of weight whatever is already on the scale. When the dripper and the server is detected on the scale or on the brewing machine, the scale should tare so that the brewing machine can calculate and follow the recipe precisely. The

scale is also connected to the wifi so that we can see the current weight during the brewing of a cup of coffee on the smartphone app. However, we need to be aware that sometimes there will be a delay in scale and the smartphone due to the weak wifi connection. This delay can make the brewing machine make a bigger portion than expected.

The flowmeter is one of the essential parts of the brewing machine because all the water for brewing goes through the flowmeter and it makes the water path or stream constant. This constant stream makes the brewing machine to make a cup of coffee more stable. The flowmeter is also connected to the wifi so that we can control the amount of water by using the smartphone app. Also if we get time from the smartphone server we also can get the flow rate which can help brew the recipe perfectly. However, sometimes the water stream can be out of control due to the internet problem.

The thermometer is a part for heating water and maintaining the temperature of water in the brewing machine interacting with the heating element which is explained later. It is always turned on when the brewing machine is turned on. The thermometer interacts with the smartphone app via wifi so that it can receive the temperature data that the user set on the smartphone app. Also the thermometer interacts with the over heating element to share the target temperature the user set.

The heating element is the one which interacts with the thermometer. The heating element is turned on when the thermometer has got the target temperature from the smartphone app. After that, the heating element heats the water until the target temperature and maintains that temperature. This is a thing that only interacts with another thing, not the smartphone app or server. The thermometer and heating element has a big risk of overheating, in which the temperature of water exceeds the target value due to the delay time of interaction with the thermometer and the heating element.



This figure shows the brief outline of the 4 things of functionality we all read above. The cloud server and internet (wifi) are excluded because we wanted to see the functionalities between the things more intuitively.

## Managing Human-Computer Interaction

This is a situation where the user tries to have a cup of filter coffee in the morning.

Use Case: Having a cup of coffee in the morning

Actors: User, Server, Met Office , time, scale, flowmeter, heating element and thermometer

Precondition:

1. Rainy and chilly day
2. UK barista champion recipe is in the cloud server
3. Recipe: coffee beans 20 grams, medium coarse grinding (photo is given due to minimising differences, brewing (40g/10 sec, 0g/20sec, 80g/20sec, 130g/50sec) for 1min 40sec, finish at 2min 30sec

Flow of Events:

1. The user opens the smartphone app to drink a cup of filter coffee when he wakes up in the morning.
2. The system gets the weather data from the Met office and shows it to the user like "Rainy and chilly day".
3. The system lets the machine boil the water and the app shows the user "stop boiling water" && "HOT or ICED""
4. User select 'HOT'
5. The system recommends the champion recipe to the user based on the weather from the cloud server.
6. The user selects the recommended recipe on the smartphone app
7. The app shows the user the grams of beans and grinding size."20grams and medium grinding size. (A picture is supported.)



8. The user prepares for brewing coffee based on the app recommendation. Rinse the dripper and put the grinded coffee to the dripper
9. The user put the dripper and server on the brewing machine
10. When the scale sensor in the machine gets weight, make zero the scale.
11. The app shows the user the flow rate set and start brewing button
12. The user presses the start button and the user can see the scale and flow rate on the smartphone app. The user can change the flow rate during the brewing
13. The brewing machine starts brewing with the flow rate 3.



14. After the brewing is completed, the user can see the temperature and flow graph on the app
15. The user fix the recipe based on the graph, save the recipe and upload to the cloud server
16. The other user can download from the cloud server and use it as a recommended recipe.

### **Managing Security and Privacy**

There are two main potential risks when the user uses our IoT device. First, there is information that the user is in the house or not. This is important because some crimes are planned for a long time and the criminal observes the target for a long time. If the IoT user is a target for the crime, it is really easy to get the daily information for the criminal due to the internet and wifi connection if there's weak and poor passwords. To address this problem, we need to change passwords with a strong security.

The second one is it is hard to always believe the machine at all which means lack of reliability. The coffee brewing machine gets lost on the internet and the thermometer is broken, it is possible to get scalded. Because the temperature on the app would not be working and it will show like home temperature. To address this problem, we need to get a stable wifi or we can connect a cable to the coffee machine.

In a nutshell, home and internet security and reliability are two potential risks to our design concept.

### **Approaches to Evaluation**

As a non-technical requirement, we missed one thing: our hands are extremely detailed and sensitive. We can't say which is better but trained hands also brew a really good cup of filter coffee with various flavours.

In technical requirements, there are some weak explanations on the context widgets. In the abstract, the background story is too short and the next part, the application domain and problem part, was too long to explain. I should have focused more on the Mobile and Computation not the Coffee. Also I could not write in detail and long due to the lack of ideas.

